CIRCULAR A-592

1975 CROP PRODUCTION GUIDE

Compiled by
the Plant Science Section of the
Cooperative Extension Service and
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Many staff members contributed in one way or another to the work necessary to compile this circular. Thanks is in order to all that had any part in the job. The following staff had major input in preparation of portions of the text.

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The assistance given by the many secretaries in the typing of respective sections is very much appreciated. A special thank you is given to the Plant Science Section Head's Secretary for the final assembly of this publication.

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The Major Soils of North Dakota

North Dakota is approximately 210 miles wide, north to south, 300 miles long on the Canadian border and about 360 miles long on its boundary with South Dakota. It ranks 17th in size among the states, with an area of 70,665 square miles, or about 45,000,000 acres.

The climate is continental, ranging from semiarid in the west to subhumid in the east. Summers are warm and winters are cold. Most of the precipitation occurs during the spring and summer months.

Elevations range from about 800 feet in the northeast corner to 3,500 feet in the southwest. Various ranges in elevation are shown in Figure 1.

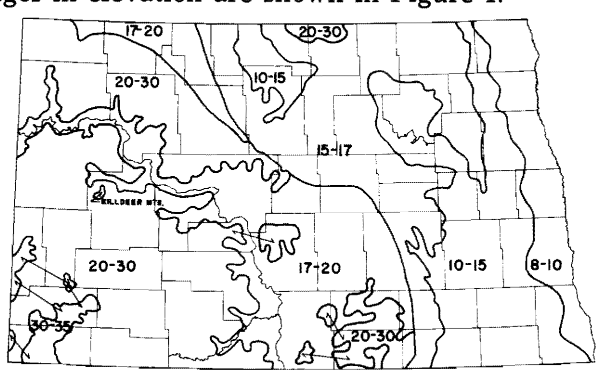


Figure 1. Elevations in hundreds of feet.

North Dakota lies within the drainage basins of the Missouri River and the Red River of the North (Figure 2). The two drainage basins are nearly equal in area.

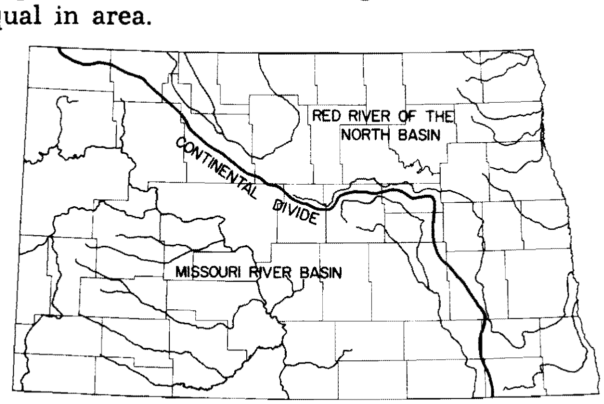


Figure 2. Continental divide and major drainage basins.

Physiography

The three principal physiographic areas of North Dakota are the Missouri Plateau, the Drift Prairie and the Lake Agassiz Basin (Red River Valley). The approximate boundaries are shown in Figure 3.

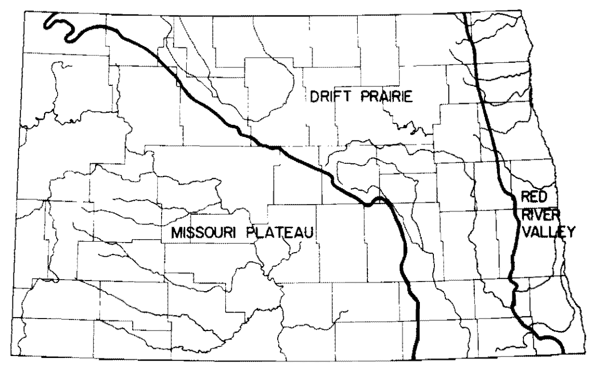


Figure 3. Principal Physiographic Areas. (Adapted from Fenneman, Physiography of the Western U. S. and Hainer, N. Dak. Geol. Survey Bul. #31, 1956.)

The Missouri Plateau

The Missouri Plateau is the largest of the three areas. Its eastern boundary extends from the northwest corner of the state southeasterly to the southwest corner of Foster county and then southward to the South Dakota line in western Dickey county. It occupies an area of about 38,000 square miles, slightly more than half of the area of the state. The Missouri Plateau covers nearly the same area as that portion of the state that has a semiarid climate.

The Missouri Plateau is drained by the Missouri River and its tributaries. The Yellowstone River drains the western edge of McKenzie county. The Little Missouri River drains the Badlands and the uplands to the west. The headwaters of the Knife, Heart and Cannonball Rivers and their major tributaries rise at the edge of the Badlands and flow east to the Missouri River.

The area west of the Missouri River has a highly developed, dendritic drainage pattern. The upland tributaries of the rivers in this area extend nearly to the crests of divides which separate the drainage basins.

Stream drainage in the area east of the Missouri is weakly developed. Little Muddy Creek, White Earth River, Apple Creek and Beaver Creek are the main tributaries of the Missouri on the north and east. These streams are small, widely spaced, and have few tributaries. They extend 40 to 60 miles north or east from the Missouri River. The area between the headwaters of these streams and the eastern edge of the plateau is without a system of stream channels. Except for the slope at the eastern edge, all runoff within the area collects in numerous closed depressions and small lakes.

Drainage of the Missouri Plateau was greatly altered by glaciation. Colton and others in the Preliminary Glacial Map of North Dakota, U. S. G. S., 1963 indicate that prior to glaciation the Missouri River flowed northeast through Divide county, the Yellowstone River flowed north through the present valley of Little Muddy Creek and the Little Missouri continued north in the valley of the present White Earth River. The pre-glacial Heart and Cannonball Rivers are believed to have joined in the vicinity of Long Lake in Kidder county and flowed to the north and east.

With their northward flow blocked by the ice sheet, the Yellowstone and Missouri Rivers were diverted to the south and east and the northern end of the Little Missouri was diverted to the east.

The Missouri Plateau is sub-divided into five areas on the basis of the influence of glaciation upon landform, drainage and the presence of glacial sediments (Figure 4).

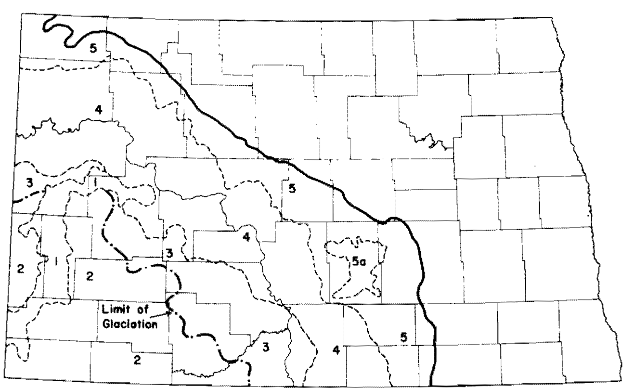


Figure 4. Physiographic subdivisions of the Missouri Plateau (1) Badlands, (2) unglaciated, (3) glaciated with drift remnants, (4) glaciated with a drift mantle, (5) Missouri Coteau. (Limit of glaciation from Colton and others, Preliminary Glacial Map of North Dakota, U.S.G.S., 1963.)

The unglaciated portion of the plateau is a gently undulating to rolling plain east and west of the Badlands. The area slopes to the east with the highest elevations, 3,000 to 3,500 feet, in Golden Valley and central Bowman and Slope counties. Hills and buttes, capped with materials resistant to erosion, are common. These rise one to several hundred feet above the general level of the plain and mark the elevation of an earlier land surface. The Killdeer mountains, Sentinel, Bullion, Rainy, Black, White, and Wolf Buttes are some of the prominent elevations. Eastward flowing intermittent streams with valleys 1/4 to one mile wide are common.

The Badlands occupy an area 8 to 15 miles wide bordering the Little Missouri River. It is a rough, severely dissected area, much of it eroded several hundred feet into the soft, layered, sedimentary beds. On its northward course the depth of entrenchment below the level of the pre-glacial terraces ranges from about 80 feet in the south to 300 feet in the northern part. During the same period the river has eroded into the upland to a depth of more than 500 feet on its eastward course.

The western section of the glaciated part of the plateau (Area 3, Figure 4) differs from the unglaciated section by having broad glacial meltwater channels, fewer prominent buttes, more extensive hilly areas, and remnants of drift on the uplands.

At the time the ice sheet occupied a part of the area west of the present Missouri River the eastward flow of many streams was blocked. The river basins filled with water, overtopped their divides, and flowed south into the adjoining river basins. The overflow cut deeply into the divides and developed broad channels connecting the Knife, Heart and Cannonball River basins. The largest and longest of these channels extends from near the center of Dunn county through the northeast corner of Stark county and southeast to the Cannonball River near the boundary of Grant and Morton counties. After the ice had melted to a point east of the Missouri River, these channels were abandoned and the Knife, Cannonball and Heart Rivers resumed their eastward flow to the Missouri River. Some sediments of glacial origin occur in the valleys of the abandoned glacial meltwater channels.

The only remaining evidence of glaciation on the uplands in this area consists of numerous stones and boulders on the crests of ridges and hills in the eastern part of the area (Figure 5).

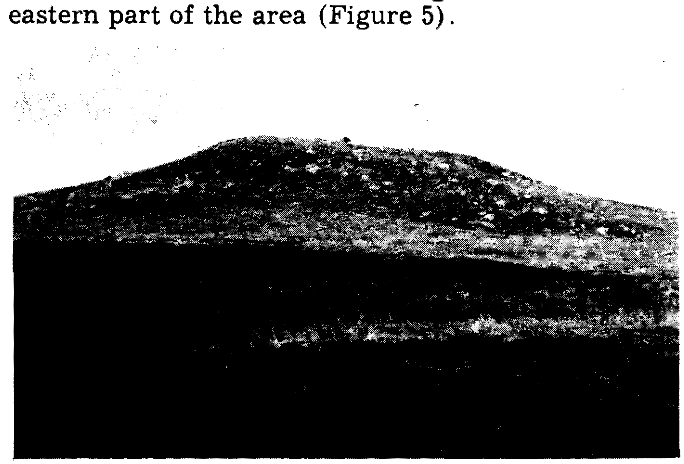


Figure 5. Stones and boulders are remnants of glacial drift on the uplands near the limit of glaciation.

The Cannonball and Heart Rivers are more deeply entrenched in the glaciated than in the unglaciated area. Wide hilly areas border the valleys of these streams and the valley of the Missouri River in Emmons and Sioux counties.

Much of the area east and west of the Missouri River is mantled with glacial drift (Area 4, Figure 4). On the west side of the River most of the undulating to rolling areas are mantled with glacial till. A few nearly level areas, in McKenzie, Mercer and Morton counties, are loess covered. Rolling to hilly areas are partially mantled with glacial till in association with exposures of Tertiary sedimentary formations.

Except in McLean county and northeast Mercer county, the area adjacent to the Missouri River is strongly dissected by drainageways extending a few miles into the upland. Here the topography is hilly and steep. Much of the glacial sediment has been removed by post-glacial erosion and drainageways have cut deeply into the sedimentary formations.

Between the Missouri River and the Missouri Coteau is an undulating to rolling plain which has been called the Missouri Slope. Most of the area is mantled with glacial till. Areas with a thin loess mantle are in Emmons and McLean counties. On the eastern edge of this plain are nearly level areas of sandy and gravelly outwash. These were deposited near the base of the westward slopes of the Coteau by glacial meltwaters flowing toward the Missouri River. The major outwash areas are in central McIntosh county, near Napoleon in Logan county, in north central Burleigh, east central McLean, south central Ward, southwestern Divide and northern Williams counties. Outwash areas also are present along Little Muddy, Apple and Beaver Creeks.

The Missouri Coteau extends across the state on the eastern edge of the Missouri Plateau. The Coteau rises abruptly above the Drift Prairie on the east. It is most prominent in western Dickey county (Figure 6), southwest Foster county, on the Sheridan-Wells county boundary, and in northwest Sheridan county.

Figure 6. The eastern edge of the Missouri Coteau in western Dickey county.

Except for areas in central Sheridan county, southwest LaMoure, and northeast and southeast McIntosh counties, the Coteau is a rough and hilly area without a system of stream channels; surface runoff flows into the numerous enclosed depressions and small lakes. Surface stones and boulders are numerous on the crests and the steep upper slopes of hills and ridges.

The largest area of outwash in North Dakota lies within the Missouri Coteau in Kidder county (Area 5a, Figure 4). It is a nearly level to gently undulating plain bordered on the north, east and south by a half circle of high, morainic hills; water from the melting glacier poured into the area, depositing gravel and sand. The water drained to the Missouri River through Long Lake and Badger and Apple Creeks.

Two smaller outwash areas in the Coteau are in north central Logan and western Divide counties.

The Drift Prairie

The Drift Prairie (Figure 7) is about 225 miles from east to west on the Canadian border and narrows to a width of about 75 miles on the South Dakota line. It occupies an area of about 25,000 square miles.

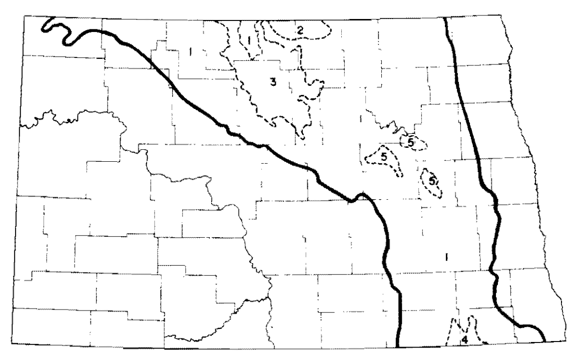


Figure 7. Subdivisions of the Drift Prairie: (1) till plain, (2) Turtle Mountains, (3) Glacial Lake Souris, (4) Glacial Lake Dakota, (5) outwash areas.

Except for the Glacial Lake Souris Basin, the general slope of the Drift Prairie is to the south and east. Elevations range from about 2,000 feet in the northwest to about 1,200 feet in the east and south near the Red River Valley, except for the Turtle Mountain area which has elevations greater than 2,000 feet.

Stream systems are poorly developed in the Drift Prairie; most of the runoff drains into the numerous closed depressions where it percolates to a ground water table or evaporates.

Most of the existing streams occupy channels which carried water from the melting glaciers. The major streams, namely the DesLacs, Souris, James and Sheyenne Rivers, occupy large, glacial meltwater valleys and are grossly underfit in relation to the size of the valleys in which they flow.

The cutting of deep, steep-sided coulees back from the glacial stream valleys is the principal development of drainage in the 10 to 12 thousand years since the last glaciation. The valleys during this post-glacial period have been modified by the deposition of alluvium, the meandering of the present streams on the wide valley bottoms, and the deposition of alluvial fans at the coulee mouths.

The till plain occupies more than 80 percent of the area of the Drift Prairie. This is an undulating plain with low rounded knolls, numerous closed depressions, and a few widely spaced streams. The dominant relief is less than 25 feet. Within the area are four distinct moraines which rise from 50 to more than 100 feet above the general level of the surrounding plain. These linear and curved ranges of hills mark either the limits at which the glacier remained stationary for a time, because of a lull in melting, or are end points of readvances of the ice sheet. The relief in these hilly areas exceeds that of the rest of the till plain; slopes are steeper and depressions are larger, deeper and less numerous.

One range of hills extends south from the eastern part of the Turtle Mountains into Benson county and then curves southwest to the Missouri Coteau in Sheridan county. Another extends eastward from central Benson county on the south side of Devils Lake and Stump Lake. A third extends east from the northeast corner of Wells county to north central Eddy county and then curves southeast to northwestern Griggs county. The fourth and least prominent range of hills borders the Sheyenne River on the east from Nelson county to northwest Ransom county.

The Turtle Mountains (Figure 8) is a rolling to hilly upland thickly mantled with glacial drift and dotted with many deep, closed depressions and small lakes. The area rises 500 to 800 feet above the general level of the adjacent Drift Prairie and is the larger of the two wooded upland areas in the state. It has no stream drainage.

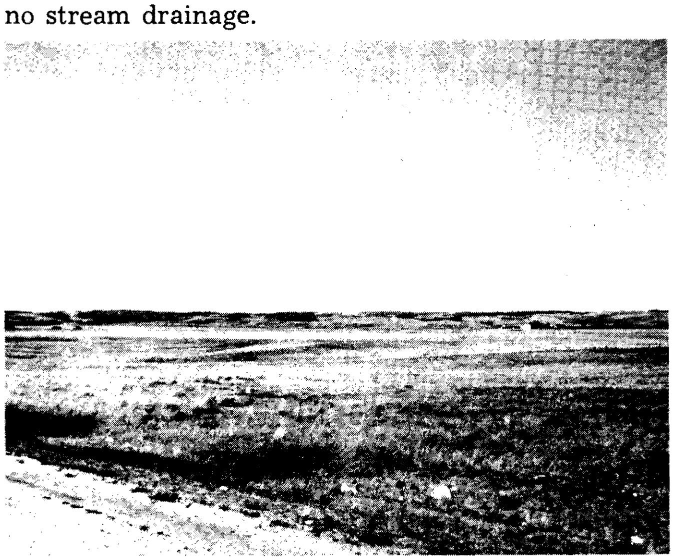


Figure 8. Turtle Mountains in background, outwash plain in foreground.

The basin of Glacial Lake Souris lies in McHenry, Pierce and Bottineau counties. The lake sediments in McHenry and Pierce counties are mostly sandy loams and loamy sands. "Sand hill' areas in central and northeast McHenry county mark areas of the most active post-glacial wind reworking of the sands. In Bottineau county, the center of the lake basin is occupied by an "island" of till plain, most of which lies on the east side of the Souris River. East of this "island" the lake sediments are clayey; on the west side the sediments are sandy.

The northern tip of Glacial Lake Dakota occupies the southeast and southwest corners of Dickey and Sargent counties respectively. Like Glacial Lake Souris, most of the sediments in the North Dakota portion of Lake Dakota are sandy loams and loamy sands. The area in both counties adjacent to the common county boundary are, in some places, hummocky and duned from post-glacial wind reworking of the sands. Near the center of the lake basin is a prominent range of hills that rises 50 to 100 feet above the level of the basin. It lies one to two miles east of the county line and extends about eight miles north from the South Dakota boundary. These hills have a core of glacial till and are mantled to various depths with wind-blown sands from the lake basin to the west.

The three largest outwash areas are in the central part of Drift Prairie. The outwash in Griggs county was deposited by glacial meltwaters flowing from the northwest. Much of the sand and gravel is derived from Cretaceous shales. In central Eddy county the outwash was deposited by meltwaters from the north and west. The eastern part of this area also has a high proportion of sediments derived from Cretaceous shale. The third large area lies north of the Sheyenne River in northeast Eddy and western Nelson counties and south of Devils and Stump Lakes in southeast Benson and western Nelson counties. The outwash here was deposited by meltwaters from the north and west.

Other smaller areas of outwash are at the south edge of the Turtle Mountains, the "sand prairie" in the northwest corner of Ransom and south central Barnes counties, and "Englevale slough" in western Ransom county, through which the Sheyenne River flowed into Lake Dakota.

Lake Agassiz Basin (Red River Valley)

The Lake Agassiz Basin (Figure 9), better known as the Red River Valley, extends from the Canadian border to the South Dakota line. It extends 30 to 40 miles westward from the Red River through most of its length and tapers to a width of about 10 miles in the southeast corner of the state. The area of the lake basin is about 7,000 square miles.

In the north the Pembina Escarpment marks the boundary between the Lake Agassiz Basin and the Drift Prairie. Here there is an abrupt rise from the lake basin to the level of the Drift Prairie. Elsewhere the differences in elevation between the two areas is slight but the boundary is easily distinguished. The smooth, nearly level lake basin contrasts sharply with the low knolls, numerous depressions, and undulating surface of the Drift Prairie.

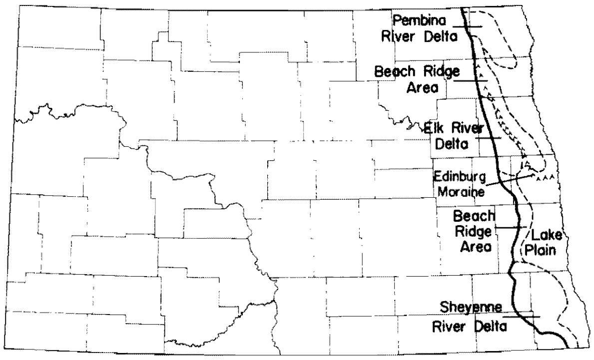


Figure 9. Lake Agassiz Basin (Red River Valley).

The western part of the lake basin slopes to the east while the lake plain slopes very gently to the north and east. Elevations of the deltas and beach areas range from 1,000 to 1,150 feet; the lake plain elevations range from 1,000 feet in the south to about 800 feet in the north.

The western or outer part of the lake basin is occupied by deltas and beach areas; the eastern part is a nearly level lake plain. The two are nearly equal in size although they vary greatly in width. Sediments in the western part range from medium to coarse-textured.

The Wild Rice, Sheyenne, Goose, Turtle, Forest, Park and Pembina Rivers flow across the lake basin to the Red River. With the exception of the Sheyenne and Pembina Rivers, these streams have their headwaters in the eastern edge of the Drift Prairie. They enter the beach and delta areas on the western edge of the lake plain flowing southeast; they are deeply entrenched in these areas. On the lake plain their courses are to the north and east. On the lake plain the streams are primarily shallow channels with little or no flood plain because the low gradient of the lake plain has prevented downcutting and entrenchment. Except for the stream channels, the development of natural surface drainage in the Lake Agassiz Basin since glaciation is no further advanced then that of the Drift Prairie.

The Lake Agassiz Basin, particularly the lake plain, is divided into northern and southern parts by the Edinburg moraine. This moraine extends from the extreme southwest corner of Pembina county south and slightly east into northwest Traill county and then curves eastward into Minnesota parallel to the Goose River. South of the Goose River the lake plain sediments are mostly moderately fine and fine-textured. North of it medium and moderately fine-textured sediments are most common. The deltas of the lake basin are the Pembina in the north, the Elk in the central part, and the Sheyenne in the south.

The Sheyenne is the largest of the three deltas. Sands, loamy sands and sandy loams are the dominant sediments with areas of very fine sandy loams and loams on the eastern edge. The most prominent feature is the "sand hills" area in the central part of the delta bordering the Sheyenne River. The sandy sediments have been blown into dunes and hummocks with numerous "blowouts".

The Pembina Delta lies in Pembina and Walsh counties. Fine sandy loam and very fine sandy loam sediments are most extensive on the Pembina Delta. Sands and loamy sands cover the area near the point where the Pembina River enters the lake basin. Most of the sands and loamy sands have been blown about by wind but "sand hills" are less extensive and less prominent than on the Sheyenne Delta.

The Elk River delta was laid down by a glacial stream which existed only during the glacial period. The delta sediments are finer-textured than those of the Pembina and Sheyenne deltas with a range from fine sandy loam to loam. Little if any, loamy sand and sand sediments occur on this delta.

The lake plain is a nearly level area which slopes very gently to the north and east. Elevations range from near 1,000 feet in the south to about 800 feet on the Canadian border. The elevation declines at a rate of about one foot per mile from south to north. Adjacent to the Red River, the northward rate of fall is about 1.5 feet per mile south of Fargo, and about one foot per mile from Fargo to Grand Forks. From Grand Forks to the international boundary the fall is about 6 inches per mile. The eastward slope of the lake plain toward the Red River averages about 2 feet of fall per mile. The fall is greater in the outer portion of the plain. Within a few miles of the Red River the fall per mile decreases to less than a foot in many places.

Five beaches of Glacial Lake Agassiz extend for nearly its entire length. From west to east they are the Herman, Norcross, Tintah, Campbell, and McCauleyville beaches. They mark major levels of the lake and are the only beaches in the southern half of the basin. In the northern half, the Blanchard, Hillsboro and Emerado beaches mark lower lake levels. Several other low, indistinct beaches are on the northern part of the lake plain.

Herman beach, which marks the outer limit of the lake basin, and Campbell beach are the longest and most continuous of the prominent beaches.

Two major areas with distinct beach ridges are in the lake basin. One lies between the Elk and Sheyenne deltas; the second lies between the Pembina and Elk River deltas and extends southward on the east side of the Elk River delta. Both range from 6 to 10 miles in width. The slope is eastward between the beach ridges. At the major beaches the elevation drops 10 to 20 feet within a short distance. Although McCauleyville beach is the eastern boundary of the southern area of beach ridges, it is but a slightly discernible rise at the edge of the lake plain. Campbell beach marks the approximate boundary clearly because of the abrupt change in elevation. Emerado beach marks the eastern boundary of the northern area.

Most of the sediments in the beach areas are loams and sandy loams with some small areas of loamy sands in northern Cass, northern Grand Forks, and Walsh counties. The beach ridges have loam and sandy loam sediments underlain by gravel and coarse sand at depths of less than 2 feet in most places. In some places the beach ridges are composed of very fine sands and silts. The thickness of the mantle of lake sediments overlying glacial till is less than 5 feet in the western part of the southern beach area and the part of the northern area which borders upon the Edinburg moraine.

Large areas on the lake plain have a complex pattern of very low, connecting ridges and intervening depressions. In the southern half of the lake plain the elevation of the ridges is usually a foot or less; in the north the ridges usually rise one to two feet. Near the streams the ridge-depression pattern has been obliterated by stream overflow and the deposition of sediments during floods. The natural levees bordering the entrenched stream channels are higher than the adjacent lake plain. The very low slope gradients, few streams and natural levees, and the complex pattern of low ridges (with elevations which frequently exceed the amount of fall per mile) retard the runoff of excess water and cause a major drainage problem on much of the Lake Agassiz Plain.

In two areas of the lake plain the materials consist of water-worked glacial till or a mantle of lake sediments one to three feet thick overlying the glacial till. One of these areas is in the central and southern areas of eastern Richland county. The other is on the western edge of the lake plain in Walsh, Grand Forks and Traill counties.

Climate

North Dakota has a continental climate with cold winters and warm summers. The climates of eastern and western North Dakota have been referred to as "cool temperate subhumid" and "cool temperate semiarid", respectively.

The features of climate that are of the most interest and greatest importance are the amount and seasonal distribution of precipitation, seasonal temperatures, and the length of the frost-free season. Precipitation data are presented in Table 1. The areas listed are those used by the Crop Reporting Service. Temperature data are presented in Table 2.

Table 1. Approximate long-time average annual and warm season (April to September, inclusive) precipitation in various areas of North Dakota (compiled from U. S. Weather Bureau data).

Area of State	Annual precipitation (Inches)			Warm season precipitation (Inches)		
	West	*Central*	*East*	*West*	*Central*	*East*
North	14 to 16	15 to 17	17 to 20	10 to 12	12 to 14	14 to 16
Central	14 to 16	16 to 18	18 to 21	10 to 13	13 to 15	15 to 17
South	14 to 16	16 to 18	18 to 21	10 to 13	13 to 15	15 to 17

Table 2. Approximate long-time average July and January temperature in various areas of North Dakota (compiled from U. S. Weather Bureau data).

Area of State	July temperature (°F)			January temperature (°F)		
	West	*Central*	*East*	*West*	*Central*	*East*
North	65 to 70	65 to 68	65 to 68	2 to 8	-1 to 7	-2 to 3
Central	67 to 70	67 to 70	67 to 69	7 to 14	2 to 9	2 to 6
South	70 to 72	69 to 72	69 to 71	9 to 14	6 to 11	4 to 10

The data in Table 1 are long-time averages. The value for an individual year may differ considerably from these averages. For example, the precipitation at some weather stations has been less than half of the amount shown in some of the driest years and more than double the amount shown in some of the wettest years.

The data indicate a west to east trend of increasing precipitation. The areas in the east with the highest precipitation receives about 1½ times as much moisture as the driest areas in the west. Warm season precipitation amounts to about 70 per cent of the annual precipitation in the eastern area and about 80 per cent of the annual precipitation in the west.

Table 2 data show a north to south trend of increasing temperature. July temperatures are slightly higher in the western areas. In January, the temperatures in the western areas are several degrees higher than the temperatures in the eastern areas.

The length of growing season increases from north to south as indicated by the data in Table 3.

Table 3. Average long time length of frost-free season in various areas of North Dakota (Compiled from U. S. Weather Bureau data).

Area of State	Frost-free season (days)		
	West	*Central*	*East*
North	110 to 120	100 to 120	100 to 125
Central	120 to 130	110 to 125	115 to 130
South	120 to 130	110 to 130	120 to 135

A comparison of the actual long-time water supplies (precipitation) and the "ideal" water supply (the amount needed to meet the average potential water removal by evaporation and transpiration of plants) is presented in Table 4.

Table 4. Comparison of actual long-term and "ideal" water supply (potential evaportranspiration)* for Central North Dakota.

	Month						
	Apr.	*May*	*Jun.*	*Jul.*	*Aug.*	*Sept.*	*Total*
Actual water supply (inches) [1]	1.3	2.4	3.9	2.3	1.9	1.4	13.2
Ideal water supply (inches) [2]	1.0	3.1	4.4	5.6	4.8	2.8	21.7
Surplus (+) or deficit (-)	+0.3	-0.7	-0.5	-3.3	-2.9	-1.4	-8.5

[1] = rainfall
[2] = evaporation and transpiration with ideal soil water supply.
* Thornthwaite and Mather method.

The data in Table 4 indicate that the long-time average monthly rainfall during the growing season is sufficient to meet the long-time average evaporation and transpiration needs only in April. A moisture deficit occurs from May to September. Thus, moisture stored in the soil by accumulation during the non-growing season is of great importance in making up the precipitation deficits for plant growth which occur in all areas of the state in most years. The moisture deficits decrease from west to east and from south to north.

Non-growing season precipitation is higher in the eastern areas of the state than in the west.

Geology

Much of North Dakota lies within the Williston Basin. At one time this large basin was subjected to periodic invasions of the sea. During the periods of submergence, sediments of marine origin accumulated; between and following the invasions of sea water, land-deposited or continental sediments were laid down.

The deepest part of the Williston Basin is near the Killdeer Mountains in Dunn county. The sediments here are estimated to be about 15,000 feet thick. The location of the surface exposures of the various sedimentary formations are shown in Figure 10.

The sedimentary rocks exposed at the surface were laid down in the Cretaceous and Tertiary periods. The Cretaceous period, marked by the development of early mammals and the extinction of the dinosaurs, began about 130 million years ago and lasted for 60 million years.

The oldest Cretaceous formation is the Niobrara, a marine formation. It is exposed in western Pembina and eastern Cavalier counties near the Pembina River and its tributaries. The Pierre shale, also of marine origin, is at the surface in several areas in addition to those shown in Figure 10. These are along the Pembina, Sheyenne and James River valleys and in LaMoure and Dickey counties. The youngest marine formation of the Cretaceous period is the Fox Hills. The Hell Creek, of continental origin, is the last formation of the Cretaceous period.

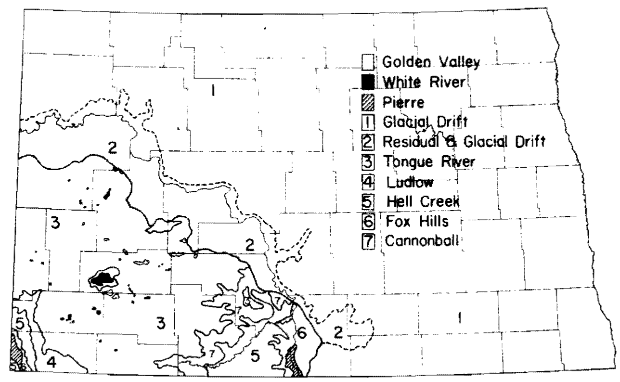


Figure 10. Exposures of sedimentary formations (Adapted from: Hainer, North Dakota Geological Survey Bulletin #31, 1956)

The Tertiary period began about 70 million years ago. The Ludlow is a continental formation and the earliest of the Tertiary beds. Following the deposition of the Ludlow, the basin was again invaded by the sea and the sediments of the Cannonball formation deposited. This was the last submergence of the basin by seawater and all subsequent formations are of continental origin.

After the final recession of the sea western North Dakota became a vast humid lowland with shallow lakes and densely vegetated, forested swamps. The plant remains accumulated in the shallow waters and were buried beneath alluvial sediments. The cycle of vegetative growth, the accumulation of plant remains and their burial by sediments was repeated a number of times. The layers of plant remains eventually were altered, under the burden of the sediments, into lignite coal. This formation, with its vast commercial lignite beds, is called the Tongue River. It is the most extensively exposed sedimentary formation in western North Dakota.

The Golden Valley formation is inextensive and was deposited from 60 to 35 million years ago. The most prominent area is in the Little Badlands in Stark county.

The most recent formation is the White River which, like the Golden Valley, is inextensive. Some of the areas on which it occurs are the Killdeer Mountains, Rainy Buttes, Black, White, and Wolf Buttes. Its deposition started about 35 million years ago and coincides with the development of modern plants and animals.

Mountain formation in western North America began about 12 million years ago. The uplift accompanying the development of mountains in Montana and Wyoming and the Black Hills in South Dakota increased the elevation of western North Dakota. The increase in slope gradients resulted in more rapid down cutting by streams and erosion of the weakly consolidated sedimentary formations. The buttes, capped by sandstone and other materials resistant to erosion, mark the level of an earlier landscape. The elevation difference between the tops of the buttes and the uplands and entrenched valleys indicate the amount of sediments removed from the area by geologic erosion.

About a million years ago continental ice sheets spread over Europe and North America. Four ice sheets advanced across North America—the Nebraskan, Kansan, Illinoian, and Wisconsin. Two and possibly four ice sheets invaded North Dakota. It has been about 10,000 to 12,000 years since the last glaciation.

The limit of glaciation is shown in Figure 4. Near the outer limit the deposits of glacial drift have been removed by post-glacial erosion. Only stones and boulders remain as evidence of glaciation. The sediments deposited by glaciation cover more than 80 per cent of the state. The locations of the various kinds of glacial sediments are shown in Figure 12.

Soil

Soil is defined as the natural medium for the growth of land plants. It is a continuous body on the land surface (except in perpetually frozen areas, on mountain peaks, barren rocks and sands, and where it is broken by streams or other bodies of water). "Soil" or "the soil" are general terms which include all soils. Thus it includes many kinds of soils formed from differing materials under a variety of conditions. The term "a soil" refers to a single soil with defined characteristics. Although there are many soils which differ greatly from one another in their characteristics, all mineral soils have some characteristics in common.

All soils consist of solid matter and pore space. The solid matter includes mineral and organic particles; the open spaces between the mineral and organic particles, or groups of particles, are occupied by air and water. The proportion of the total volume of the soil occupied by solids and pore space varies from soil to soil. There is also variation from soil to soil in the size of the mineral particles, the amount of organic matter, and the size of pore spaces.

The mineral portion consists of sand, silt and clay-sized particles weathered from rocks and minerals. The organic matter includes living organisms and the remains of dead organisms in various stages of decomposition. Water moves up, down, and laterally in the pore spaces. Air occupies and moves in the pore space not filled with water.

Clay particles and organic matter are the most active portions of the solid matter of soils. Clay particles are plate-shaped, sticky when wet, and have the capacity to expand and contract with wetting and drying. The clay fraction of the soil has high chemical activity. The ability of the clay to attract, absorb and release nutrient ions for plant use reduces plant food losses by leaching. Clay, because of its cohesion and adhesion, is important to the development of soil structure. In general, soils low in clay have weak soil structure.

The organic matter or humus has, like clay, the capacity to attract, adsorb and release plant nutrients. Organic matter coats the mineral particles of the soil, particularly in the surface layer. It aids in the development of soil aggregates and structure. Soils high in organic matter are more friable than soils of similar texture that are low in organic matter. Organic matter is also a source of nutrients, especially nitrogen, for plants, bacteria, and other organisms. Organic matter, because of its low density, occupies a much greater volume of the solid matter portion than is indicated by its percentage of total weight. An organic matter content of 5 per cent, by weight, in a loam-textured surface layer occupies about 10 per cent of the total volume of the layer.

The soil water and soil air which occupy the pore space differ from water and the air of the atmosphere. Water in the soil is a solution containing materials dissolved from the soil. The soil air is lower in oxygen and higher in carbon dioxide than the atmosphere. The carbon dioxide content of soil air is 10 to 100 times greater than in the atmosphere.

Soil is a natural body that is the meeting place of the biological and physical forces. The solid matter provides the framework or skeleton of the soil; the pore space is a sort of combination respiratory and circulatory system.

The Soil Profile

A soil consists of two or more horizons or layers that are roughly parallel to the land surface. Each layer, or horizon, has characteristics that distinguish it from the layer above and below it. These characteristics are the result of the influence of the material from which the layer has formed, climate, and living organisms (plants, bacteria, insects, animals) upon soil formation. The horizons differ from each other in one or more properties such as thickness, structure, texture or color. The sequence of horizons from the surface downward is called the soil profile.

Each soil has a profile which varies in the number of horizons, kind of horizons and sequence of horizons. Horizons vary in their distinctness. Some differ sharply from the layer above or below and are easily seen. Others have gradual boundaries which grade into the layer below over a distance of several inches.

The major horizons of a mineral soil are designated A, B and C in order from the surface downward. A soil with these horizons has an A-B-C horizon sequence. In some soils the B horizon is absent; these soils have an A-C horizon sequence or an A-C profile.

A horizon

The A horizon is often called the surface soil. Thickness of the A horizon varies greatly. In places it is as much as 2 feet thick. The most common thickness is from 6 to 14 inches in eastern North Dakota and 3 to 10 inches in the western half of the state.

The A horizon is the first to receive precipitation. Soluble materials are dissolved and carried downward by the water moving into the soil. These materials may be deposited in the lower layers or removed entirely by water percolating to the ground water table. This removal of materials in solution is called **leaching.** Continued leaching, particularly the removal of calcium, can lead to the development of soil acidity and requires the replacement of calcium by liming. The precipitation in North Dakota during the period of soil formation has not been sufficient to cause enough calcium removal by leaching to develop acidity. Only in the Planosols, which are intermittently ponded, has leaching been sufficient to cause acidity. The clay particles present, or which form by weathering or synthesis, may also be moved downward in the water and accumulate in a lower horizon.

The A horizon in North Dakota soils is dark-colored (black, very dark gray, or very dark brown) and contains more organic matter than the B or C horizons. Plant roots, bacteria, fungi, insects and animals are most common and most active in this horizon. The dark color of the horizon is caused by the coating of the mineral particles with fine particles of strongly decomposed organic matter.

The grasses are heavy users of calcium and magnesium. These are taken up by the plants during the growing season and returned to the soil in the dead tops and roots in amounts sufficient to maintain a neutral reaction.

B horizon

The B horizon occurs below the A horizon. It is lower in organic matter and is not as dark-colored as the A horizon. Although it contains organic matter, the amount is too low to completely mask the color of the mineral grains. The colors are commonly brown in well-drained soils.

The B horizon occurs at depths of 1 to 24 inches. Except in coarse-textured and Solonetz soils, the dominant types of structure are prismatic and blocky.

In many North Dakota soils, the leaching of the B horizon has been sufficient to remove the soluble salts and free lime. Other materials moved downward from the A horizon, particularly clay and organic matter, have accumulated in appreciable amounts in the B horizon in only a few North Dakota soils, such as the Planosols and Solonetz soils. Consistence of the material in this horizon is usually less friable and more sticky than the A horizon material, usually because of the lower organic matter content. In soils such as the Planosols and Solonetz the less friable B horizon also is related to higher clay content.

C horizon

The C horizon is the deepest horizon in the profile and has undergone the least change by soil forming processes. The C horizon is called the soil parent material because the materials usually are like those in which the A and B horizons have developed. If it is unlike the materials in which those horizons have formed, the horizon is designated IIC.

The C horizon usually is lighter-colored than the A1 and B horizons. It has little organic matter and weak or no structural development. Except in the Planosols and some soils with coarse textures, the entire horizon is usually calcareous. The upper C horizon is commonly enriched with accumulated lime leached from the A and B horizons. This lime accumulation indicates the approximate average depth of downward water movement or the depth of leaching. The more soluble salts have been leached out of this horizon or into the lower part.

In describing soil profiles the major horizons often are split into subhorizons as shown in the hypothetical soil profile in Figure 11. These subhori-

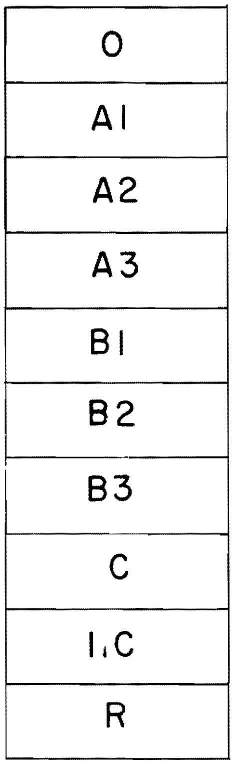


Figure 11. Hypothetical soil profile.

zons are further divided as necessary in making the detailed descriptions necessary to study the soil.

The descriptions of soils used in this report are general and only major horizons and subhorizons are used. Some of the horizons shown in the hypothetical soil profile have not been used in the general descriptions. Gradational soil layers sometimes are designated by combination of these symbols in some soils as AC, A2-B2, etc.

The symbols—letters and numbers—used to designate the soil horizons are defined and described briefly below:

O	organic surface layer; an accumulation of fresh and partially decayed plant residues; occurs only in undisturbed areas of Gray Wooded soils; destroyed by grazing or tillage.
A1	dark-colored mineral surface soil layer high in organic matter (humus).
A2	a subsurface layer from which some clay has moved downward; usually has gray color and platy structure.
A3	transitional to B but more like A than B.
B1	transitional to A but more like B than A.
B2	a subsoil layer that contrasts with the overlying and underlying layers in color, texture and/or structure, often brown in color and prismatic and/or blocky; in most sandy soils this layer is distinguished from the overlying and underlying layers primarily on the basis of color.
B2t	a subsoil layer that contrasts with the overlying and underlying layers in color, texture and/or structure and in which considerable clay has accumulated by movement downward from the overlying layer or layers; usually prismatic, columnar and/or blocky.
Bsa	a subsoil layer containing soluble salts.
C	subsoil or substratum material similar to that from which the overlying layer or layers are presumed to have developed (C1 and C2 are subdivisions of C).
Cca	subsoil or substratum layer of material similar to that from which the overlying layer or layers have developed; contains a considerable accumulation of lime (calcium carbonate).
IIC	subsoil or substratum material that contrasts in texture, structure or origin with that from which the overlying layer or layers are assumed to have developed.
IICca	subsoil or substratum material that contrasts in texture, structure or origin with that from which the overlying layer or layers are assumed to have developed; contains a considerable accumulation of lime (calcium carbonate).
R	substratum of bedrock; used only for sandstone, hard shale or "scoria" in North Dakota soils.

Soil Formation

Soils form in the unconsolidated material on the earth's surface. The kind of soil formed in a place is determined by (1) the nature of the parent material, (2) climate, (3) living organisms, (4) the influence of topography or relief upon climate and living organisms and (5) the length of time since soil formation started.

These are called the five factors of soil formation. The influence of any one factor upon the formation of a soil depends upon the nature of the other four at the particular place. Each factor modifies the effect of the others on soil development.

Parent Material

The accumulation of parent material or particles weathered from rock is necessary before soils can form. In North Dakota most of the parent materials have been transported by glacial ice. The parent materials in the southwestern part of the state have weathered in place from sedimentary rocks.

Soils developed from sandy parent materials are coarse-textured, have weak structural development, low moisture-holding capacity and low inherent fertility. Nearly all of the precipitation enters the soil but the large pore spaces permit the loss of much of the moisture by deep percolation.

Fine-textured parent materials develop into soils that often are slowly permeable, have very high moisture-holding capacity, and have high fertility levels. Their capacity to shrink and swell with drying and wetting develops wedges of dark A horizon material which extend deep into the profile. The soils have a limited range in which tillage can be performed. If they are tilled when wet they are very sticky and structure breaks down; when dry they are very cloddy. Productivity may be reduced by the small pore spaces which hold water tightly and reduce aeration.

Soils developed from medium-textured parent materials usually are the most desirable for crop production. Aeration, water-holding capacity, structure, inherent fertility and the range of moisture content at which the soils can be tilled are favorable for crops.

The locations of the various sedimentary rock exposures are shown in Figure 10. East and north of the Missouri the parent materials have been transported by ice with some subsequent movement by water and wind. The locations of ice, wind and water-transported materials are shown in Figure 12.

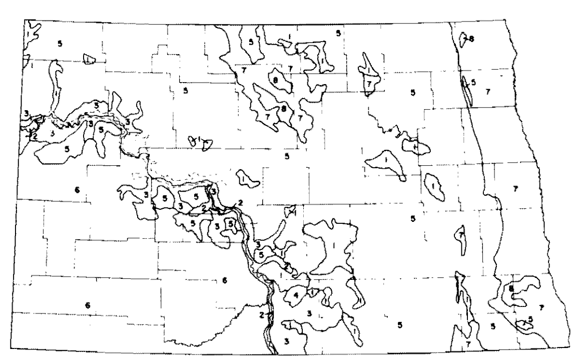


Figure 12. The location of parent materials of different origins:

(1) glacial outwash, (2) glacial outwash and alluvium, (3) complex of glacial till, loess, and residuum, (4) loess, (5) glacial till, (6) residuum, (7) glacial lake sediments and (8) aeolian sands.

Residuum is the material weathered from rocks in place. It occurs mostly west of the Missouri River and ranges from loamy sand to clay in texture.

Glacial till is unsorted material deposited by glacial ice. It is a random mixture of sand, silt, clay, pebbles, and stones with no sorting of the various sized particles. Textures of the glacial till are dominantly loams and clay loams but include loamy sands and sandy loams.

Glacial outwash is material carried by water flowing outward from the melting glacier. Gravel, sand, loamy sand, sandy loam and loam are the dominant textures. The coarser sediments are deposited near the ice front; the sediments become finer as the distance from the source increases. Sandy outwash in most areas has been blown into undulating and hummocky topography by wind.

Glacial lake sediments were deposited by glacial streams flowing into natural basins or ice-blocked basins. Silts and sands were deposited as deltas near the river mouths in the glacial lakes; the clays settled out in the deep, quiet waters of the lakes. Other lake sediments near the shore lines or beach ridges result from the sorting of sediments by wave action and the associated currents.

Loess is silty wind-transported material. Coarser sand and pebbles are lacking. Loess occurs adjacent to the Missouri River. The areas lie leeward from places where the prevailing northerly winds had a sufficient sweep across the Missouri River bottomlands to pick up large quantities of silt. The loess areas lie southeast of these areas. The only area in which loess is dominant is in Emmons county. Loess is thicker on the south and east slopes than on north and west slopes and seldom occurs on slopes greater than 6 per cent. The loess deposits on the stronger slopes probably have been removed by later geologic erosion.

Aeolian or wind blown sands occur in the glacial lakes and deltas and areas of sandy Tertiary formations. The sandy sediments have been blown into dunes and hummocks and are known as "sand hills". The major areas are in the Lake Agassiz and Souris basins.

Alluvium consists of sediments deposited by floodwaters on stream bottoms. Textures range from sands to clays.

Colluvium occurs on positions at the base of slopes. The sediments are largely local alluvium, material moved by local wash or gravitational creep from the higher lying slopes.

Climate

Climate and living organisms are the dominant forces in soil formation. The climate of an area determines the kinds of plants and animals that can thrive in the particular location. The influence of climate upon soil formation is so great that the world pattern of broad groups of soils follows the climatic regions of the earth.

Precipitation and the amount of water entering the soil influence the amount of leaching, the kind and amount of vegetative growth, rate of weathering and clay formation, and the release of plant nutrients from the mineral fraction of the soil.

In North Dakota the leaching is sufficient to remove the more soluble salts from the profile or into the lower part of well-drained soils. Calcium is leached from the A and B horizons and accumulates in the upper C horizons of the soils on well-drained positions. Except on coarse-textured soils, water loss by deep percolation is limited and plant nutrient losses from leaching also are low.

Alternate wetting and drying in most soils is accompanied by some expansion and shrinkage which aids in the development of prismatic soil structure in the subsoil and granular structure in the A horizon.

Precipitation decreases from east to west and form south to north in North Dakota.

Temperatures during the winter months are low. Weathering and decomposition of mineral and organic matter during the period when the soil is frozen are at a standstill. During the frost-free season temperatures and precipitation are not high enough for rapid decomposition and loss of organic matter. Expansion and contraction of soil aggregates during freezing and thawing are factors in soil structure development. In periods when day and night temperatures fluctuate above and below the freezing point the clods and larger aggregates are rapidly broken down to granular structure.

Temperatures decrease from south to north. In counties bordering Canada from the Turtle Mountains to the Red River Valley the slight decrease in temperature creates a climatic balance that is slightly more favorable for the growth of trees. The lower temperatures are accompanied by a decrease in evaporation, higher humidity, and a greater effectiveness of precipitation. The northeast corner of Cavalier county and the Turtle Mountains are wooded. Between these two areas, the small depressions are ringed by thickets of aspen and willows as shown in Fig. 13.

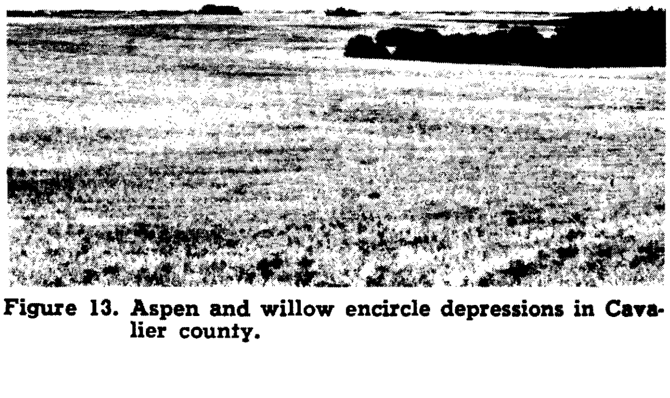


Figure 13. Aspen and willow encircle depressions in Cavalier county.

The climate of the state is discussed on page 6. The climate of landscape segments or "microclimate" is discussed in the section on topography.

Living organisms

Grass was the dominant native vegetation in North Dakota. The species changed gradually from east to west with the decrease in precipitation. Tall grasses were dominant in the east; westward the percentage of mid and short grasses increased and the percentage of tall grasses decreased. Many of the species occur in all parts of the state with a decrease in both vigor and the amount of growth from east to west.

Wooded areas occur in the Turtle Mountains, on the uplands bordering the Pembina River, and on the bottoms of some of the stream valleys.

In all areas of the state, the vegetation varied on different segments of the local landscape in relation to the influence of topography on the moisture relationships of the various sites. The short grasses were dominant on steep convex slopes in the western part of the state; in the eastern part mid and short grasses were most common. Tall grasses flourished on the concave and level areas with more favorable moisture. In the depressions wetland grasses, sedges and rushes were dominant.

The contributions to the soil of the tops and roots of grasses from the thousands of years of growth before settlement of the state has resulted in the dark-colored surface soil layer. The plant materials were largely decomposed. The plant remains resistant to decomposition accumulated and coated the mineral particles. Surface layers are black in the eastern part of the state and very dark brown in the western part. The accumulation of organic matter or humus was favored by the seasonal distribution of precipitation and cool temperature. The amount of organic matter accumulated is less in the soils on the steep and convex slopes than in the soils on concave positions.

Most of the nutrient elements used by grasses are returned to the soil each year in the dead tops and roots. This annual cycle and the weak leaching due to low precipitation tend to maintain a neutral reaction in the soil surface. Grasses are heavy users of the bases calcium and magnesium. These are taken up by plants below the surface, returned during the decomposition of the plant remains, and offset the effect of the removal of bases by leaching.

The return of vegetative growth from trees is much slower. Only the leaves are returned annually. Thus the accumulation of organic matter in the soil and the return of nutrients is less than under grass. A light-colored A2 horizon develops. Only in the Turtle Mountains and in western Pembina and northeast Cavalier counties is the influence of woodland vegetation reflected in the kind of soil profile. Gray Wooded soils have not developed on the wooded bottomlands because of the short time interval since the deposition of the alluvium.

Micro-organisms, insects and small animals also are important in soil development. The number of bacteria in a gram (about 1/28 of an ounce) of surface soil from a Chernozem may be as high as 5 billion. Bacteria and fungi decompose the remains of plants and animals and release nutrients for plant use. These organisms die, decompose and additional nutrients become available.

The amount of organic matter accumulated in the dark surface layer of most soils in North Dakota is 4 or 5 per cent. In the surface 6 inches or the plow layer the amount accumulated is 30 to 50 tons per acre. However, the total amount in the soil may be from 100 to 150 tons per acre but varies with soil texture, climate, landscape position and drainage.

Topography

Topography, or relief, influences soil formation by its effects on soil water relationships, the rate of geologic erosion, soil temperature, and vegetation.

Topography is the lay of the land. The phases of topography that affect soil formation are slope gradient, slope shape, aspect or direction of slope, and elevation.

The amount of water that enters the soil is not the same on all parts of a local landscape despite the fact that the precipitation on all parts of the landscape is nearly equal. Except on coarse-textured soils, the runoff of precipitation on steep slopes often is rapid. Less water enters the soil and the steep slopes are drier than the climate of the area. The gently sloping areas have lower runoff and the amount of water entering is greater. The soils on these well-drained positions reflect the influence of the climate of the area. On foot slopes and on nearly level areas below slopes, additional moisture is received in the form of water running on from the higher slopes. The climate of the soils in these positions is more moist than typical for the amount of precipitation the area receives.

In addition to slope gradient or per cent of slope, shapes of slope influence the effectiveness of precipitation. Convex slopes are subject to runoff; concave slopes usually receive additional water from the run-on of water from higher lying convex and plane slopes. Closed depressions or "potholes" usually receive enough additional water to cause intermittent or permanent ponding. The actual amount of moisture entering the soil here is probably more than double the precipitation of the area.

The influence of slope and shape of slope is better illustrated by a common sequence of soils on the till plain in the eastern half of the state. The soil profiles are shown in Fig. 14.

The Buse soils occur on the steep and convex

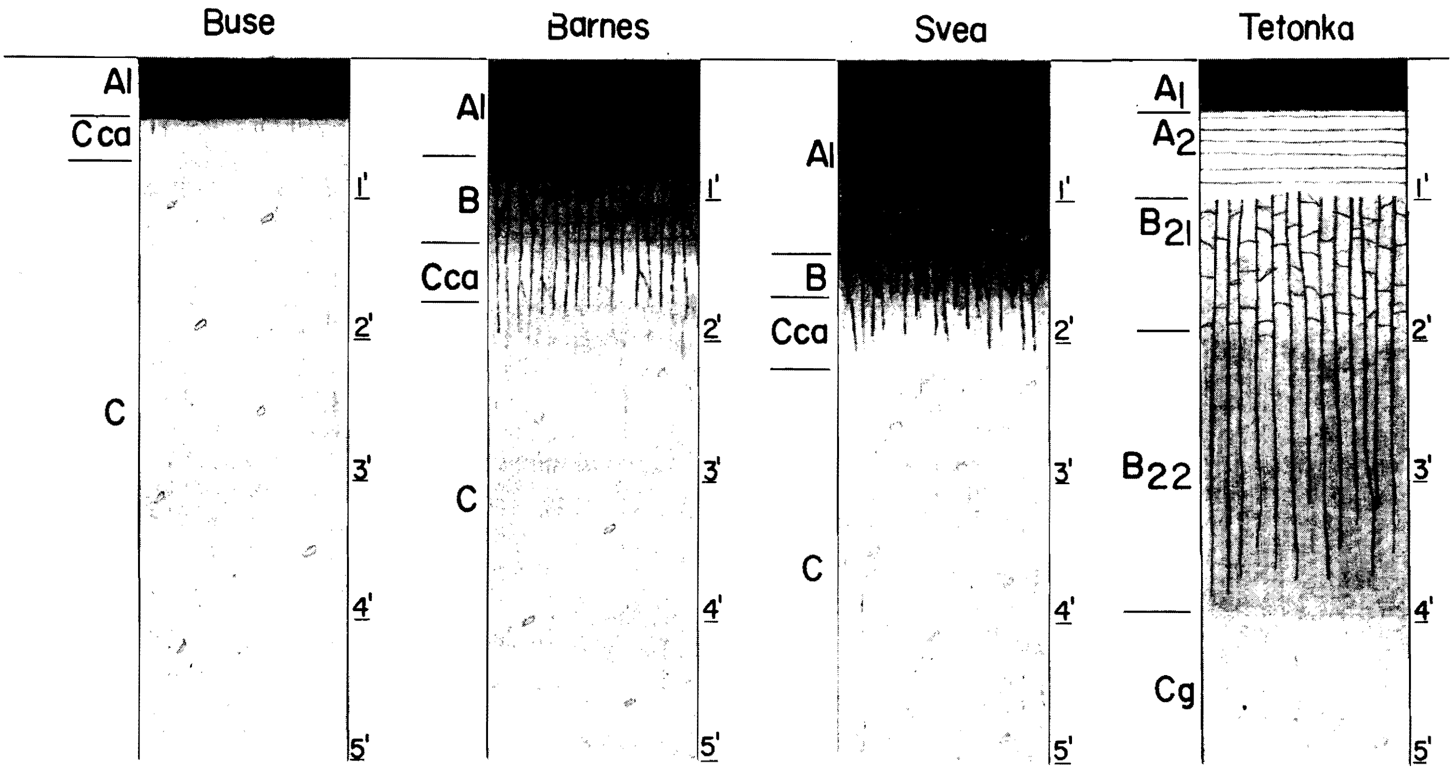


Figure 14. Soil profiles: left to right Buse, a Regosol; Barnes, a well-drained Chernozem; Svea, a moderately well-drained Chernozem; and Tetonka, a Planosol.

slopes subject to runoff. Here geologic erosion removes soil at about the same rate as it is formed. Barnes soils occur on the well-drained positions. Svea soils occur on the concave and nearly level positions which receive additional moisture from the run-on of water. The Tetonka soils occur in shallow depressions and are intermittently ponded. The development of soil characteristics and thickness of the true soil increases with increasing moisture.

The amount of moisture stored in the soil influences the kind, density and amount of vegetative growth. The Buse had a mid, short and tall grass vegetation typical of a drier climate. Barnes had a tall and mid grass vegetation typical of the area while on the Svea soil the vegetation was entirely tall grasses. Wet land grasses such as prairie cordgrass, sedges and rushes were common on the Tetonka soils in the "potholes".

The surface soil removed from the steeper slopes by geologic erosion is often deposited on lower slopes of lower gradient, especially on concave positions. The accumulation of this dark-colored surface material is partly responsible for the thicker A1 horizon of the soils on these positions.

North and east facing slopes are usually cooler than the south and west facing slopes. Steep north facing slopes support more abundant vegetation than south facing slopes of the same gradient. Stream valleys often provide examples of the effects of direction of slope on vegetation in an area. North facing slopes of stream valley sides often are wooded high up the slope; south facing slopes are usually in grass. An extreme example of the effect of aspect or direction of slope on vegetation growth and effectiveness of precipitation is shown in Figure 15.

Figure 15. North facing slope left foreground, south facing slope in the background.

Because of the prevailing northwesterly winter winds east and south facing slopes receive additional moisture from accumulations of drifted snow. The amount of snow accumulated on some steep east facing slopes in western North Dakota is sufficient to support, on undisturbed areas, a vegetation of tall grasses.

Elevation differences in the state are not sufficient to influence temperature and effective precipitation to any great extent. However, the change in elevation from the Drift Prairie to the Turtle Mountains is sufficient to cause a change in vegetation from prairie to woodland. As mentioned under the climate soil forming factor, the wooded area borders on a tension zone between grasses and woodland and the slight change in elevation probably influences effective moisture and favors the change in vegetation.

Time

Time is required for soil formation. The degree of development of the soil characteristics and the soil profile depend upon the length of time that the materials have been exposed to the soil forming forces if all other factors are equal. For example, two soils developing from the same kind of parent material under similar climate, similar vegetation, and similar relief but differing in the length of time that the forces of soil formation have been operative will have differences in the degree of expression of soil properties. The one developed for the longer period of time will have more clearly expressed horizons, more soluble materials removed by leaching, more clay formed, and more clay accumulated in the B horizon. On the older soils in western North Dakota, despite the drier climate, accumulated clay in the B2 horizon is more common than in the younger soils in the eastern part of the state.

Soils on steep slopes and those formed on coarse-textured materials are exceptions. In the first, runoff is rapid and the rate of soil removal by geologic erosion is about equal to the rate of soil formation. On the latter the materials are resistant to weathering. In these cases topography and parent material are dominant and override the effects of time.

The oldest sediments in the state are the exposed Cretaceous and Tertiary beds. However, the length of time since the overlying sediments were removed and these formations were exposed to soil forming forces is guesswork. Probably the oldest exposures date to the beginning of the glacial period or close to a million years. The age of the oldest glacial drift is unknown because of the overriding of later ice sheets and the lack of information on the location of drift of the various advances. In the eastern half of the state, the age of the drift is less than 12,000 years. This estimate is based on the Carbon 14 dating of coniferous wood from Kidder county reported by Moir in the 1957 Proceedings of the North Dakota Academy of Science.

The time for soil formation in many cases is much less than that of the youngest glacial drift. Alluvium on floodplains may be only a few days to a few years old. Duned and hummocky sands, and local alluvium on foot slopes and fans range in age from a few tens to a few hundreds of years.

The ages of the sedimentary formations in western North Dakota are discussed under "Geology" on page 7.

Soil Characteristics

Soils are studied, described, and classified on the basis of profile characteristics which can be seen or observed in the field or measured in the laboratory. Many of the important characteristics are listed in the discussion of the soil series as a unit of classification. The terms used are defined and discussed in the following sections.

Soil Color

The color of a soil is one of its most obvious characteristics and one that is used to describe the various soil layers. The color names used are obtained by comparison of the soil with standard soil color charts. Color is related to other soil properties. Dark-colored soils usually are higher in organic matter and nitrogen than light-colored soils. With adequate drainage, they usually are more productive. Soil color also is an indicator of the degree of soil drainage and aeration. In North Dakota, soils with uniform grayish brown to yellowish brown subsoils have good internal drainage. Poorly drained conditions are indicated by gray and olive gray subsoil colors or mixed shades (mottles) of gray, olive and yellow. "Mottling" is a color condition in which several colors occur in a splotchy or spotty pattern. In addition to gray and olive gray colors, a "mottled" color condition often serves as a clue to the occurrence of extended periods of excessive wetness or waterlogging in the soil layer in which it occurs.

Soil Texture

Perhaps the most useful basis for classifying the mineral particles in soils is in terms of their size. Many of the important properties of soils are related to the proportions of mineral particles of various sizes. The name of the mineral particles in soils, in decreasing order of size, are sand, silt and clay. Sand particles range from coarse to very fine and are abrasive. Silt particles are extremely fine, (microscopic in size) smooth to the feel, do not aggregate when dry and are nonsticky when wet. Clay particles are smaller than silt particles (submicroscopic in size) and tend to aggregate or hold together to form hard clumps when dry; clay is sticky, plastic and greasy when wet. The particle size limits are given in Table 5.

Table 5. Size limits of soil mineral particles and the number of particles per inch

Soil Particle Name	Diameter Limits (mm)	Particles per inch
sand	2. to 0.05	12 to 500
very coarse sand	2. to 1.00	12 to 25
coarse sand	1. to 0.50	25 to 50
medium sand	0.50 to 0.25	50 to 100
fine sand	0.25 to 0.10	100 to 250
very fine sand	0.10 to 0.05	250 to 500
silt	0.05 to .0002	500 to 12,500
clay	less than 0.002	more than 12,500

Soil texture is a measure of the coarseness or fineness of the soil and depends upon the proportions of sand, silt, and clay. The names of the soil textural classes are based on the percentages by weight of the various particle sizes. In addition to being particle size names, sand and clay are also used as texture classes.

Texture class names are modified by the use of an additional term where particles larger than sand size are present in sufficient amounts to affect the behavior or use of the soil. Examples are "gravelly" loam, "cobbly" loam, or "stony" loam.

The most commonly used texture classes are shown in Table 6. Because of the number of texture classes used it often is convenient to use a grouping of the texture classes in discussing soils. The groups also are given in Table 6.

Table 6. Soil texture groups and classes*

Texture groups		Texture classes
sandy	coarse	sand fine sand loamy sand loamy fine sand
	moderately coarse	sandy loam fine sandy loam
loamy	medium	loam silt loam
	moderately fine	clay loam silty clay loam
clayey	fine	silty clay clay

* Adapted from USDA Handbook #18, Soil Survey Manual, p. 213.

Soil Structure

Soil structure refers to the arrangement of individual soil particles (sand, silt and clay) into aggregates or clusters. The types of soil structure are described below and illustrated in Figure 16.

Prismatic: Pillar-shaped aggregates with longer vertical than horizontal dimensions and flat tops.

Columnar: Prisms with rounded tops.

Blocky: Closely fitting cube-shaped aggregates. Angular blocks have prominent edges; subangular blocks have rounded edges.

Platy: Aggregates consist of thin sheets with the vertical dimension much shorter than the horizontal dimensions.

Granular: Small, relatively nonporous aggregates with irregular, but rounded, surfaces.

Crumb: Porous granules.

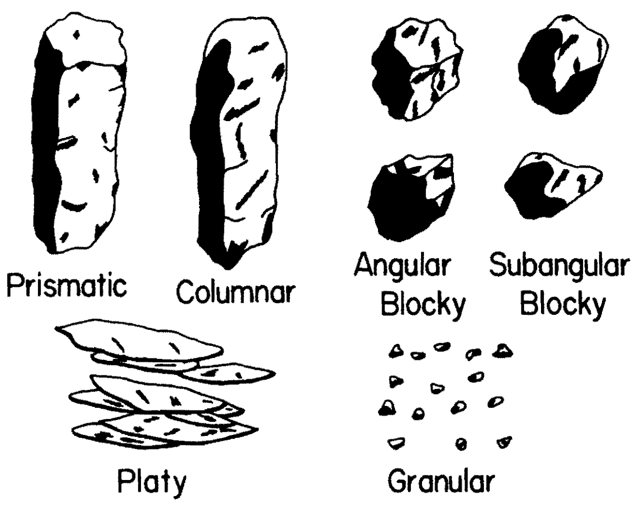


Figure 16. Kinds of soil structure. (Adapted from USDA Handbook #18, Soil Survey Manual, p. 244).

Soil that has no definite structure is either single grained or massive. Loose, sandy soils which have little clay or organic matter to bind the particles together are typically single grained. In massive soil the particles stick together in shapeless lumps.

Structure has an important bearing on the movement of air and water within the soil. Hence it affects seed germination, root growth and bacterial activity. Poor structural conditions may limit the productivity of a soil which is well supplied with plant nutrients.

Many North Dakota soils have granular surface layers (A horizons) and subsoils (B horizons) with prismatic and/or blocky structure. These soils are optimum for the penetration of air, water and plant roots.

Soil Consistence

Consistence refers to the tendency of the soil mass to crumble or retain its shape under pressure. It is due to the attraction of the soil particles for one another. Soil consistence is related to texture, and is a measure of the ease or difficulty of cultivation. Sandy soils generally are loose or very friable. Clayey soils often are very firm. Medium-textured soils generally are friable, easily cultivated, and produce the most desirable seedbeds.

In detailed soil descriptions, soil consistence is described at three standard moisture contents—dry, moist and wet. Moist consistence is the most significant because soils generally are cultivated when in this moisture range. The terms used to describe consistence in this report are for moist soil and are listed below.

Loose — Noncoherent (does not hold together)

Very friable — Soil material crushes under very gentle pressure but coheres weakly when pressed together.

Friable — Soil material crushes easily under gentle to moderate pressure and coheres when pressed together.

Firm — Soil material crushes under moderate pressure but resistance is distinctly noticeable.

Very firm — Soil material crushes under strong pressure; barely crushable between thumb and forefinger.

Soil Slope

Soil slope is an external characteristic of soil. Slope is classified by gradient or per cent of slope and shape of slope. Most soils and soil associations have typical slope patterns and slope gradient limits.

Slope gradient is described in per cent, the number of feet that elevation changes per 100 feet of horizontal distance. A 5 per cent slope rises or falls 5 feet in every 100 feet of horizontal distance.

Soil slope also is described with terms denoting the shape of the slope. Convex, plane and concave are used. A convex slope bows upward like the surface of a ball or sphere. A plane slope is like a tilted flat surface; it does not curve upward or downward. A concave slope curves downward, like the inside of a saucer. These terms are useful in describing the position of soil series in a landscape.

Slopes are complex or simple. Complex slope areas have short slopes which extend in several directions. Areas of simple slopes have a smoother appearance with long slopes extending in one or two directions.

Slope has important practical aspects in addition to its effect upon soil formation. It is important to soil use and management because of its influence on runoff, soil drainage, erosion, the use of machinery, the choice of crops that can be grown, and the management practices that are required.

The slope classes commonly used are listed below.

Dominant	Slope Class Names	
Slope Range	Simple Slopes	Complex Slopes
0 to 3 per cent	nearly level	nearly level or gently undulating
3 to 6 per cent	gently sloping	undulating
6 to 9 per cent	sloping	rolling
9 to 15 per cent	strongly sloping	strongly rolling
15 to 30 per cent	steeply sloping	hilly and steep
greater than 30 per cent	steep	steep

Soil Permeability

Soil permeability is the rate at which the soil can transmit water or air. It is measured by the rate of flow of water through a section of the soil in a specified time. Permeability classes for the soil series are given for the B and C horizons. The classes are listed below.

Permeability class	Inches per hour
very slow	less than 0.05
slow	0.05 to 0.20
moderately slow	0.20 to 0.80
moderate	0.80 to 2.50
moderately rapid	2.50 to 5.00
rapid	more than 5.00

Soil Drainage

The natural drainage of a soil refers to the rate at which excess water is removed from the soil.

Drainage conditions can be measured accurately by the use of instruments, piezometers, and observation wells over a period of time sufficient to cover the climatic range of the various landscape segments and the kinds of soil. Such procedures require long-time observations.

The drainage class is based upon observations of soil characteristics and the inferences that can be made from them. In addition, the degree of wetness, duration of wetness, water table levels and fluctuations, the ponding of surface water together with its frequency and duration, and the kind of vegetation are observed and considered in the classification of soil drainage.

Variations in soil drainage are related to soil color. Mottling and gray and olive gray colors, along with thick surface layers high in organic matter, usually indicate poor drainage. In North Dakota, soils with brown or grayish brown subsoils generally are well-drained.

Certain groups of soils are subject to varying degrees of wetness during the growing season. Soils with high seasonal water tables, for instance, may range from poorly drained in the early spring to moderately well drained in mid-summer. Placement of these soils in a specific drainage class is misleading unless it is understood that the wetness of a soil can vary considerably from year to year or within a single year.

The natural soil drainage class often determines the land use, kinds of crops that can be grown and the farming methods used. Knowledge of the drainage conditions under which a soil developed also is essential in predicting its response to management when artifically drained or irrigated.

The five natural drainage classes used in describing North Dakota soils are explained below.

Poorly drained—The water table is commonly at or near the surface for a large part of the growing season. Poorly drained soils are the result of a high water table, slowly permeable layers within the soil profile, seepage, runoff from surrounding slopes or a combination of these conditions. Soils of this drainage class generally occupy broad flats and shallow depressions or potholes. Under natural conditions, poorly drained soils normally are too wet for early spring tillage except in the driest years. Artificial drainage generally is necessary for the regular production of crops. These soils may be productive for pasture or hay in many years; in the driest years they can be cropped.

Somewhat poorly drained—The soil is wet for a significant part of the growing season, particularly in the spring or after periods of heavy rainfall. Fluctuating water tables and slowly permeable layers within the profile generally are responsible for the seasonal wetness of these soils. Somewhat poorly drained soils are on nearly level flats or slightly elevated positions adjacent to areas of poorly drained soils. Early spring seeding operations on these soils are delayed in many years.

Moderately well drained—These soils often are wet for a short time in the early spring or after heavy rains. Water movement through the soil may be somewhat restricted by slowly permeable soil materials or a temporary high water table. Moderately well drained soil conditions often are due to the position of the soil area in the landscape. These soils commonly occur on nearly level sites or lower concave slopes and swales where they receive some runoff from the higher soil areas. Moderately well drained soils are more likely to be adequately supplied with moisture in the latter part of the growing season than the well-drained soils.

Well-drained—Water is removed from these soils readily but not rapidly. Depth of rooting is not restricted by waterlogged soil conditions at any time of the year. Well-drained soils occur on convex or plane slopes where surface water does not accumulate; the soil materials are sufficiently permeable to prevent extended waterlogging. Textures commonly range from loamy sand to silty clay loam, although soils of other textural classes also can be well-drained.

Excessively drained—Water is removed from these soils rapidly because of steep slopes, coarse soil materials of high permeability and low water-retentive capacity or both. On the steep slopes considerable precipitation may be lost as surface runoff. On the coarse sandy or gravelly materials most of the precipitation is lost by deep percolation. These soils usually are drouthy.

Other Terms (calcareous, saline)

The term **"calcareous"** is used in describing soils. A soil horizon containing free lime (calcium carbonate) bubbles or effervesces when wetted with a drop or two of a dilute solution of hydrochloric acid. Calcareous or "high-lime" soil material usually is slightly to moderately alkaline and is not harmful to the crops commonly grown in the state.

Saline refers to the presence of salts, usually those that are more soluble than gypsum (calcium sulfate). Some North Dakota soils, or certain horizons of some soils, are saline (salty). This means that they contain sufficient amounts of certain soluble salts to have a harmful effect on the growth of some plants. One of the salts that is commonly present is gypsum (calcium sulfate). In some soils gypsum occurs as crystals. If gypsum is the only salt present, the soils will be only slightly saline because of the low solubility of this salt. Higher degrees of salinity usually are caused by the presence of more soluble salts such as calcium chloride or the sulfates and/or chlorides of magnesium and/or sodium.

Soil Classification

Soil classification is the branch of soil science that deals with the arranging of many kinds of soils into classes. It is the organization of the accumulated knowledge of soils to increase our understanding of soils. The purpose of soil classification, in addition to the organization of knowledge, is to bring out the significance of soil characteristics, to establish relationships among soils, to establish relationships between soils and the environments in which they develop, and to provide a basis for predicting how soils respond to management under different uses.

The categories used in classifying soils represent different degrees of specificity. Some categories are defined within a narrow range of soil characteristics, such as soil series; other categories are more broadly defined, such as great group (replaced great soil group), and include many of the more narrowly defined units.

The soils in North Dakota have been classified into soil series and grouped into soil associations. More detail on North Dakota soils and soil associations is available in Bulletin No. 472, "The Major Soils of North Dakota" and Bulletin No. 473, "Soil Survey Report-County General Soil Maps-North Dakota". These bulletins are available at a nominal fee from the Dept. of Soils, Agricultural Experiment Station, North Dakota State University, Fargo, North Dakota 58102.

General and detailed soil surveys also are available for many counties in North Dakota. Local Soil Conservation Service offices should be contacted regarding the availability of county soil surveys.

CONSERVATION

CONSERVATION IS MAN LIVING IN HARMONY WITH HIS SURROUNDINGS

The North Dakota landscape was originally covered with a native sod, dotted with trees along the major streams and ravine bottoms where moisture was abundant. Woodlands were growing in the Pembina Hills and Turtle Mountain areas. Rivers and streams ran clean and clear. Wildlife was plentiful on the prairies. The minerals lay intact beneath the soil.

Native Prairie Vegetation ▲

Pioneers Plowed Native Sod ▲

Through the years man has expanded his basic industry, agriculture. He plowed vast acreages of native grassland and cleared woodlands, removing nature's natural protective cover from the soil. Large open fields were eroded through the action of wind and running water. Grasslands were abused by overgrazing. Wildlife numbers decreased as farming methods intensified. The quality of water in lakes and streams deteriorated through the addition of nutrients attached to eroded soil particles, improper waste disposal and careless use by people.

Natural Erosion Caused by Wind, Water, Ice and Gravity ▲

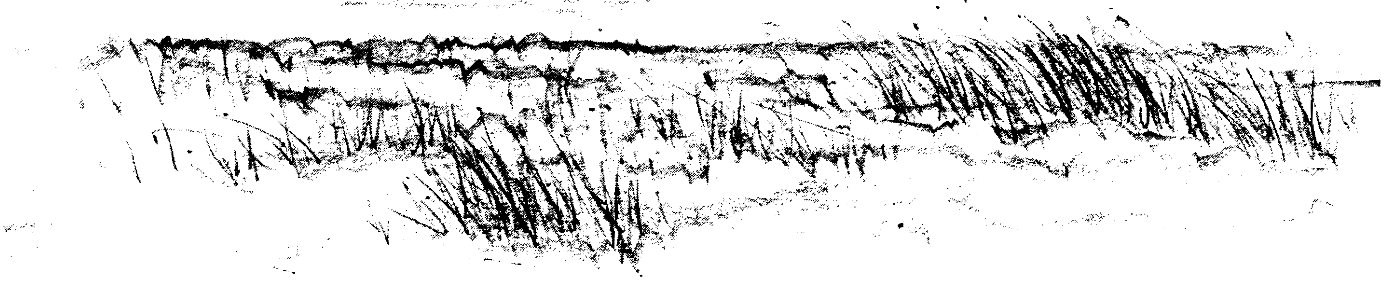
North Dakotans, both rural and urban, must develop a more positive attitude towards conservation of natural resources -- soil, water, plants and wildlife.

In North Dakota about one-half of the agricultural land is adequately protected with soil and water conservation practices to prevent soil loss due to wind and water erosion. Individuals must take the initiative to apply and maintain the needed conservation practices to adequately protect all other lands.

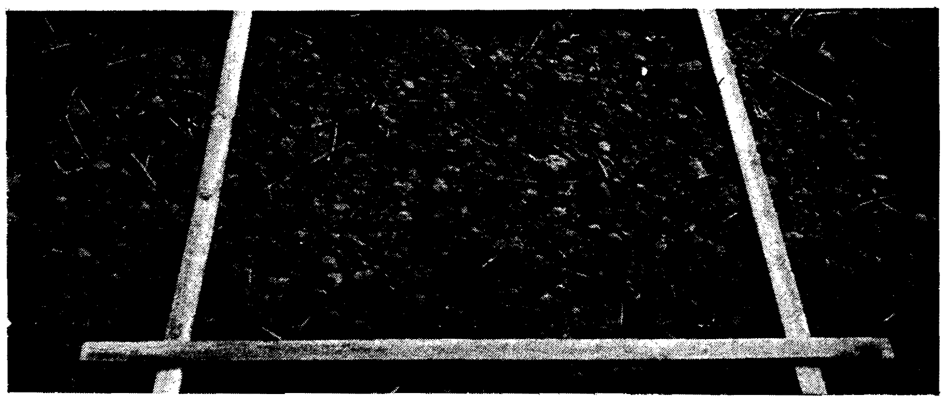
Accelerated Erosion Caused by the Action of Man ▲

The picture story presented in this brochure portrays examples of major conservation problems in North Dakota. Conservation practices are shown that effectively enhance the soil, water, plant and wildlife resources.

Wind and Water Erosion

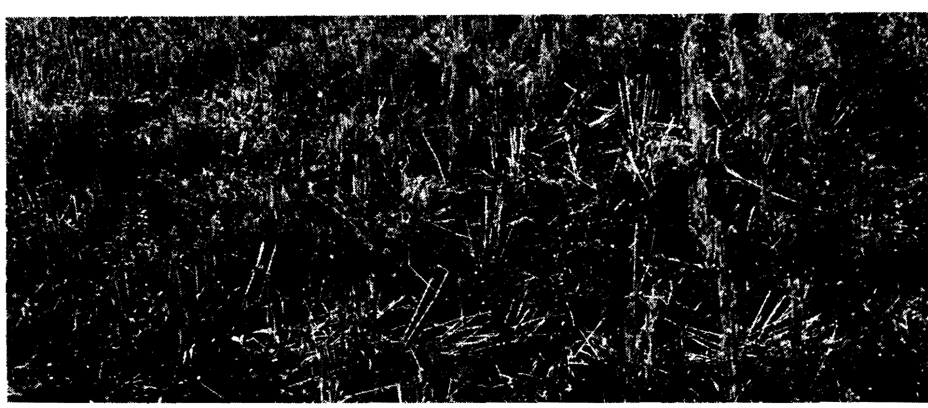


FACTORS THAT INFLUENCE WIND EROSION



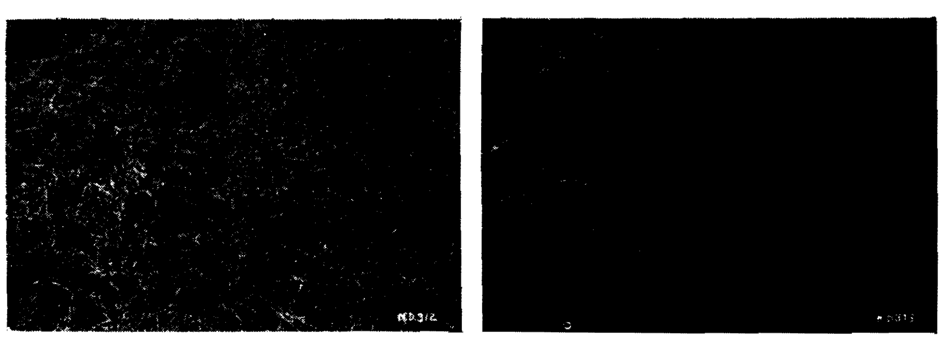
1. SOIL CLODDINESS

Soil clods resist wind erosion and protect smaller soil particles. The smaller clods provide the most protection because they have a greater total surface area. ▶



2. SURFACE SOIL COVER

Standing crop stubble protects soil more than disturbed or partially incorporated residue. ▶

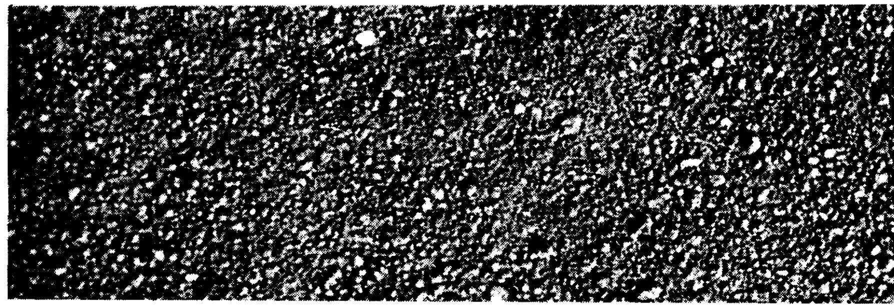


3. SURFACE SOIL ROUGHNESS

Surface residue and soil ridges trap wind blown soil particles and slow down the wind at the soil surface. ▶

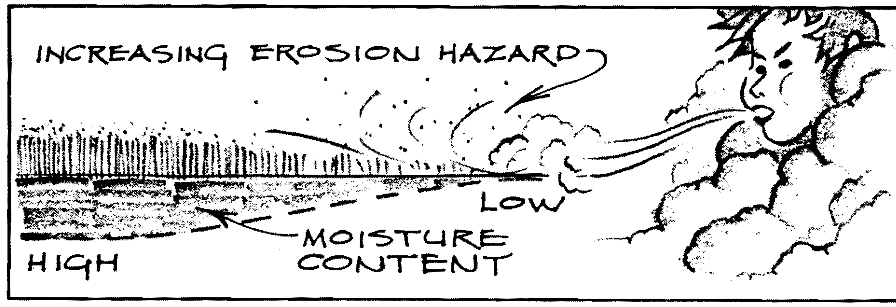
4. SOIL ERODIBILITY

Coarse textured soils (sands and loamy sands) erode easily. Soil particles greater than 1 mm in diameter are considered non-erodible. A soil containing at least 2/3 its weight in non-erodible fractions is resistant to erosion. ▸



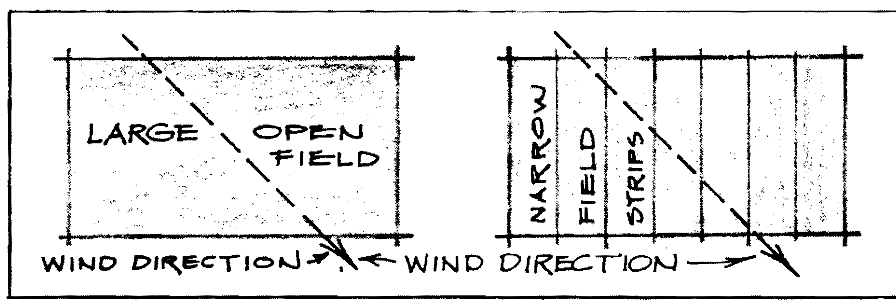
5. WIND VELOCITY - SOIL MOISTURE

Wind must blow for soil erosion to begin. Soil will not erode if surface soil moisture will support plant growth. ▸



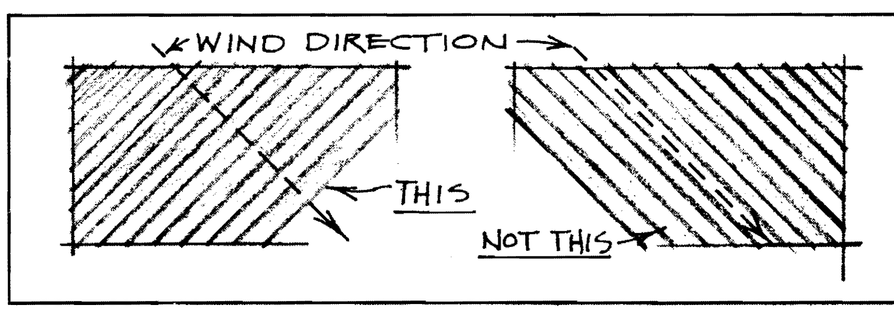
6. WIDTH OF FIELD

Large open fields are more susceptible to wind erosion than narrow fields. ▸



7. FIELD LAYOUT AND WIND DIRECTION

Arrange fields or apply tillage practices at right angles to prevailing winds. ▸

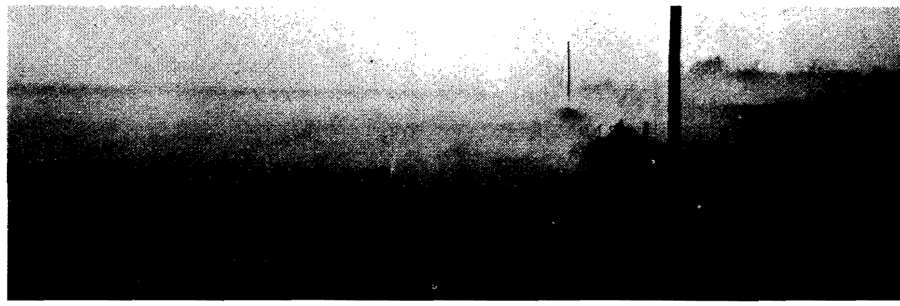


8. WIND BARRIERS

Trees and crop barriers reduce wind erosion. ▸

WIND EROSION IN ACTION

Wind erosion can be a serious problem on all soils. Generally, sandy soils are the most susceptible. North Dakota has a large acreage of summerfallow and fall-plowed land. During the fall, winter and spring months these lands are a serious erosion hazard, especially if fields are large and left unprotected.



STOP WIND EROSION with conservation practices

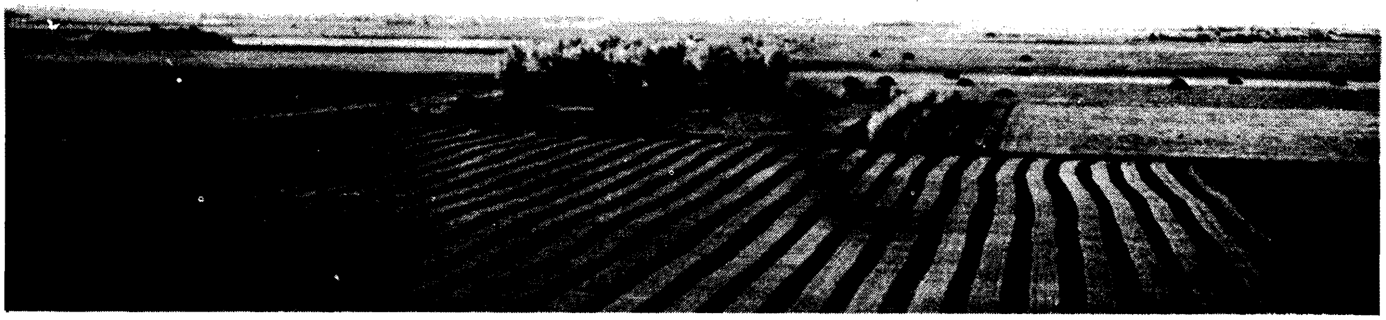
Field Shelterbelts ▲

Wind Strip Cropping ▲

Crop Residue Management ▲

CROP GROWTH PROTECTS THE SOIL AND AIDS SOIL MOISTURE CONSERVATION.

Flax Barrier ▲



Small Grain Cover Crop or Barrier ▲

Corn Barrier Strips ▲

Sunflower Barriers ▲

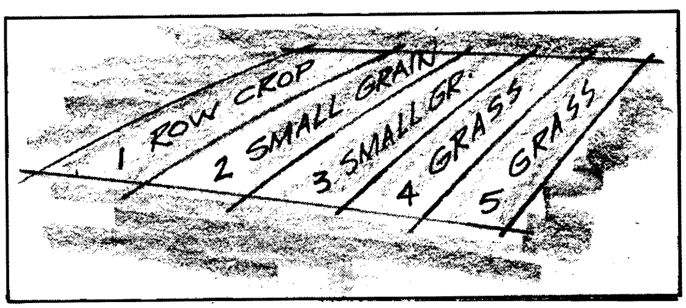
Tall Wheatgrass Barriers ▲

FACTORS INFLUENCING WATER EROSION

1. RAINFALL
Raindrop energy causes splash erosion. Intense rainstorms cause more water to run off the land, which also erodes soil.

2. SOIL ERODIBILITY
Kind of soil, ability of soil to absorb water and stability of soil clods or aggregates affect erodibility of a soil.

3. LENGTH AND STEEPNESS OF SLOPE
Potential for soil loss increases as length and/or steepness of slope increase.



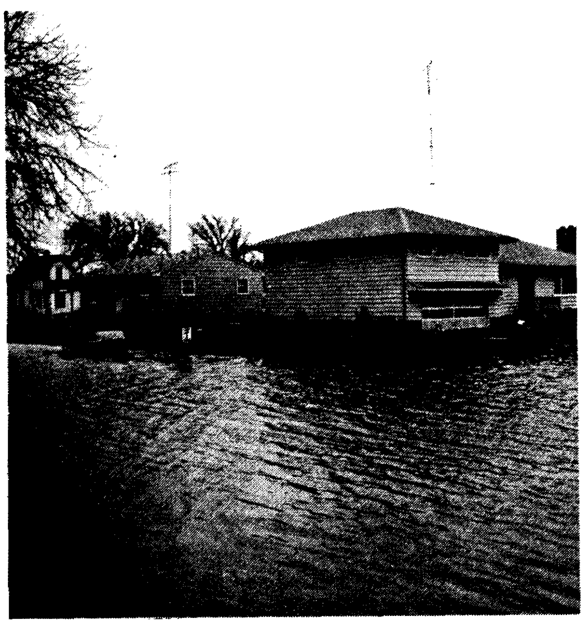
4. CROP ROTATIONS
The kinds of crop and their sequence in the crop rotation influence the rate of soil erosion.

5. CONSERVATION PRACTICES
Type of conservation practices applied influence susceptibility of field to erosion.

WATER EROSION IN ACTION

◄ Gully erosion makes farming operations difficult.

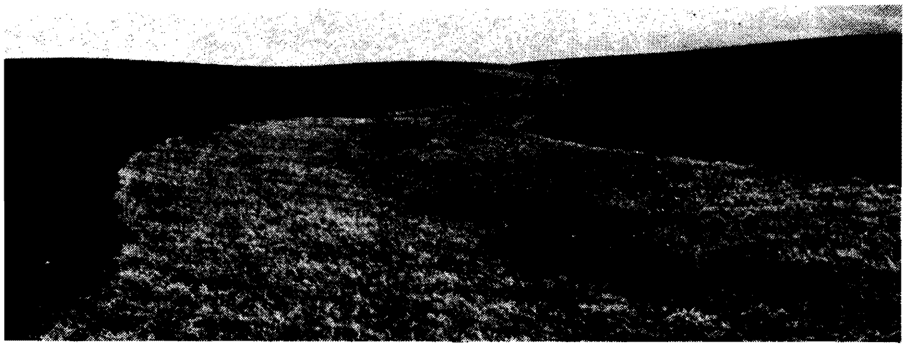
Soil particles from eroded fields enter streams and lakes, filling them in, and pollute recreation and fish and wildlife areas with sediments. ►



Excess runoff water may cause flooding of farm and city property. ▲

Streambank erosion carries tons of soil downstream annually. Stream sediments lower water quality for recreation and for fish and wildlife. ▲

STOP WATER EROSION
with soil conservation practices



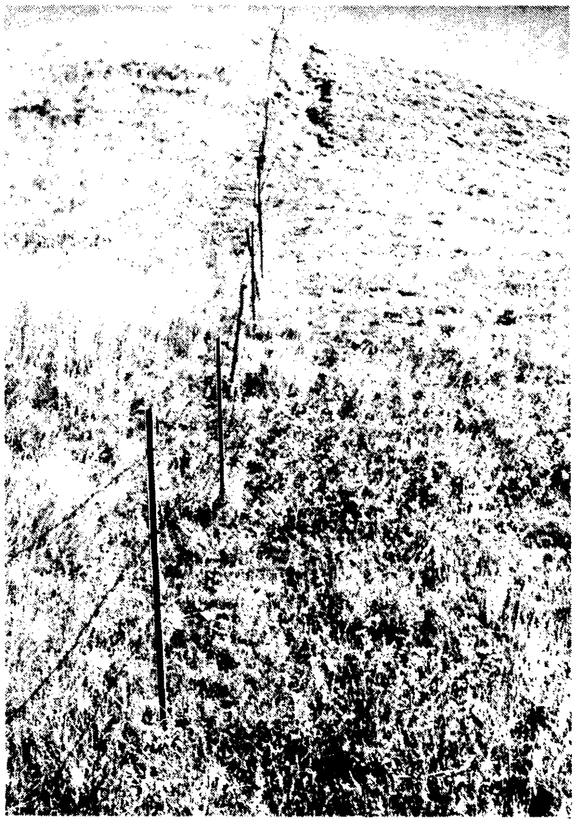
Grassed waterway -- safe path for runoff water. ▶

Contoured strip cropping slows runoff water. ▲

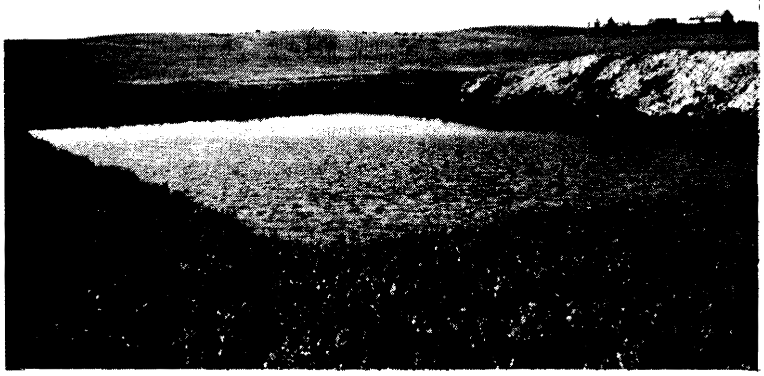
Surface residue helps water enter soil. ▲

Keep steep land planted to grass. ▲

Grasslands need protection from overgrazing. Too many cattle grazing an acre of grassland reduces forage yield and increases weeds, brush and other undesirable plants. ▶



Grassland Conservation



Livestock watering facilities, i.e., stock ponds, springs and wells, and salting areas properly located encourage uniform livestock grazing. ▲

Woodland Conservation

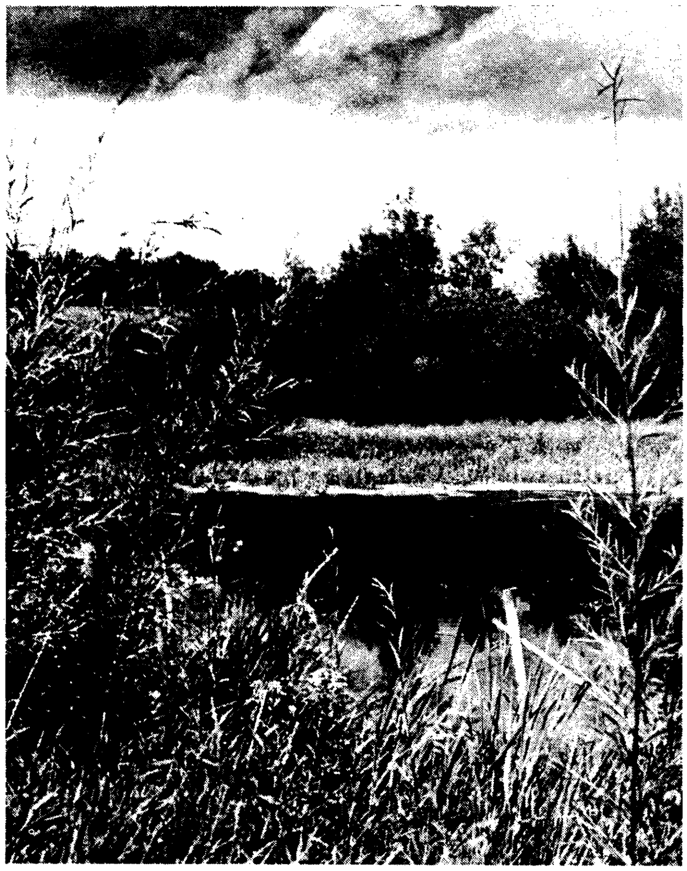
Typical Turtle Mountain woodland scene showing rolling topography, lakes and scattered farmland. ▲

◀ Woodlands should not be cleared from rolling lands. Trees, shrubs and grass hold snow, slow down snowmelt and intercept rainfall, which prevents erosion by runoff waters.

Wildlife Conservation

Wildlife is a product of the land and this is where we must start to maintain it. Barren fields, naked fence rows, odd areas reduced to ashes by burning, and denuded stream banks will neither maintain nor produce a crop of game.

There are five essentials for good wildlife habitat. They are called welfare factors.



COVER. Wildlife must have cover for mating, nesting, rearing young, winter protection, concealment from enemies, and travel. ▲

FOOD. This must be the right type, in the right amount, and where it can be obtained without danger to the animal. ▲

◂ **WATER.** Water requirements vary with different animals, but they follow the pattern of food requirements.

SPACE. Most animals cannot survive if overcrowded. Only a certain number can survive on a limited area. ▸

ARRANGEMENT. This is actually a combination of the other four items but it is important. Without proper arrangement, the other essentials may be useless. ▸

Wildlife resources are products of the land and water. These resources must be managed as a part of the whole natural community which consists of soils, water and all plants and animals, including man.

Our challenge then is this: to learn to know what is right for the land; to do what is right for the land and all things on it, and to do it through our own efforts with the support of those professionals promoting sound conservation and ecological programs.

TILLAGE

Tilling the soil is a basic crop production practice. Tillage is done to prepare seedbeds; conserve moisture; manage residues; control erosion; or aid in weed, disease, or insect control. Some of these aspects of tillage as they apply to specific crops are discussed in the crop sections of this guide.

Each tillage operation must be evaluated for its potential economic return especially in light of energy shortages and the resulting higher cost of tillage. The subject of tillage as used by North Dakota farmers is well covered in Extension Bulletin No. 5, Tillage for Profit in North Dakota. It is an excellent reference regarding tillage practices for summer fallow and other more intensive rotations. It can be obtained at any county agent office.

SUMMER FALLOW

Summer fallow is often cited as a conservation practice because it supposedly conserves moisture. The good and bad attributes of summer fallow have recently been closely examined in the publication Summer Fallow In The Western United States. This publication is Conservation Research Report No. 17 by the Agricultural Research Service of the United States Department of Agriculture. It is for sale by the Superintendent of Documents, U.S. Government Printing Office. Washington, D. C. 20402 for $1.90. Anyone using summer fallow should read the publication so he can better ascertain the practice as a crop production tool.

Portions of the chapter on Summer Fallow In The Northern Great Plains (Spring Wheat) in the above mentioned publication have been reproduced with permission of the authors located at the Northern Great Plains Research Center of the Agricultural Research Service, USDA, Mandan, North Dakota. The reproduction follows:

Advantages and Disadvantages of Fallow

Both wind and water erosion are serious problems on land fallowed for spring grains (21-month period), because the land is usually bare over the second winter of fallow. When winter small grains follow fallow (14-month period) and good growth is obtained in the fall, erosion is not so severe as with spring grains on fallow.

Although yields of spring wheat after fallow have generally not been twice as high as those on continuously cropped land, the yield advantage of fallow does not need to be this great to be considered economical, at least from the immediate needs of the farmer. However, soil erosion and its associated problems have not been included in the cost of summer fallowing in the past. Erosion not only causes the direct loss of soil (which is essentially irreplaceable) and nutrients from the land but also deposits soil in road ditches, fence rows, windbreaks, reservoirs, streams, and around farm and city buildings, and the cost of removal is high. Crops adjacent to eroding fallow are sometimes damaged or completely destroyed. Dust blowing across highways causes accidents, and the air is sometimes so polluted with dust that breathing is difficult for both man and animals. At the present time in North Dakota, dust from wind erosion and sediments from water erosion associated with summer fallowing are the greatest respective sources of air and water pollution.

The public is becoming increasingly conscious of the significance of erosion, and will eventually demand that wind and water erosion either be controlled or that fallow be eliminated, not only from the standpoint of its effect on our soil and water resources but from the standpoint of air and water pollution.

Problems associated with summer fallow for spring wheat production in the northern Plains, compared with annual cropping, are as follows:

1. Greatly increased wind and water erosion of soil.
2. Increased air and water pollution.
3. Lower soil-water storage efficiency.
4. Lower water-use efficiency.
5. Greater soil-fertility decline.
6. Promotes development of saline seep areas under certain soil and management conditions.

The advantages of summer fallow over annual cropping for spring wheat production are:

1. Higher yield per planted acre.
2. More stable production.
3. Higher soil-water content.
4. Greater supply of available nitrogen in the soil.
5. Aids in the control of weeds.
6. Aids in distributing the work load of the farmer.
7. Reduce insect and disease problems.

Alternatives for Fallow

Results of longtime research show that summer fallow is being used in many areas of the northern Great Plains for spring wheat production where it cannot be justified from yield increase alone. Experimental results during the past 15 years indicate that fertilizers can reduce the yield advantage of fallow in some areas. In addition, intertilled crops, such as corn and sorghums, are excellent crops to precede spring wheat, and the seedbed they provide acts as a partial substitute for fallow. Where the corn or sorghum can be used on the farm, the forage or grain produced generally more than offsets the yield reduction of the following spring wheat crop in comparison to alternate spring wheat and fallow. However, soil nitrogen losses from row-crop land are high, and, when row crops are included in the rotation with small grains, the decline in total soil nitrogen is similar to that from alternate small grain and fallow. Soil losses from row crop land by wind and water erosion may also be high.

An average of 19 percent of the precipitation received during the 21-month fallow period is stored in the soil compared with 32 percent from harvest to seeding time in an annual cropping system. Both systems are extremely inefficient and emphasize the need for improved water conservation methods. Generally, sufficient water is received to produce good crops annually, if most of it could be stored and used by economic crops. If the storage efficiency during the 9 months from harvest to seeding time in an annual cropping system could be increased from the present 32 percent to at least 54 percent, then as much water would be stored in the soil as at the end of a 21-month fallow period. One source of water that is not being fully utilized in the northern Great Plains is snow. Studies with grass barriers and level benches with nonharvested grass on the dikes, indicate some of the possibilities for increased snow collection and overwinter soil-water storage. With improved water-storage efficiency in an annual cropping system and the addition of adequate fertilizer, the acreage of fallow could be materially reduced.

One of the primary questions that needs to be answered regarding summer fallowing is, "Are there better uses for the 14 million acres of good cultivated land lying fallow each year in the northern Great Plains, not only from the standpoint of present needs but also of future needs?" If the acreage of fallow were reduced, then that not needed for crop production could be seeded to grass for livestock grazing, game refuges, or recreational areas and parks, and the soil held in place and preserved for posterity. However, some means of reimbursing the land owner would be needed. If such a program were followed, the food and fiber needs of the populace would still be met as well as the needs for recreational areas and a more healthful environment.

NOTES

PLANT NUTRITION

All green plants are known as autotrophic organisms which simply means that they have the ability to manufacture their own food by using energy derived from the sun to combine chemical elements, taken up as inorganic combinations, into a multitude of organic compounds such as the various proteins, carbohydrates and fats.

Sixteen elements have been shown to be essential for normal plant growth and reproduction. These essential elements are shown in Table 7.

TABLE 7 - ELEMENTS ESSENTIAL FOR PLANT GROWTH AND REPRODUCTION

From Air and Water	Primary	Secondary	Micronutrients
Carbon (C)	Nitrogen (N)	Calcium (Ca)	Iron (Fe)
Hydrogen (H)	Phosphorus (P)	Magnesium (Mg)	Manganese (Mn)
Oxygen (O)	Potassium (K)	Sulfur (S)	Boron (B)
			Chlorine (Cl)
			Zinc (Zn)
			Copper (Cu)
			Molybdenum (Mo)

The sources of carbon, hydrogen, and oxygen are air and water and thus there is little control over the availability of these nutrient elements except through drainage, irrigation, modification of soil physical factors or under conditions where atmospheric conditions can be modified as in greenhouses. These three elements comprise about 95% of the total dry matter of most plants. The remaining 5% of the dry matter is made up of the other 13 essential elements along with the many other elements that may be taken up in small amounts by the plants but are not known to perform any essential functions within the plant. When plant growth is limited because of a lack of an essential element it is usually due to a deficiency of one or more of these 13 elements. These elements are usually taken up by the plants from the soil.

The major objective of any soil fertility program should be to develop crop production management systems that will eliminate yield-limiting soil fertility conditions in order to maximize net return per acre. Some people feel that one way this can be done is to use nutrient removal data and replace these nutrients on a one to one basis with fertilizer. Table 8 shows approximate amounts of plant nutrients removed by selected crops.

TABLE 8 - APPROXIMATE AMOUNTS OF PLANT FOODS REMOVED IN CROPS (LB/ACRE)

Crop	N	P_2O_5	K_2O	Ca	Mg	S	B	Fe	Mn	Zn	Cu	Mo
Alfalfa (4 T)	200*	55	200	112	21	19	.06	.90	.44	.42	.42	-
Barley (60 Bu)												
Grain	70	28	30									
Straw	40	12	180									
Corn (150 Bu)												
Grain	135	53	40	2	8	10	.1	.17	.09	.15	.06	.005
Stover	100	37	145	26	20	14	.1	1.20	1.5	.30	.05	.003
Flax (20 Bu)												
Grain	50	12	16									
Straw	21	5	75									
Oats (80 Bu)												
Grain	50	20	15	2	3	5	-	.15	.12	.05	.03	-
Straw	25	15	80	8	8	9	1.50	1.21	-	.29	.03	-
Soybeans (40 Bu)	150*	35	55	7	7	4	.05	.63	.05	.04	.04	-
Wheat (40 Bu)												
Grain	68	25	15	1	6	3	.1	.19	.09	.14	.03	-
Straw	56	5	35	6	3	5	.2	.50	.16	.05	.01	-
Sugarbeets (20 T)												
20 T Roots	80	35	133	44	32	13	-	-	1.00	-	.04	-
12 T Tops	115	20	220	-	-	-	-	-	-	-	-	-
Potatoes (220 cwt)	100	28	155									
Timothy Hay (2 T)	50	23	40									

* Inoculated legumes fix nitrogen from the air.

Use of such crop removal data will give an indication of the amount of the different essential plant elements that must be available to the crop if normal growth and reproduction is to be obtained. However, it is very difficult to arrive at optimum fertilizer recommendations through the use of plant composition data. Uptake data gives very little information about the supply of nutrients in the soil. For example, the harvest of a four ton alfalfa crop will involve the removal of approximately 200 pounds per acre of K_2O. Does this mean that 200 pounds of K_2O should be added to the soil to maintain the potassium supply in the soil even if little growth response can be expected? In North Dakota, approximately 95% of the soils have sufficient native reserves of potassium to produce optimum yields for several years, thus, paying responses to potassium fertilizers cannot be expected in most cases. In addition, there is no evidence that a decrease in this large reserve of potassium will effect the physical or chemical properties of the soil.

PRIMARY NUTRIENTS

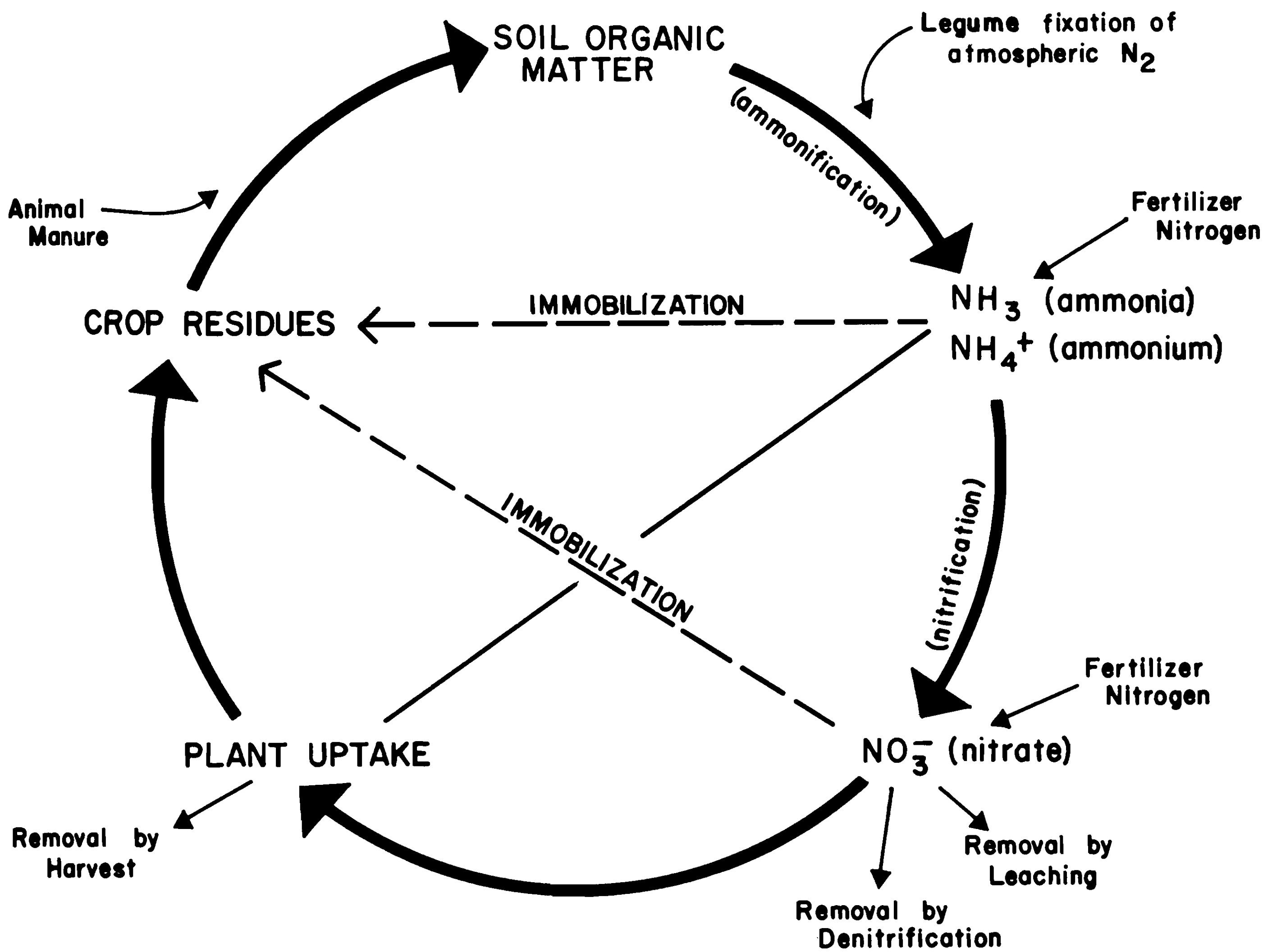
Nitrogen (N)

The ultimate source of nitrogen used by plants is gaseous N_2, which makes up about 79 percent of the atmosphere, however, nitrogen in this form cannot be used by green plants. Atmospheric nitrogen must be converted to other forms before it will be available for plant use. Most nitrogen in the soil is contained in the organic matter. Availability of nitrogen in the organic matter fraction of the soil is dependent upon decomposition of N-containing materials by soil organisms. Cool soil temperatures associated with North Dakota climate, especially in early spring, result in comparatively slow release of available nitrogen from organic matter. As a result North Dakota soils are often relatively high in organic matter, but available nitrogen levels may be low. Available nitrogen levels are usually higher following the practice of summerfallow because of accumulation of available nitrogen during the fallow period. Under cultivation reserves of organic matter nitrogen have been depleted sufficiently on some soils so that accumulation of available nitrogen is insufficient for optimum crop production even after a summerfallow period.

Yearly variability in moisture and temperature makes for variation in amounts of nitrogen released from organic matter. Nitrogen needs for crops also vary with growth and yield potential limitations imposed by annual variations in growing conditions. Variability in soil supplies and need for available soil nitrogen makes it somewhat difficult to predict supplemental fertilizer nitrogen needs at rates that will give the greatest return, however, determination of available nitrogen by a reliable soil test coupled with realistic yield expectations based on management decisions will provide good fertilizer nitrogen rate recommendations.

Nitrogen Cycle

Solutions to the problems of providing adequate nitrogen for crop production are contingent on an understanding of the nitrogen cycle. The following schematic diagram is a simplified version of the nitrogen cycle.



Although the atmosphere is about 78% nitrogen, and may be considered a warehouse for nitrogen, atmospheric nitrogen cannot be used by plants.

What changes must atmospheric nitrogen undergo before it can be used by plants? This process is known as nitrogen fixation and the primary pathways are:

1. Symbiotic Nitrogen Fixation - A symbiotic relationship is one which is mutually beneficial to two different forms of life which grow together in close association. An example is the relationship between legumes and nodule forming bacteria. The plant supplies the bacteria with organic and inorganic food and the bacteria is able to fix atmospheric nitrogen and make it available to the plant. Legume plants which are not infected by root-nodule bacteria are unable to use atmospheric nitrogen and root-nodule bacteria growing alone are unable to fix nitrogen.

   Atmospheric nitrogen "fixed" by root-nodule bacteria is available to the legume plant and is then released as available nitrogen upon decay of the legume plant residue.

   The amount of soil nitrogen gained under production of legume plants depends upon legume species, effectiveness of the root-nodule bacteria, amount of plant residue returned to the soil and original level of available nitrogen in the soil. Table 9 shows the total amount of nitrogen present in both the roots and tops of several legume crops grown for green manure.

TABLE 9 - TOTAL NITROGEN YIELDS PER ACRE OF TOPS PLUS ROOTS FROM SEVERAL LEGUMES IN THE FALL OF THE SEEDING YEAR. AMES, IOWA

Legume	Roots Plus Tops Tons/A	Total N lb/A
Madrid sweetclover	2.57	141
Grimm alfalfa	1.48	87
Southern common alfalfa	1.51	82
Ladino clover	1.30	74
Huban annual sweetclover	1.24	54
Medium red clover	83	48

From Fribourg and Johnson. Agron. J. 47:73-76.

   A portion of the total nitrogen contained in the legume plant has come from the atmosphere by way of the symbiotic nitrogen fixation process, however, it is important to remember that the rest of the nitrogen in the plants was plant available nitrogen already present in the soil. Many research studies indicate that the ratio of soil: atmospheric nitrogen present in the legume plant is dependent to some extent on the soil nitrogen level and that the plants will tend to use soil nitrogen first when it is available. It is not uncommon to find as much as one-half of the nitrogen present in legume plants to be soil nitrogen, thus if a sweetclover crop containing 150 pounds of nitrogen is plowed down the net increase in soil nitrogen levels might be 75 pounds.

   It is also important to point out that when a hay crop, for example, is taken and the stubble plowed under that nitrogen levels in the soil might be lowered due to more nitrogen being removed from the field in the hay than was "fixed" by the root-nodual bacteria.

2. Nitrogen fixation by free-living soil microorganisms - Species of blue-green algae and some free-living bacteria can fix atmospheric nitrogen and thus contribute nitrogen to the cycle as organic matter upon their death. The practical importance of non-symbiotic nitrogen fixation is not great. A fair average in fertile soils is about 5 to 10 pounds per acre per year.

3. Nitrogen fixation through electrical discharge - Nitrogen compounds are present in the atmosphere and are returned to the earth during periods of precipitation. Ammonia, nitrate, nitrite, nitrous oxide and organic combinations are often present in the atmosphere. Some of the nitrite and nitrate are the result of lightning. The ammonia comes largely from industrial sites. The total amount of nitrogen in rainfall is estimated to be 1 to 50 pounds per acre per year. The higher figures would apply around areas of intense industrial activity. Under North Dakota conditions amounts of 5-10 pounds of N per acre per year may be present in rainfall.

4. Nitrogen fixation by industry - All the common forms of nitrogen fertilizer used commercially are produced by industrial nitrogen fixation. It is by far the most important source of nitrogen from the standpoint of commercial agriculture. Some of the basic processes used in the production of nitrogen fertilizer will be covered later.

It is apparent that these pathways contribute both to organic and inorganic forms of nitrogen found in soils. By far the largest amount of nitrogen in soils occurs as a part of the organic matter complex. Soil organic matter is not well defined, but is used to cover organic materials in all stages of decomposition. It is often broken into two categories - humus and easily decomposed organic material. Humus is a relatively stable material which is somewhat resistant to additional decomposition. The easily decomposed portion is made up of organic materials that are subject to fairly fast breakdown such as fresh crop residues.

Mineralization of nitrogen compounds: The breakdown or decomposition of organic nitrogen compounds resulting in the formation of inorganic nitrogen compounds is called mineralization. Mineralization takes place in three steps known as aminization, ammonification and nitrification.

Aminization - Numerous groups of bacteria and fungi are responsible for one or more of the steps involved in organic matter decomposition. The end product of one group's activity is the starting point for another group until decomposition reaches final stages. One of the final stages in decomposition of nitrogenous materials is the hydrolytic decomposition of proteins with the release of amines and amino acids. This step is termed aminization and can be schematically represented as:

$$\text{Proteins} \longrightarrow R\text{-}NH_2 + CO_2 + \text{energy} + \text{other products}$$

Ammonification - The amines and amino acids released by aminization are further utilized by other microorganisms with the release of ammoniacal compounds. This step is called ammonification and is often represented as:

$$R\text{-}NH_2 + HOH \longrightarrow NH_3 + R\text{-}OH + \text{energy}$$

The ammonia (NH_3) so released undergoes rapid conversion to the ammonium ion (NH_4^+) which may be used in one of several ways: 1) converted to nitrite and nitrate, 2) absorbed by plant roots, 3) used in further decomposition of organic carbon residues or 4) fixed in unavailable forms.

Nitrification - Most of the ammonium ions released by ammonification is converted to nitrate-nitrogen. This biological oxidation of ammonium ions to nitrate ions is nitrification. It is a two-step process whereby NH_4^+ is first converted to NO_2^- (nitrite) and then on to NO_3^- (nitrate). The following equations represent the nitrification process:

$$NH_4^+ + O_2 \longrightarrow NO_2^- + 4H^+$$

$$2NO_2^- + O_2 \longrightarrow 2NO_3^-$$

Several important points are brought out by the above equations. These reactions (aminization, ammonification, and nitrification) all involve microbial activity. As a result the rapidity and extent to which these reactions take place will be greatly influenced by soil environmental conditions such as soil reaction (pH), soil aeration, soil moisture, and soil temperature. In general, the environmental factors favoring good growth of most plants will also favor these reactions. The fact that nitrification requires molecular oxygen means that it will occur most readily in well-aerated soils. Another point of importance is that nitrification releases hydrogen ions (H^+). It is the release of this hydrogen that results in the acidification of soil (reduction of soil pH) when ammoniacal and most organic nitrogen fertilizers are converted to nitrate. The use of these nitrogen sources over a period of time will result in a lower soil pH. Many North Dakota soils contain lime ($CaCO_3$) which buffers the soil against reductions in pH. Under these conditions reduction in pH may not be noticed even after several years of nitrogen fertilizer application.

Immobilization of nitrogen: The temporary tie-up of available soil nitrogen by microorganisms decomposing organic matter is called nitrogen immobilization. This occurs when soil nitrogen is used by the microorganisms when decomposing organic matter. If the organic material being decomposed has a small amount of nitrogen in relation to carbon (high C/N ratio as in wheat straw or corn stalks) the microorganisms will draw on NH_4^+ or NO_3^- present in the soil. If the decomposing material contains much nitrogen in proportion to carbon (low C/N ratio as in alfalfa) little soil nitrogen may be immobilized.

Because of the possibility of nitrogen immobilization many people believe that nitrogen fertilizers should be used to help hasten residue decomposition, however, under climatic conditions of North Dakota and Canada, researchers have found that incorporation of normal rates of straw do not often affect yields (Ferguson and Gorby, 1964, Canadian J. of Soil Science). Recommended nitrogen rates have been developed under field conditions where residues of preceeding crops were incorporated. The rates recommended usually provide adequate nitrogen nutrition for the crop to be grown (including decay of the previous crop residue). Fertilize the crop to be grown not the residue.

Losses of available nitrogen from soil can occur in a variety of ways, some of these are:

1. Leaching: The ammonium ion (NH_4^+) carries a positive charge and can be adsorbed or held by the negative charge of soil and organic matter particles, therefore, it is not as subject to leaching losses as nitrate ions. Nitrate ions are mobile in soil, moving with soil water. The recommendation often

seen in farm magazines about waiting until soil temperatures are 50° F. or lower before applying nitrogen fertilizer in the fall relate to these characteristics of ammonium and nitrate forms of nitrogen. Ammonium sources applied at temperatures below 50° F. are slow to convert to nitrate forms, thus, the applied nitrogen is held on soil particles and not as subject to leaching by the fall and winter rainfall.

Leaching of nitrate-nitrogen to depths below the root zone is of considerable importance in areas of heavy rainfall and with soil unfrozen during the winter months, however, there is little chance of leaching losses from fall broadcast application of fertilizer nitrogen on medium and fine textured soils under North Dakota conditions. For this reason the use of soil temperature as a guide as to when to make nitrogen applications is not of great importance. On coarse textured soils or any soil subject to flooding and ponding in the spring, leaching to depths below the root zone is possible, thus, spring broadcast nitrogen applications are recommended under these conditions.

2. Surface run-off: Fertilizer nitrogen broadcast on frozen ground and especially on snow or ice over frozen ground could be lost in spring run-off waters.

3. Erosion: Any removal of solid soil material will result in losses of nitrogen from soil.

4. Denitrification losses: Substantial amounts of available soil nitrogen can be changed to unavailable gaseous atmospheric nitrogen compounds when soils become waterlogged. Denitrification is carried out by bacteria that thrive when there is no oxygen present in the soil. Significant losses by this means can occur where water stands on a field for several days and when water and soil temperatures are above 45-50° F.

   This is another reason for avoiding fall broadcast of nitrogen fertilizers where ponding may occur in the spring.

   The probable pathways for denitrification losses are represented as follows:

$$\underset{\text{nitrate}}{2(HNO_3)} \longrightarrow \underset{\text{nitrite}}{2(HNO_2)} \longrightarrow \underset{\text{hyponitrous acid}}{H_2N_2O_2} \longrightarrow \underset{\text{nitrous oxide}}{N_2O} \longrightarrow \underset{\text{nitrogen gas}}{N_2}$$

5. Volatilization losses of ammonia: Ammonium salts in an alkaline (pH above 7) aqueous medium undergo the following reaction allowing free ammonia gas to escape:

$$NH_4^+ + H_2O + OH^- \longrightarrow \underset{\text{ammonia gas}}{NH_3} + 2H_2O$$

   If fertilizer materials containing ammonium nitrogen are placed on the surface of alkaline soils (our soils are often on the alkaline side with pH above 7), free ammonia may be lost. This loss can be prevented by placing the nitrogen material several inches under the soil (anhydrous ammonia, aqua ammonia) or working them into the soil surface as soon as possible after application (broadcast dry or non-pressure liquids). These losses are increased under conditions of high soil temperatures and rapid evaporation of water. Losses of ammonia precipitated by surface applied urea may take place regardless of soil pH.

   These factors led to the recommendations to incorporate broadcasted nitrogen materials into the soil as soon as possible.

Fertilizer Nitrogen Materials

The primary nitrogen fertilizers used in North Dakota are as follows:

Name of fertilizer	Chemical formula	Usual analysis	Form
Ammonium nitrate	NH_4NO_3	33.5-0-0	Solid
Nitrogen solutions	(Variable)	21 to 41.0-0	Liquid
Anhydrous ammonia	NH_3	82-0-0	Gas
Urea	$NH_2 \cdot CO \cdot NH_2$	48-0-0	Solid
Ammonium Sulfate	$(NH_4)_2SO_4$	20-0-0	Solid

The production of synthetic ammonia in the United States constitutes by far the principal original source of all chemical nitrogen fertilizers. The basic reaction is:

$$3H_2 + N_2 \longrightarrow 2NH_3$$

This reaction gives anhydrous ammonia which contains the highest percentage of nitrogen (82%) of any nitrogenous fertilizer now available. Since no further processing is needed after its manufacture, it can be sold at a very attractive price. Since ammonia is a gas at atmospheric pressure it must be handled in suitable tanks and must be applied in, not on, the soil. This means it must be knifed in, plowed down, or in some way completely covered immediately. Possibilities of losses to the atmosphere exist when it is improperly applied or applied on soils too wet or dry or with very low exchange capacity. Once it is in the soil it converts rapidly to the ammonium ion (NH_4^+) and enters the nitrogen cycle as this form.

Anhydrous ammonia is toxic to crop seeds and roots. Thus, if seeds are planted to close to the zone of application, or if side-dressing, too close to growing plants, injury will occur. Application ten days to two weeks before planting will allow time for the NH_3 to be converted to non-toxic forms.

Ammonia can be oxidized to nitric acid as follows:

$$4NH_3 + 5O_2 \longrightarrow 4NO + 6H_2O$$

$$2NO + O_2 \longrightarrow 2NO_2$$

$$3NO_2 + H_2O \longrightarrow \underset{\text{nitric acid}}{2HNO_3} + NO$$

This nitric acid is then used in the manufacture of ammonium nitrate as follows:

$$HNO_3 + NH_3 \longrightarrow NH_4NO_3$$

Ammonium nitrate is hygroscopic and is coated with clay to prevent caking. This reduces the nitrogen content from 35% for pure material to about 34% for the fertilizer material. Since this material does contain some ammonium it can undergo volatilization losses in alkaline soils.

Ammonia can also be reacted with sulfuric acid to form ammonium sulfate as follows:

$$2NH_3 + H_2SO_4 \longrightarrow (NH_4)_2SO_4$$

This material contains 20.5 percent nitrogen and 24.2 percent sulfur. Because of the sulfate anion this material tends to be somewhat more acid in its reaction in soil than ammonium nitrate. It is not a common material in our state mainly because its low analysis makes it a more expensive source of nitrogen on a per pound of nitrogen basis than other nitrogen materials and because most North Dakota soils do not require additional sulfur applications.

Another nitrogen material made from ammonia is urea. This is made by reacting ammonia with carbon dioxide as follows:

$$CO_2 + 2NH_3 \longrightarrow \underset{\text{Urea}}{CO(NH_2)_2} + H_2O$$

Urea contains the highest percentage of nitrogen (45-46%) of any solid nitrogen material now available. It is not an ammonium containing fertilizer when marketed, but it changes to ammonium carbonate very quickly upon addition to soil as follows:

$$CO(NH_2)_2 + 2H_2O \longrightarrow (NH_4)_2CO_3$$

Ammonium carbonate is unstable and decomposes to ammonia and carbon dioxide as follows:

$$(NH_4)_2CO_3 \longrightarrow 2NH_3 + CO_2 + H_2O$$

This rapid hydrolysis means that if urea is applied to the soil surface or on sod, volatilization losses of ammonia may be significant. These losses would take place regardless of the soil pH, therefore, urea containing fertilizers should be incorporated as quickly as possible.

Aqua ammonia is made by dissolving ammonia gas in water. Nitrogen solutions are made using materials such as ammonium nitrate and urea dissolved in water or aqua ammonia. All nitrogen solutions are classed as pressure (have a vapor pressure because free ammonia is present) or nonpressure (contain no free ammonia). Aqua ammonia and low pressure nitrogen solutions should be applied in, not on, the soil. Nonpresure nitrogen solutions are more commonly used in North Dakota with 28-0-0 being most common.

The composition of nitrogen solutions can be determined by obtaining the nitrogen solution code. This code gives the percentage of total nitrogen, with the decimal point omitted, followed in parentheses by the percentage composition of ammonia, ammonium nitrate, urea and any other significant source of nitrogen, if present. Consider 28-0-0 as an example: Solution code could be 280 (0-40-30) meaning it is a 28% nitrogen solution with none of the nitrogen coming from ammonia, 40% of its nitrogen coming from ammonium nitrate, and 30% of its nitrogen coming from urea. Since such a solution does contain urea nitrogen, it is then subject to the same volatilization losses of ammonia as was pointed out for dry urea materials.

<u>Summary for Nitrogen (N)</u>

Several things about nitrogen behavior in soils are noteworthy. Nitrogen added to soils as commercial N fertilizers are the same forms that occur naturally in the nitrogen cycle. Regardless of the form of soluble nitrogen fertilizer added to the soil it undergoes conversion to nitrate rather quickly if the soil is warm and moist.

The nitrate form of nitrogen is not attracted to soil particles and thus is free to move with the soil water. Any significant losses of fertilizer nitrogen usually occur from improper use.

Phosphorus (P)

Reference to Table 8 will show plant uptake of phosphorus to be considerably less than nitrogen. This does not mean that it is less essential for plant growth than nitrogen. Phosphorus is required by plants for cell division and energy transfer.

Phosphorus does not exist in nature as the elemental form (P), but is combined with other elements into minerals such as the apatites. Rock phosphate contains apatites and is heat-treated or acid-treated to render the phosphorus more soluble. Rock phosphate is the starting point of commercial phosphorus fertilizers and has been used as a fertilizer in untreated form. Phosphorus is also found in organic compounds.

Forms of Soil Phosphorus

The total amounts of phosphorus found in a soil may range from 200-3,400 pounds of P per acre. The usual range of soil phosphorus, however, is 800 to 1,600 pounds of P per acre. At first glance this may seem to be enough phosphorus to produce good crops, however, as will be explained later, only a very small amount of the total phosphorus is available for plant growth. In most soils only 2 to 3 pounds of P is available for plant growth at any one time.

Soil phosphorus can be divided into two broad groups, the first being organic phosphorus. Like nitrogen, organic phosphorus is concentrated in the top soil where the organic matter levels are highest and must be mineralized before the phosphorus can be used by plants. Under favorable conditions, organic phosphorus can become a significant source of the nutrient for plant growth, however, organic phosphorus usually is not considered to be of much significance in North Dakota soils.

Some of the inorganic phosphorus, the second group, reacts with clay, organic matter, iron, aluminum, calcium and other soil constituents. Some of these reactions result in unavailable phosphorus while others are available to different degrees. Factors such as pH, clay type, organic matter, amounts of phosphorus, etc. determine which reactions will take place in a particular soil and what forms of phosphorus can be expected.

Phosphorus is taken up by plants largely as the primary and secondary orthophosphate ions ($H_2PO_4^-$ and $HPO_4^=$) which occur in the soil solution. Both forms are present in soils that are neutral to alkaline (pH 7.0 - 7.8). The proportion of $HPO_4^=$ ions occuring in the soil solution increases as pH increases.

Inorganic phosphates occurring in North Dakota soils are mainly calcium phosphates (predominate forms in alkaline and calcareous soils) such as:

1. Fluor-apatite $3Ca_3(PO_4)_2 \cdot CaF_2$
2. Carbonate-apatite $3Ca_3(PO_4)_2 \cdot CaCO_3$

3. Hydroxy-apatite $3Ca(PO_4)_2 \cdot Ca(OH)_2$
4. Oxy-apatite $3Ca(PO_4)_2 \cdot CaO$
5. Tricalcium phosphate $Ca_3(PO_4)_2$
6. Dicalcium phosphate $CaHPO_4$
7. Monocalcium phosphate $Ca(H_2PO_4)_2$

In most alkaline soils having a high pH, chemical precipitation of relatively insoluble dicalcium phosphate and other basic calcium phosphates is favored.

Phosphate ions coming in contact with solid phase calcium carbonate are precipitated on the surface of these particles. The amount of precipitation is influenced by the amount of surface exposed by the $CaCO_3$ and the concentration of P in solution.

Most calcium phosphates are insolbule in water and the phosphate is in a relatively unavailable form. However, in the midly acidic conditions produced around plant roots, due to root excretions, calcium phosphates are more soluble and thus more of the phosphorus is available to plants.

Water soluble phosphorus is the major form available for plant growth. Plants absorb phosphorus from the soil solution in proportion to the concentration of phosphate ions in solution and growth will be proportional to amounts of phosphorus absorbed. Under field conditions the many forms of phosphorus approach chemical equilibrium with each other as illustrated:

$$\text{Water soluble phosphates} \longleftrightarrow \text{Adsorbed phosphate} \longleftrightarrow \text{Insoluble phosphates}$$

This equilibrium results in some of the fertilizer phosphorus added in water soluble forms being converted (fixed) to the less available forms.

Iron and aluminum phosphates (predominate forms in acid soils) are of minor importance in North Dakota soils.

Phosphorus adsorbed to soil particles by the above chemical precipitation processes or by more complex processes (Soil Fertility and Fertilizers, 1966) will be lost from the field when erosion removes the soil particles.

Behavior of Phosphate Fertilizers in Soils

The reactions taking place in the soil and the properties of the various phosphate fertilizer materials combine to determine the effectiveness of any source of phosphorus under any set of soil and cropping conditions. Fertilizer particle size, water solubility and placement of the phosphate material with respect to the seed determine the effectiveness of the fertilizer. In calcareous soils most of the phosphate is precipitated as dicalcium phosphate on the surface of calcium carbonate particles.

Relatively little, often less than one-half of one percent, of the native soil phosphorus is available to plants in any one growing season. The fate of fertilizer phosphorus, because of soil absorption or fixation (formation of unavailable phosphorus compounds in the soil) is not much better. It is not uncommon for only 5 to 10 percent of the added phosphorus to be taken up by the first crop to which it was applied. This percentage may go as high as 40 percent under very favorable conditions, but this is uncommon. Fixation can be reduced by minimizing the area of contact between the fertilizer and the soil. Granules present much less surface for contact per unit for phosphorus than do equal amounts of pulverized fertilizer. Banding further reduces contact and, thus, fixation is reduced or delayed.

As one fertilizes at higher rates, fixation of phosphorus becomes less of a concern. As more of the soils' soluble iron, aluminum, or calcium reacts with phosphorus, less remains to fix the additional applied P. Therefore, at high levels of crop production one should not be too concerned about "fixation". The soluble fertilizer phosphorus applied and not recovered by the crop reacts mostly with soil calcium in our North Dakota soils. Accumulation from repeated applications of phosphorus results in increasing the level of plant available phosphorus in the soil.

Phosphate Fertilizers

During the past few years we have seen not only a rapid increase in the use of phosphate fertilizers, but also a great change in the fertilizer industry and many different fertilizers coming into the market. The primary phosphorus fertilizers used in North Dakota are as follows:

Name of fertilizer	Chemical formula	Usual analysis	Form
Superphosphate	$Ca(H_2PO_4)_2$	0-45-0	Solid
Monoammonium phosphate	$NH_4H_2PO_4$	11-48-0	Solid
Diamonnium phosphate	$(NH_4)_2HPO_4$	18-46-0	Solid
Ammonium polyphosphate	$NH_4H_2PO_4 + (NH_4)_3HP_2O_7$	10-34-0 14-62-0	Liquid Solid

Rock phosphate contains apatite as the phosphate compound and is either heat or acid treated to make the phosphate more soluble. The acid treatment is the more important group of commercial fertilizer phosphates.

Phosphoric Acid - This material is produced by treating rock phosphate with sulfuric acid (H_2SO_4) or by burning elemental phosphorus, forming P_2O_5 and reacting with water. So called green or wet acid results from the H_2SO_4 treatment; white or furnace acid from the burning process.

Agricultural phosphoric acid contains 24% P (55% P_2O_5). It can be used to acidulate additional rock phosphate to make triple super-phosphate, neutralized with ammonia (NH_3) to manufacture ammonium phosphates and liquid fertilizer or used directly as a fertilizer.

Superphosphoric Acid - This product is produced by dehydrating (removing water) from green acid or furnace acid. It is completely water soluble and contains 34% P (79% P_2O_5). Superphosphoric acid contains 35 to 50 percent of such condensed phosphate radicals as pyro-, tri- and tetrapoly- phosphates. It is used primarily for the manufacture of ammonium and calcium polyphosphates.

Calcium Orthophosphates - The most important phosphate fertilizer consisting of calcium orthophosphate are ordinary superphosphate containing 7 to 9% (16-22% P_2O_5), triple or concentrated superphosphate containing 19 to 23%

(44-52% P_2O_5) and ordinary and triple superphosphates that have been reacted with ammonia to form ammoniated superphosphates.

The superphosphates are slightly acidic fertilizers, but have no appreciable effect on soil pH. Ammoniated superphosphates produce a slightly acidic soil reaction.

Ordinary superphosphate (OSP) is made by reacting sulfuric acid with rock phosphate. The product of the reaction is essentially a mixture of mono-calcium phosphate and gypsum. About 90% of the phosphorus is water soluble and essentially all is classed as available. OSP also contains 8 to 10% sulfur as calcium sulfate.

Triple or concentrated superphosphate (CSP) is made by treating rock phosphate with phosphoric acid. The resulting product is mostly monocalcium phosphate containing 19 to 22% P (44-52% P_2O_5).

Ammonium Phosphate - This fertilizer material is produced by reacting different amounts of ammonia, phosphoric acid and sulfuric acid. The most common ammonium phosphate fertilizers are monoammonium phosphate (MAP), diammonium phosphate (DAP), and ammonium phosphate-sulfate (16-20-0). The most common, MAP, is 11-48-0; 16-48-0 or 18-46-0 are the most common DAP materials.

Ammonium phosphates are completely water soluble, are excellent sources of both nitrogen and phosphorus, have a relatively high plant-food content which minimizes shipping, handling and storage costs, and good handling properties. All of the factors combine to make these phosphate materials very popular. They are used for formulating solid fertilizers, in manufacturing liquid materials, and by direct application as starter fertilizers.

Ammonium Polyphosphate - This is a mixture of ammonium salts of simple and complex phosphoric acids. This material is increasing in importance, and is common in liquid fertilizers here in North Dakota.

Summary of Phosphorus (P)

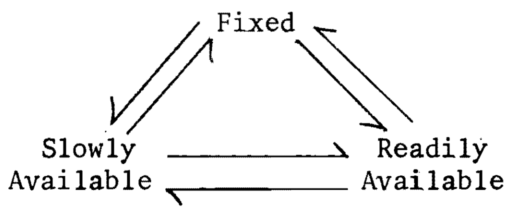
Recommendations concerning the use of phosphorus fertilizers are largely based on 1) most soils contain relatively small total amounts of native phosphorus derived from rocks and minerals from which the soil formed, 2) native soil phosphorus is largely present in forms unavailable to growing plants, 3) there is a marked "fixation" or conversion in the soil to unavailable forms of added soluble fertilizer phosphorus, 4) phosphorus is considered to be immobile in the soil and 5) soil erosion is the main mechanism of phosphorus loss from soils.

Potassium (K)

Except for what has been added in fertilizer, the potassium in soils comes from rocks containing minerals bearing potassium. Some of the secondary and clay minerals in soils also contain potassium. Potassium is present in these forms in rather large amounts in most North Dakota soils.

Potassium is taken up by plants as the potassium ion (K^+) from the soil solution or directly from the cation exchange complex. It exists in the soil as fixed (not available), slowly available and readily available forms.

The equilibrium between these forms is illustrated as follows:



The fixed portion is not available to plants and is a part of unweathered or slightly weathered minerals. The slowly available potassium is associated with minerals which alternately release or fix potassium. Readily available potassium is present in the soil solution or held on the cation exchange positions of clay minerals and organic matter as the positively charged K^+ ion.

Since the readily available potassium is attracted to the negative charge on soil components it normally is not subject to movement in the soil. If a soil has low cation exchange capacity the excess K^+ can move with water. For most soils in North Dakota there is usually enough negative charge present to keep the K^+ associated with soil particles. Should these soil particles be removed as a result of soil erosion, the K^+ associated with them is also lost.

Potassium Fertilizers

Potassium chloride (KCl), commercially called nuriate of potash, is mined and used as the primary potash fertilizer in the state. Some sulfate of potash (K_2SO_4) is also used as a potash source.

The characteristics of these materials are as follows:

Name of fertilizer	Chemical Formula	Usual analysis	Form
Muriate of potash	KCl	0-0-60	Solid
Sulfate of potash	K_2SO_4	0-0-50	Solid

Both of these materials go into solution in the soil (readily available form) to supply the K^+ ion for plant uptake and soil reactions.

Summary of Potassium (K)

Potassium added in commercial fertilizer is not subject to much movement by water since it is attracted by the negative charge associated with soil particles and organic matter. Loss of soil particles by erosion does take the associated K^+ with them.

SECONDARY NUTRIENTS

Sulfur (S)

A major storehouse of soil sulfur is organic matter. Available sulfur is released from organic matter as it is decayed by soil organisms. Gypsum ($CaSO_4$) crystals are present in large amounts in some North Dakota soils. Sulfur dioxide (SO_2) is present in the atmosphere and is added to the soil with rainfall. Sulfate salts are contained in irrigation water. Some fertilizer materials contain substantial amounts of sulfur. Among the fertilizers used in North Dakota ammonium phosphate-sulfate (12-20-0) and ammonium sulfate (21-0-0) would be the most important from the standpoint of additions of sulfur to the soil through fertilizers. 16-20-0 averages about 15 percent sulfur. 21-0-0 contains 24 percent sulfur.

So far very limited deficiencies or crop responses to sulfur have been demonstrated in North Dakota soil and crops. These have been on very sandy low organic matter soils.

Calcium (Ca)
Magnesium (Mg)

Calcium and magnesium are present in rather large quantities in North Dakota soils - as ions stored on the base exchange and as free salts: lime, gypsum and magnesium salts. As a consequence deficiencies of these nutrient elements are not likely and none have been identified. High amounts of free lime in many surface soils interferes with iron and zinc availability for the most sensitive crops. In saline soils, magnesium sulfates and/or chlorides have been found as major soluble salts (along with sodium salts) in contributing to the total soluble salts in these problem soils.

With the elements calcium and magnesium, excesses rather than deficiencies are most apt to present problems in North Dakota.

Micro-Nutrients (Trace elements)

- Iron, manganese, copper, zinc, molybdenum, boron, chlorine -

In North Dakota soils only zinc and iron are known to be deficient and then only in certain soil conditions and for a few most sensitive crops or plants.

Corn has exhibited zinc deficiency symptoms in certain soil areas of fields in southeastern North Dakota. Symptoms are most often associated with high lime (calcareous) surface soil spots in coarse textured (sandy) soils. Corn grain yield responses to fertilizer zinc treatments have been obtained in a few trials on such sites.

Zinc deficiency in corn and yield response to treatment has been established where topsoil was removed in land leveling for irrigation at Upham, N. D.

Zinc deficiencies have also been identified in Navy beans.

Paying responses to zinc treatment have not been demonstrated with other crops.

A characteristic leaf chlorosis symptom in many sensitive ornamental plants, and the crop plants; soybeans and flax; often occurs on soils with free lime in the surface. The chlorotic condition of such sensitive plants is attributed to a lack of sufficient available iron.

Correction of this iron deficiency is a difficult problem. Iron chelates work well as soil additions but rates and price of the material makes treatment too expensive for field crop use.

Foliar applications of soluble iron salts must be applied a number of times during the season to correct the deficiency. In the case of soybeans, varieties that are resistant to iron chlorosis have been developed and should be planted on soils having a history of iron problems.

Various minor elements alone and in combinations were tried on wheat, barley and potatoes without significant influence on yield with a variety of soil conditions. Until deficiencies have been established and details have been worked out as to materials, rates and methods of application that give paying response there is little reason to make fertilizer applications of micro-nutrients.

Soil tests for copper (Cu), zinc (Zn), iron (Fe) and manganese (Mn) are now available through the Soil Testing Laboratory at North Dakota State University. The charge is $2.00 per nutrient or the four nutrients for $5.00.

NOTES

DIAGNOSTIC METHODS

Soil Testing

Soil testing is the foundation of good fertilizer management. The Soil Testing Laboratory at North Dakota State University offers farmers the services of a central soil testing laboratory. Soil samples can be submitted to the laboratory through county Extension offices, or cooperating fertilizer companies.

The laboratory offers the following analyses:

1. Texture
2. Conductivity
3. pH
4. Nitrate-nitrogen
5. Phosphorus ($NaHCO_3$ method)
6. Exchangeable potassium (NH_4Ac method)
7. Zinc
8. Iron
9. Manganese
10. Copper
11. Organic matter

Additional information regarding the tests available and proper sampling is available in Extension Circular A-336 Revised.

An example of a completed Soil Sample Information Sheet is shown in Figure 17. An example of a Soil Test Report is shown in Figure 18.

Soil tests are used to evaluate the fertility levels of the soil. With soil test information it is possible to rate the soil as being very low (VL), low (L), medium (M), high (H), or very high (VH) for each plant nutrient tested. These are qualitative ratings. A VL rating indicates that it is highly probable that crops grown on a soil with this rating will respond to additions of the nutrient tested. Responses to the addition of the nutrient are not likely on soils rated VH. You must consider field research data to determine what rates of fertilizer will give the most profitable responses. This type of research is known as soil-test calibration.

Nitrogen: Table 10 is an example of the assigned soil fertility ratings for nitrogen for various corn yield goals when the amount of nitrate-nitrogen (NO_3-N), as determined by NDSU soil test procedures, fall into specified ranges. Since the amount of needed plant-available nitrogen increases as yields increase, the nitrogen fertility ratings are adjusted according to yield goals.

Nitrogen fertility ratings for other crops are contained in the Extension circular series on fertilizing various crops.

FIGURE 17 - **SOIL SAMPLE INFORMATION SHEET**

SHEET NUMBER 1 OF 1

NAME: Bin Buster	EXTRA COPY: NAME: Well Fed Crop Company
ADDRESS: 1846 P Road	ADDRESS: 2882 N Street
Green Valley, N. Dak. ZIP 10340	Progress, N. Dak. ZIP 23230

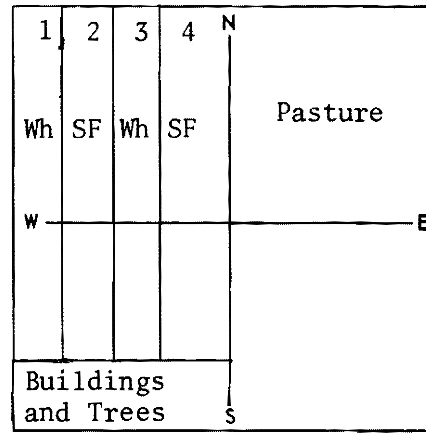
SEE CIRCULAR A-336 FOR SOIL SAMPLING INSTRUCTIONS

DATE SAMPLED 10/15/74 SAMPLE IDENTIFICATION 1

COUNTY Stark ACRES 80

DEPTH SAMPLED (CHECK ONE OF THE FOLLOWING):

1. 0-6" ____ (PHOSPHORUS, POTASSIUM, ACIDITY @ $2.00)
2. 0-6"+6-24" ____ (NITROGEN, PHOSPHORUS, POTASSIUM, ACIDITY @ $4.00)
3. 0-6"+0-24" X (NITROGEN, PHOSPHORUS, POTASSIUM, ACIDITY @ $4.00)
4. 0-24" ____ (NITROGEN @ $2.00)
5. 0-6", 6-12", 1'-2', 2'-3', ETC. ____ (SOLUBLE SALTS @ 25¢ PER DEPTH)



MAP OF SECTION NO. 8

Pleasant TOWNSHIP

OTHER TESTS REQUESTED ON 0-6" SAMPLE 1. ____ 2. ____ 3. ____ 4. ____

SOIL TYPE Morton Loam

CROP TO BE GROWN (19 75) Spring Wheat

YIELD GOAL 35 bushels

LAST CROP OR LAND USE (19 74) Wheat YIELD 30 bushels

CROP OR LAND USE 2 YEARS AGO (19 73) Summerfallow YIELD 0

NOTE ANY SPECIAL PROBLEMS ASSOCIATED WITH THIS FIELD:

Never grows much unless has been fallow the year before it is cropped.

FOR LAB USE ONLY

FEE PAID YES NO
DATE REC'D. ____
DATE SAMPLED ____
COND. OF SAMPLE ____
COUNTY ____
ACRES ____
SAMPLE NO. ____
LABORATORY NO. ____
SAMPLE DEPTH ____
LAST CROP ____
CROP ____
YIELD GOAL ____
TEXTURE ____
pH ____
NO_3N ____
ORGANIC MATTER ____
P ____
K ____
SOLUBLE SALTS ____
Zn ____
FE ____
MN ____
CU ____
DATE SENT ____

MAKE CHECK PAYABLE TO: SOIL TESTING LABORATORY
MAIL TO: WALDRON HALL
NORTH DAKOTA STATE UNIVERSITY
FARGO, N.DAK. 58102

RETURN ALL 4 PARTS · THE ORIGINAL WILL BE RETURNED TO YOU.

FIGURE 18 - **SOIL TEST REPORT**

NORTH DAKOTA STATE UNIVERSITY • SOIL TESTING LAB • FARGO, NORTH DAKOTA 58102

TO:
BIN BUSTER
1846 P ROAD
GREEN VALLEY ND 10340

COPY TO:
WELL FED CROP COMPANY
2882 N STREET
PROGRESS ND 23230

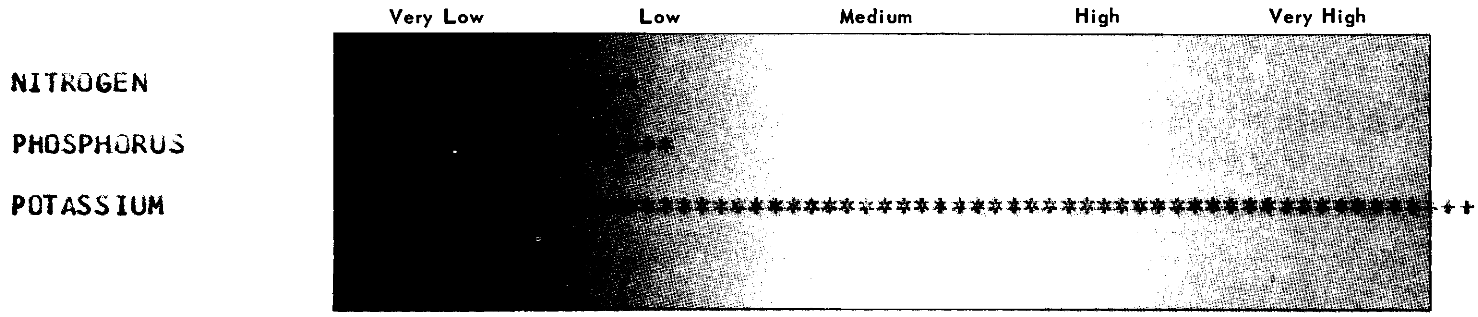
County: STARK
Lab No.: 18924
Date Received: 10/26/74
Date Reported: 10/28/74

SOIL TEST RESULTS

Sample Designation	Soil Texture	Soil pH	NO_3-N* Nitrogen (lb/A-2')	Organic Matter %	P** Phosphorus	K** Potassium	Soluble Salts (mmhos)	Zn Zinc ppm				
1	M	7.2	20		15	380						

* To convert Lbs./A-2' of NO_3-N to ppm divide by 8. ** Lbs. per acre of extractable P & K in the 0-6" layer of soil.

INTERPRETATION OF SOIL TESTS



RECOMMENDATIONS

FOR A 35 BU/A YIELD GOAL OF WHEAT

APPLY: 70 LBS OF N PER ACRE
15 LBS OF P2O5 PER ACRE
0 LBS OF K2O PER ACRE

THE NITROGEN RECOMMMENDED CAN BE BROADCAST BEFORE PLANTING OR AFTER PLANTING THROUGH THE TILLERING STAGE.
INFESTATIONS OF WIREWORMS USUALLY CAUSE THIN STANDS AND PATCHY AREAS. SEE NDSU EXTENSION CIRCULAR E-188 "WIREWORM CONTROL" FOR MORE INFORMATION. THIN STANDS AND PATCHY AREAS ALSO OCCUR ON SODIC (ALKALI) SOILS. SEE NDSU EXTENSION BULLETIN NO. 2,"SALT AFFECTED SOILS IN NORTH DAKOTA".
ROOT ROTS, HEAD BLIGHTS, AND LEAF SPOTTING DISEASES INCREASE WHEN SMALL GRAINS ARE GROWN IN SHORT ROTATION, ESPECIALLY UNDER MINIMAL TILLAGE.
THE ABOVE PHOSPHATE AND POTASH RECOMMENDATIONS ARE FOR PLANTER OR BAND APPLICATIONS. IF BROADCASTING, DOUBLE THE RECOMMENDATION AND RETEST PHOSPHORUS AND POTASSIUM IN 2 YEARS.
FOR SMALL GRAIN VARIETY RECOMMENDATIONS AND PERFORMANCE, SEE CIRCULARS A-170 AND A-574.
SEE CIRCULAR W-253 FOR WEED CONTROL INFORMATION.

RECORDS

Crop variety ______ Soil moisture at seeding: Low: ______ Medium ______ High ______
Date of seeding ______ Rate of seeding or plant population ______ Growing season rainfall ______ in.
Fertilizer grade ______ Rate ______ Date of application ______
Name of herbicide ______ Rate ______ Date ______ Degree of weed control ______
Yield ______ Quality ______ Comments: ______
Yield of check strip ______ Quality ______

For additional information contact your County Extension Agent:

MICHAEL ROSE
P.O. BLDG. 225-3851
DICKINSON, ND

CUSTOMER COPY

TABLE 10 - NITROGEN SOIL FERTILITY RATINGS BASED ON SOIL NO_3-N LEVELS FOR DIFFERENT CORN YIELDS.

Yield Goal		Nitrogen Soil-Fertility Rating				
Grain	Silage	Very Low	Low	Medium	High	Very High
bushels/acre	tons/acre	----------- pounds NO_3-N/acre 2 feet -----------				
20	3	0-15	16-30	31-45	46-59	60+
40	7	0-20	21-40	41-60	61-79	80+
60	10	0-25	26-50	51-75	76-99	100+
70	12	0-29	30-58	59-87	88-114	115+
80	13	0-33	34-66	67-99	100-129	130+
90	15	0-36	37-73	74-109	110-144	145+
100	17	0-40	41-80	81-120	121-159	160+
110	18	0-45	46-90	91-135	136-179	180+
120	20	0-50	51-100	101-150	151-199	200+
140	23	0-63	64-128	129-189	190-249	250+
160	27	0-75	76-150	151-225	226-299	300+

Phosphorus and Potassium: Table 11 shows the assigned soil fertility ratings for phosphorus (P) and potassium (K) when amounts of these nutrients, as determined by NDSU soil test procedures, fall within specified ranges. Phosphorus and potassium needs also increase as yields increase, but the amounts of phosphorus are less than in the case of nitrogen. In the case of potassium, the increased need is taken care of by the potassium levels present in most of our soils. As a result, soil fertility ratings for phosphorus and potassium are not adjusted with increased yield goals.

TABLE 11 - SOIL FERTILITY RATINGS FOR AMOUNTS OF PHOSPHORUS (P) AND POTASSIUM (K) EXTRACTED FROM THE SOIL.

Extracted P	Extracted K	Soil Fertility Ratings
lb/acre	lb/acre	
0-11	0-50	very low
12-17	51-120	low
18-25	121-210	medium
26-36	211-300	high
37+	301+	very high

Interpretation guides for other analyses besides N, P, and K are as follows:

Texture

Samples are textured by hand and given a rating of fine, medium or coarse. The textural classes falling under each of these ratings are as follows:

Fine (F)	Medium (M)	Coarse (C)
Sandy clay	Loam	Sand
Silty clay	Silt loam	Loamy sand
Clay	Sandy clay loam	Sandy loam
	Clay loam	
	Silty clay loam	

Conductivity

Conductivity is determined on a 1:1 soil-water suspension using a Solu-Bridge. The following soil salinity classes are given based on the conductivity reading and soil texture.

	Soil Texture		
Conductivity mmhos per cm	Fine	Medium Soil Salinity Classes	Coarse
0-1.00	Non-saline	Non-saline	Non-slightly
1.00-2.00	Very slightly saline	Slightly saline	Moderately
2.00-4.00	Slightly saline	Moderately	Strongly
4.00-7.00	Moderately saline	Strongly saline	Very strongly
over 7.00	Strongly saline	Very strongly saline	Very strongly

These salinity classes aan be expected to influence crop growth as follows:

Soil Salinity Class	Influence on crop plants
Non-saline	Salinity effects negligible.
Very slightly saline	Yields of very sensitive crops may be very slightly restricted, especially in dry periods.
Slightly saline	Yields of sensitive crops may be restricted.
Moderately saline	Yields of many crops restricted.
Strongly saline	Only a few tolerant crops yield satisfactorily.

pH

The pH is also determined on a 1:1 soil-water suspension using a pH-meter. The following terms are used for pH ranges.

pH	Interpretation
Less than 5.6	Strongly acid
5.6-6.0	Moderately acid
6.1-6.5	Slightly acid
6.6-7.3	Neutral
7.4-7.8	Mildly alkaline
7.9-8.4	Moderately alkaline
More than 8.4	Strongly alkaline

Zinc, Iron, Copper, Manganese

These micronutrients are extracted from the soil using DTPA (diethylene-triamine pentaacetic acid). The interpretation given based on amounts extracted is as follows:

DTPA Extractable Zinc & Iron*

ppm Zinc	ppm Iron	Deficiency Level
0 - 0.5	0.0 - 2.0	Low
0.51 - 1.0	2.1 - 4.5	Marginal
1.0+	4.5+	Adequate

*Interpretation is for sensitive crops only (corn, sorghum, potatoes and beans)

DTPA Extractable Copper & Manganese

ppm Copper		ppm Manganese	
0 - 0.2	Soils testing below this level may require treatment	0 - 1.0	soils testing below this level may require treatment
0.2+	Adequate	1.0+	Adequate

Organic Matter

The organic matter test is made only as a guide to be used in determining type and rate of herbicide application.

PLANT ANALYSIS

A plant analysis program is designed to assist farmers in evaluating the nutritional status of their crops. A plant analysis is not a substitute for a soil test, but is designed to supplement soil testing as a means of determining those elements which may be deficient or excessive. In addition, a plant analysis can be used to diagnose suspected nutrient deficiencies or detect deficiencies before unsatisfactory growth has occurred. It permits more economical and efficient use of fertilizer materials, avoiding excessive or inadequate rates.

Plant analysis service is not presently available at North Dakota State University. It can be obtained from other states such as Wisconsin and South Dakota as well as from private laboratories.

FERTILIZER RECOMMENDATIONS

Fertilizer needs should be determined after carefully evaluating the current fertility level of the soil in combination with the particular nutrient needs of the crop to be grown and yield potentials. Soil fertility levels should be based on a systematic soil testing program. Factors to consider in estimating yield goals are (1) the expected or potential climatic conditions of the area and stored water supply at seeding, (2) the production capacity of the soil and (3) changes in management programs such as introduction of new varieties, better weed control, more timely operations, better fertilizer programs, etc.

Nitrogen: To determine fertilizer nitrogen rates needed, subtract the amount of nitrate-nitrogen (NO_3-N) in the soil, as determined by the soil test, from the total amount of available nitrogen needed for your particular yield goal and crop.

As an example:

> Your NDSU soil test shows that there are 50 pounds of NO_3-N present in the soil to two feet. Your yield goal is 40 bushels per acre of wheat. Therefore, the amount of fertilizer nitrogen that should be applied would be 60 pounds actual nitrogen (N) per acre. (This is the difference between the 110 pounds taken from the table for wheat and 50 pounds from the soil test).

The nitrogen tables are based on soil nitrate-nitrogen levels as determined from soil samples taken from about September 1 to April 1. When soil samples are taken after April 1, increase these figures by 20 pounds before determining fertilizer nitrogen needs.

Phosphate and Potash: Because of the nature of phosphate and potash chemistry in the soil and because these nutrients move very little with soil water, the simple method of subtracting the soil test level from the amount needed for the proposed crop does not work.

As an example:

> If the yield goal for wheat is 40 bushels per acre and the phosphorus fertility level is low 14 and the potassium fertility level is high 250 the fertilizer recommendation would be 20 pounds per acre of P_2O_5 and 10 pounds per acre of K_2O.

TABLE 12 - TOTAL AVAILABLE NITROGEN NEEDS FOR WHEAT, DURUM, RYE, FEED BARLEY AND OATS FOR DIFFERENT YIELD GOALS.

Yield Goals			Soil N + Fertilizer N Needed
Wheat, Durum & Rye	Feed Barley	Oats	
--------- bushel/acre ---------			---- lbs/acre ----- 2 ft.
15	25	25	20
20	30	30	35
25	35	40	55
30	40	50	65
35	45	60	90
40	50	70	110
50	60	85	140
60	70	100	175
70	80	115	210
80	90	130	250

TABLE 13 - PHOSPHATE AND POTASH RECOMMENDATION TABLE FOR WHEAT, DURUM, RYE, FEED BARLEY & OATS FOR DIFFERENT YIELD GOALS & SOIL TEST LEVELS.

Yield Goals			Recommendations									
			P Soil Test Levels (lb/A)					K Soil Test Levels (lb/A)				
Wheat, Durum & Rye	Feed Barley	Oats	0-11	12-17	18-25	26-36	37+	0-50	51-120	121-210	211-300	301+
			----- lb/acre P_2O_5 -----					----- lb/acre K_2O -------				
10	20	20	15	10	0	0	0	20	15	0	0	0
15	25	25	15	10	0	0	0	20	15	0	0	0
20	30	30	15	10	0	0	0	20	15	10	0	0
25	35	40	20	15	10	10	0	20	15	10	0	0
30	40	50	20	15	10	10	0	20	15	10	10	0
35	45	60	20	15	10	10	0	20	15	10	10	0
40	50	70	25	20	15	10	0	25	20	15	10	0
50	60	85	25	20	15	10	0	30	25	20	15	0
60	70	100	30	25	20	15	0	40	30	25	20	0
70	80	115	30	25	20	15	0	50	40	30	20	0
80	90	130	35	30	25	20	10	60	50	40	20	0

Micronutrients: To date use of micronutrients on small grain crops has not been shown to give paying yield responses. If for some reason a micronutrient problem is suspected, it is suggested that a micronutrient soil test be obtained and that the use of micronutrients be limited to a trial basis.

Nitrogen recommendations based on a planting date of May 15 or earlier. The probability of obtaining optimum yields of malting barley with a protein content that is less than 13.5 percent is best when the crop is planted as early as possible in the spring. As seeding dates are delayed the probability of producing a crop containing more than 13.5 percent protein greatly increases. The May 15 figure is used only as a guide-line date. When malting barley is seeded in late May or early June, do not fertilize with nitrogen except in soil where the soil test level is less than 85 pounds nitrogen per acre. For this situation, the total of soil plus fertilizer nitrogen should not exceed 85 pounds per acre.

TABLE 14 - SOIL NO_3-N PLUS FERTILIZER N NEEDED FOR MALTING BARLEY YIELD GOALS (SEEDED BEFORE MAY 15).

Yield Goal bu/acre	Soil Plus Fertilizer N Needed lb/acre 2 ft.
30	35
35	50
40	60
45	70
50	85
55	100
60	110
65	125
70	135
80	165
90	200

TABLE 15 - PHOSPHATE AND POTASH RECOMMENDATIONS FOR DIFFERENT YIELD GOALS AND SOIL FERTILITY LEVELS FOR MALTING BARLEY.

	Nutrient Recommendations									
	P_2O_5					K_2O				
	P Fertility Level (lb/A)					K Fertility Level (lb/A)				
Yield Goal	0-11	12-17	18-25	26-36	37+	0-50	51-120	121-210	211-300	301+
bu/acre	---- lb/acre of P_2O_5 ----					----- lb/acre of K_2O -----				
30	15	10	0	0	0	20	15	15	15	15
35	20	15	10	10	0	20	15	15	15	15
40	20	15	10	10	0	20	15	15	15	15
45	20	15	10	10	0	25	20	15	15	15
50	25	20	15	10	0	30	25	20	15	15
55	25	20	15	10	0	35	30	20	15	15
60	25	20	15	15	0	35	30	20	15	15
65	25	20	15	15	0	40	35	20	15	15
70	30	25	20	15	0	40	35	25	20	15
80	30	25	20	15	0	50	40	30	25	15
90	35	30	25	20	10	60	50	40	35	20

CORN GRAIN AND SILAGE

TABLE 16 - SOIL NO_3-N PLUS FERTILIZER N REQUIREMENTS FOR CORN GRAIN OR SILAGE PRODUCTION.

Yield Goals		Soil + Fertilizer N Needed
Grain	Silage	
bushel/acre	tons/acre	lb/acre 2 feet
20	3	30
40	7	60
60	10	90
70	12	105
80	13	120
90	15	135
100	17	150
110	18	165
120	20	180
140	23	210
160	27	240

TABLE 17 - PHOSPHATE AND POTASH RECOMMENDATIONS FOR DIFFERENT YIELD GOALS & SOIL FERTILITY LEVELS FOR CORN GRAIN AND SILAGE.

Yield Goal		Nutrient Recommendations									
		P_2O_5					K_2O				
		P Fertility Level (lb/A)					K Fertility Level (lb/A)				
Grain	Silage	0-11	12-17	18-25	26-36	37+	0-51	51-120	121-210	211-300	301+
bu/acre	T/acre	----- pounds/acre ------					----- pounds/acre ------				
20	3	40	30	20	10	0	80	60	40	10	0
40	7	55	40	20	10	0	100	75	50	20	0
60	10	65	45	25	15	0	120	90	65	25	0
70	12	70	50	30	15	0	130	100	70	30	0
80	13	75	55	35	20	0	140	110	70	30	0
90	15	80	60	40	20	0	150	115	75	35	0
100	17	85	65	40	20	0	160	120	80	40	0
110	18	90	70	45	25	0	170	130	85	40	0
120	20	95	75	50	25	0	180	135	90	45	0
140	23	105	80	55	25	0	200	150	100	50	0
160	27	120	90	60	30	0	220	165	110	55	0

Micronutrients: Zinc (Zn) deficiencies have been found in isolated areas in the state. Suspect areas are generally limited to sandy soils, especially if they are limey to the surface and in areas where topsoil has been removed during the process of leveling fields for irrigation.

A soil test for Zn is available from the North Dakota State University Soil Testing Laboratory. This test will prove helpful in identifying soils with suspected Zn problems. Table 5 gives the interpretations of soil test data for Zn.

TABLE 18 - SOIL TEST INTERPRETATIONS FOR ZINC.

Soil Test Value	Zn Rating
ppm	
0-0.50	Low
0.51-1.0	Marginal
1.0+	Adequate

For soils testing low in Zn, rates of 10 to 15 pounds per acre of Zn as zinc sulfate or 1 to 2 pounds per acre of actual Zn in an organic (chelate) form is recommended. For marginal testing soils it is suggested that the same rates of Zn be used on a trial basis unless a response has been confirmed by past experience. Zinc can be banded with starter fertilizer, but broadcasting and plow down of Zn also has been successful. Longer residual effects would be expected from broadcasting the Zn.

To date, corn responses to other micronutrients have not been demonstrated in the state.

SUGAR BEETS

Over-fertilization, particularly with nitrogen, can result in poor quality beets, and reduced net returns. Thus, in setting yield goals, improvement of management factors such as evenly spaced and adequate plant populations, weed control, timeliness of operations (especially early planting), disease and insect control, and the like must all be improved along with increased fertilizer use. Also, other yield influencing factors, such as the expected or potential climatic conditions, stored soil moisture levels, and the production capacity of the soil must also be considered in estimating yield goals.

TABLE 19 - SOIL NO_3-N PLUS FERTILIZER N REQUIREMENTS FOR SUGAR BEETS.

Yield Goal		Soil + Fertilizer N Needed
Sugar lb/acre*	Roots T/acre	
3600	12	100
3900	13	108
4200	14	115
4500	15	122
4800	16	130
5100	17	140
5400	18	150
6000	20	170
6600	22	200
7200	24	230
7800	26	260

* Sugar yields are calculated, based on beets containing 15% sucrose.

For production of high quality sugarbeets, manage nitrogen needs so that adequate nitrogen is available for early season growth, but approaches deficiency levels approximately six weeks before harvest. Thus, if late planting shortens the growing season, you should also reduce nitrogen fertilizer rates. A general guide is to reduce recommended fertilizer rates by 10 pounds of N for each week planting is delayed after May 20.

TABLE 20 - PHOSPHATE AND POTASH RECOMMENDATION TABLE FOR SUGAR BEETS.

Yield Goal		Nutrient Recommendations									
		P_2O_5					K_2O				
		P Fertility Level (lb/A)					K Fertility Level (lb/A)				
Sugar	Roots	0-11	12-17	18-25	26-36	37+	0-50	51-120	121-210	211-300	301+
lb/acre*	T/acre	------- lb/acre --------					------- lb/acre --------				
3600	12	60	45	30	10	0	70	50	30	10	0
3900	13	60	45	30	10	0	75	55	35	15	0
4200	14	65	45	30	10	0	80	60	40	20	0
4500	15	65	45	30	10	0	85	60	40	20	0
4800	16	70	50	35	10	0	90	70	45	25	0
5100	17	70	50	35	10	0	95	75	50	25	0
5400	18	75	55	35	15	0	100	75	50	25	0
6000	20	85	60	40	20	0	110	80	55	25	0
6600	22	95	75	50	25	0	130	90	60	30	0
7200	24	110	80	50	25	0	150	120	80	40	0
7800	26	130	100	60	30	0	180	135	90	45	0

* Sugar yields are calculated, based on beets containing 15% sucrose.

Micronutrients: During the past few years there have been reports of responses to zinc (Zn) on sugarbeets. However, research has not shown a positive need for this nutrient in the major sugarbeet growing areas of the state and surrounding areas.

Before using Zn, obtain a soil test for this nutrient. If results of such a test show a soil fertility level of less than 0.5 ppm Zn, try applications of 10 to 15 pounds per acre actual Zn as zinc sulfate or 2 to 3 pounds per acre actual Zn in chelate form on a trial basis.

Responses to other micronutrients have not been reported or demonstrated.

SUNFLOWERS

TABLE 21 - SOIL NO_3-N PLUS FERTILIZER N NEEDED TO SUPPORT SPECIFIED OIL AND CONFECTIONARY SUNFLOWER YIELD GOALS.

Yield Goal		
Oil	Confectionary	Soil Plus Fertilizer N Needed
------- lb/acre --------		--------- lb/acre 2 feet ----
1400	1000	60
1600	1200	70
1800	1400	80
2000	1600	90
2200	1800	100
2400	2000	110
2600	2200	120
2800	2400	135
3000	2600	150
3200	2800	170
3400	3000	190

TABLE 22 - PHOSPHATE AND POTASH RECOMMENDATIONS FOR DIFFERENT YIELD GOALS & SOIL FERTILITY LEVELS FOR OIL AND CONFECTIONARY SUNFLOWERS.

		Nutrient Recommendations									
		P_2O_5					K_2O				
Yield Goal		P Fertility Level (lb/A)					K Fertility Level (lb/A)				
Oil	Confectionary	0-11	11-17	18-25	26-36	37+	0-50	51-120	121-210	211-300	301+
------ lb/acre -------		------ lb/acre --------					------- lb/acre -------				
1400	1000	15	10	0	0	0	20	15	0	0	0
1600	1200	15	10	0	0	0	20	15	10	0	0
1800	1400	15	10	0	0	0	20	15	10	0	0
2000	1600	20	15	10	10	0	20	15	10	0	0
2200	1800	20	15	10	10	0	20	15	10	10	0
2400	2000	20	20	10	10	0	20	15	10	10	0
2600	2200	25	20	15	10	0	25	20	15	10	0
2800	2400	25	20	15	10	0	30	25	20	15	0
3000	2600	30	25	20	10	0	40	30	25	20	0
3200	2800	30	25	20	10	0	50	40	30	20	0
3400	3000	35	30	25	20	10	60	50	40	20	0

Micronutrients: To date use of micronutrients on sunflowers has not been shown to give consistent paying yield responses. If for some reason a micronutrient problem is suspected, it is suggested that a micronutrient soil test be obtained and that the use of micronutrients be limited to a trial basis.

SOYBEANS

Nitrogen: Soybeans which have been well-inoculated and are well-nodulated are not likely to respond to applied nitrogen fertilizer. Therefore, a maximum of 10 pounds of nitrogen per acre applied at planting time is suggested. Trial application of higher amounts of broadcast or banded nitrogen could be looked at if yield goals are set quite high (40 + bushels per acre). Phosphate and potash needs for such yields must also be applied.

TABLE 23 - PHOSPHATE AND POTASH RECOMMENDATIONS FOR DIFFERENT YIELD GOALS & SOIL FERTILITY LEVELS FOR SOYBEANS.

	Nutrient Recommendations									
	P_2O_5					K_2O				
	P Fertility Level (lb/A)					K Fertility Level (lb/A)				
Yield Goal	0-11	11-17	18-26	26-36	37+	0-50	51-120	121-210	211 300	301+
bu/acre	------- lb/acre --------					------- lb/acre --------				
15	25	20	15	10	0	50	35	20	10	0
20	30	25	20	10	0	60	45	30	15	0
25	35	30	25	10	0	70	50	35	20	0
30	45	40	25	10	0	80	60	40	20	0
35	55	45	25	10	0	100	75	50	25	0
40	60	50	30	15	0	120	90	60	30	0
45	65	50	30	15	0	120	90	60	30	0
50	70	55	35	15	0	140	105	70	35	0
55	75	55	35	15	0	140	105	70	35	0
60	85	60	40	20	0	180	135	90	45	0

Micronutrients: Zinc (Zn) deficiencies have been found in isolated areas in the state. Suspect areas are generally limited to sandy soils, especially if they are limey to the surface, and in areas where topsoil has been removed such as in the process of leveling for irrigation.

A soil test for Zn is available from North Dakota State University Soil Testing Laboratory. This test will prove helpful in identifying soils with suspected Zn problems.

See Table 18 for soil test interpretations for zinc.

For soils testing low in Zn, rates of 3 to 5 pounds per acre of actual Zn from zinc sulfate or 1/2 to 1 pound per acre actual Zn in the organic (chelate) form is recommended. For marginal-testing soils, use the same rates of Zn on a trial basis unless a response has been confirmed by past experience. Zinc can be banded with starter fertilizer, but broadcasting Zn and plowing down also has been successful.

Iron deficiencies causing a chlorotic condition in soybeans are usually the result of iron being unavailable in high-lime soils. The best solution to this problem is the selection of varieties resistant to iron chlorosis.

EDIBLE BEANS (PINTO, NAVY)

TABLE 24 - SOIL NO_3-N PLUS FERTILIZER N NEEDED TO SUPPORT SPECIFIED EDIBLE BEAN YIELD GOALS.

Yield Goal	Soil Plus Fertilizer N Needed
lb/acre	------- lb/acre 2 ft. -------
750	10
1000	20
1250	30
1500	40
1750	50
2000	55
2250	60
2500	70
2750	75
3000	85
3250	90

TABLE 25 - PHOSPHATE AND POTASH RECOMMENDATIONS FOR DIFFERENT YIELD GOALS & SOIL FERTILITY LEVELS FOR EDIBLE BEANS (PINTO, NAVY).

	Nutrient Recommendations									
	P_2O_5					K_2O				
	P Fertility Level (lb/A)					K Fertility Level (lb/A)				
Yield Goal	0-11	12-17	18-26	26-36	37+	0-50	50-120	121-210	211-300	301+
lb/acre	------- lb/acre --------					------- lb/acre --------				
750	25	20	15	10	0	50	35	20	10	0
1000	30	25	20	10	0	60	45	30	15	0
1250	35	30	25	10	0	70	50	35	20	0
1500	45	40	25	10	0	80	60	40	20	0
1750	55	45	25	10	0	100	75	50	25	0
2000	65	50	30	15	0	120	90	60	30	0
2250	65	50	30	15	0	120	90	60	30	0
2500	75	55	35	15	0	140	105	70	35	0
2750	75	55	35	15	0	140	105	70	35	0
3000	85	60	40	20	0	180	135	90	45	0
3250	85	60	40	20	0	180	135	90	45	0

Micronutrients: Zinc (Zn) deficiencies may occur especially on Navy beans. Areas with the most severe problems have been in fields where soils are limey to the surface and where topsoil has been removed as in the process of leveling fields for irrigation.

For soils testing low in Zn, rates of 3 to 5 pounds per acre of Zn as zinc sulfate or 1/2 to 1 pound per acre of actual Zn in an organic (chelate) form is recommended. For marginal testing soil, use the same rates of Zn on a trial basis unless a response has been confirmed by past experience. Zinc can be banded with starter fertilizer, but broadcasting Zn and plowing down has also been successful.

Iron chlorosis may also occur on edible beans, and is often confused with zinc deficiency symptoms. Zinc and iron deficiencies both cause a yellowing of the plants. In the case of zinc the older leaves are affected first and rosetting of the plant often occurs due to a shortening of the internodes. Iron deficiency affects the new leaves first and rosetting does not occur. Attempts to correct iron deficiencies have not proved to be too practical. In most cases plants will recover from iron problems after soils warm up and plants become better established.

POTATOES

TABLE 26 - SOIL NO_3-N PLUS FERTILIZER N NEEDED FOR POTATO YIELD GOALS.

Yield Goal	Soil Plus Fertilizer N Needed
	------- lb/acre 2 ft. -------
150	75
175	87
200	100
225	112
250	125
275	137
300	150
350	175
400	200
450	225
500	250

TABLE 27 - PHOSPHATE AND POTASH RECOMMENDATIONS FOR DIFFERENT YIELD GOALS & SOIL FERTILITY LEVELS FOR POTATOES.

	Nutrient Recommendations									
	P_2O_5					K_2O				
	P Fertility Level (lb/A)					K Fertility Level (lb/A)				
Yield Goal Potatoes	0-11	12-17	18-25	26-36	37+	0-50	50-120	121-210	211-300	301+
Cwt/A	------- lb/acre --------					------- lb/acre --------				
150	100	75	50	25	0	50	40	25	10	0
175	110	80	55	25	0	75	45	35	25	0
200	120	90	60	30	25	100	50	50	50	0
225	130	100	65	30	25	125	67	50	50	0
250	140	105	70	35	25	150	75	50	50	0
275	150	110	75	35	25	175	87	50	50	0
300	160	115	80	40	25	200	100	50	50	0
350	180	135	90	45	25	250	150	75	50	0
400	200	150	100	50	25	300	200	100	50	50
450	220	165	110	55	25	350	250	150	75	50
500	240	180	120	60	25	400	300	200	100	50

Micronutrients: Some isolated areas in the state have been identified as being low in zinc (Zn). Suspect areas are generally sandy soils, especially if they are limey to the surface, and areas where topsoil has been removed during the process of leveling field for irrigation.

For soils testing low in Zn, rates of 10 to 15 pounds per acre of Zn as zinc sulfate or 1 to 2 pounds per acre actual Zn in a organic form is recommended. For marginal testing soil, it is suggested that the same rates of Zn be used on a trial basis unless a response has been confirmed by past experience. Zinc can be banded with starter fertilizer, but broadcasting and plowing down has also been successful.

FLAX, MUSTARD AND RAPE

TABLE 28 - SOIL NO_3N PLUS FERTILIZER N NEEDED FOR FLAX, MUSTARD AND RAPE YIELD GOALS.

Yield Goal Flax, Mustard & Rape	Soil Plus Fertilizer N Needed
bu/A	-------- lb/acre 2 ft. ------
10	30
15	40
20	50
25	60
30	70
35	80
40	90
45	100
50	115
55	130
60	150

TABLE 29 - PHOSPHATE AND POTASH RECOMMENDATIONS FOR DIFFERENT YIELD GOALS & SOIL FERTILITY LEVELS FOR FLAX, MUSTARD AND RAPE.

	Nutrient Recommendations									
	P_2O_5					K_2O				
	P Fertility Level (lb/A)					K Fertility Level (lb/A)				
Yield Goal	0-11	12-17	18-25	26-36	37+	0-50	51-120	121-210	211-300	301+
bu/acre	------- lb/acre -------					------- lb/acre --------				
10	15	10	0	0	0	20	15	10	0	0
15	15	10	0	0	0	25	20	10	0	0
20	15	10	0	0	0	30	25	15	0	0
25	15	10	10	0	0	35	30	20	10	0
30	20	15	10	10	0	40	35	25	15	0
35	20	15	10	10	0	45	35	25	15	0
40	25	20	15	15	0	50	40	30	20	0
45	30	25	20	15	0	55	45	35	25	0
50	35	30	25	20	0	65	55	45	35	0
55	40	35	30	25	0	70	60	50	40	0
60	55	50	45	40	0	90	80	70	50	0

Micronutrients: Zinc (Zn) deficiencies have been found in isolated areas in the state. Flax has given some indications of response to Zn on such areas. The Zn deficient areas are generally limited to sandy soils, especially if they are limey to the surface. Areas where topsoil has been removed are also often low in Zn.

For soils testing low in Zn, rates of 10 to 15 pounds per acre of Zn from zinc sulfate or 1 to 2 pounds per acre of Zn from an organic (chelate) form is suggested. For soils with a marginal Zn fertility rating, use the same rates of Zn on a trial basis unless a response to Zn has been confirmed by past experience. Zinc can be banded, but broadcasting and plowing it down has also been successful.

Iron chlorosis often occurs especially during cool, wet springs and on high lime soils. In most cases, attempts to correct this problem have not proved to be practical. As the soils warm up, the plants usually out grow the problem.

CANARY SEED, MILLET AND SORGHUM

TABLE 30 - SOIL NO_3-N PLUS FERTILIZER N NEEDED FOR SELECTED YIELD GOALS OF CANARY SEED, MILLET AND SORGHUMS.

Yield Goals		Soil Plus Fertilizer N Needed
Millet Canary Seed	Grain Sorghum	
lb/acre	bu/acre	--- lb/acre 2 ft. --
850	25	55
1000	30	60
1300	40	70
1600	50	85
1900	60	100
2100	70	120
2400	80	140
2700	90	160
3000	100	180
3300	120	220
3600	140	230

TABLE 31 - PHOSPHATE AND POTASH RECOMMENDATIONS FOR CANARY SEED, MILLET AND SORGHUM.

Yield Goal		Nutrient Recommendations									
		P_2O_5					K_2O				
		P Fertility Level (lb/A)					K Fertility Level (lb/A)				
Millet & Canary Seed	Sorghum	0-11	12-17	18-25	26-35	37+	0-50	51-120	121-210	211-300	301+
lb/A	bu/A	------- lb/acre --------					------- lb/acre --------				
850	25	15	10	10	0	0	20	15	10	0	0
1000	30	20	15	10	10	0	20	15	10	10	0
1300	40	25	20	15	10	0	25	20	15	10	0
1600	50	30	25	20	15	0	30	25	20	15	0
1900	60	35	30	25	20	0	35	30	25	20	0
2100	70	40	35	30	25	0	40	35	30	25	0
2400	80	40	35	30	25	0	40	35	30	25	0
2700	90	40	35	30	25	0	40	35	30	25	0
3000	100	50	40	35	30	0	50	40	35	30	0
3300	120	50	40	35	30	0	50	40	35	30	0
3600	140	50	40	35	30	0	50	40	35	30	0

ALFALFA (MORE THAN 30% ALFALFA)

Alfalfa which has been inoculated and well-nodulated is not likely to respond to applied fertilizer nitrogen.

TABLE 32 - PHOSPHATE AND POTASH RECOMMENDATIONS FOR ALFALFA.

Yield Goal	Nutrient Recommendations									
	P_2O_5					K_2O				
	P Fertility Level (lb/A)					K Fertility Level (lb/A)				
	0-11	12-17	18-25	26-36	37+	0-50	51-120	121-210	211-300	301+
T/A	------- lb/acre --------					------- lb/acre --------				
2	40	30	20	10	0	90	75	50	25	0
3	60	50	40	20	0	120	90	60	30	0
4	80	60	40	20	0	160	120	80	40	0
5	100	70	40	20	0	200	150	100	50	0
6	120	80	40	20	0	250	190	130	70	0
7	130	90	60	30	0	300	225	150	75	0
8	160	120	80	40	0	350	270	190	80	0
9	210	150	100	50	0	400	300	200	100	0

TABLE 33 - FERTILIZER RECOMMENDATIONS FOR GRASS.

Counties	Nutrient Recommendations											
	N		P_2O_5					K_2O				
			P Fertility Level (lb/A)					K Fertility Level (lb/A)				
	Native	Tame	0-11	12-17	18-25	26-36	37+	0-50	51-120	121-210	211-300	301+
	--- lb/A** ---		-------- lb/A --------					--------- lb/A ---------				
Cass, Grand Forks, Pembina, Richland, Steele, Traill, Walsh	95	115	30	25	20	10	0	80	45	20	0	0
Barnes, Benson, Cavalier, Dickey, Eddy, Foster, Griggs, LaMoure, Nelson, Ramsey, Ransom, Sargent, Stutsman, Towner	70	90	30	25	20	10	0	80	45	20	0	0
Bottineau, Burleigh, Emmons, Kidder, Logan, McHenry, McIntosh, McLean, Pierce, Renville, Rolette, Sheridan, Ward	60	70	30	25	20	10	0	80	45	20	0	0
Adams, Billings, Bowman, Burke, Divide, Dunn, Golden Valley, Grant, Hettinger, McKenzie, Mercer, Morton, Mountraill, Oliver, Sioux, Slope, Stark	50	50	30	25	20	10	0	80	45	20	0	0
Irrigated Grass - Statewide	150*		50	35	20	10	0	100	75	50	25	0

* Apply up to 1/2 of the nitrogen in early spring and the remainder between grazing rotations and/or during irrigation water application throughout the growing season.

** N recommendations for grass are not based on the NO_3-N test. They are general recommendations based on moisture availability.

UNDERSTANDING THE USE OF FERTILIZERS

The North Dakota Fertilizer and Soil Conditioner Law requires that fertilizers must be labeled according to the content of total nitrogen (N), available phosphoric acid (P_2O_5), and soluble potash (K_2O). The North Dakota Fertilizer and Soil Conditioner Law is administered by the State Laboratories Department. The registration, sampling, analyses and testing of fertilizer and soil conditioners is done by the State Laboratories Department at Bismarck, not at North Dakota State University.

At some future time, the use of an elemental system of expressing phosphorus and potassium may replace the oxide system presently used in labeling fertilizers. The needed conversion factors are:

$$P_2O_5 \times 0.44 = P$$
$$P \times 2.29 = P_2O_5$$
$$K_2O \times 0.83 = K$$
$$K \times 1.20 = K_2O$$

Nitrogen and micronutrients are now labeled on the elemental basis.

Grade, Analysis, Ratio, Unit

Fertilizer grade and analysis are the same thing. They refer to the guaranteed minimum percentage by weight of the primary plant nutrients nitrogen, phosphorus, and potassium expressed in order as total nitrogen (N), available phosphoric acid (P_2O_5), and soluble potash (K_2O). For example, 100 pounds of an 18-46-0 fertilizer contains 18 pounds of total N, 46 pounds of available P_2O_5 and 0 pounds of soluble K_2O.

Ratio refers to the proportion of nitrogen, phosphate, and potash in the fertilizer. For example, 10-30-10 is a grade having a ratio of 1-3-1.

The term unit of nitrogen is often being used by our farmers instead of pounds of nitrogen. The interchange of unit and pound is incorrect since the term "unit" is defined in the fertilizer trade as twenty pounds of plant nutrient. Thus a unit of nitrogen is 20 pounds of actual nitrogen, not one pound.

Fertilizer recommendations in this guide are given as pounds of plant nutrients (sometimes called plant food) per acre. From these the user has to determine the fertilizer materials, or if a mixed fertilizer, the grade and amount that comes close to the recommendation. To do this he must be able to make some calculations as to how much of a nutrient is in any given amount of a material or how much material it takes to give so much nutrient. For example, an application of 70 pounds per acre of an 18-46-0 analysis contains 12.6 pounds of N (70 x .18) and 32.2 pounds of P_2O_5 (70 x .46). If a recommendation calls for an application of 55 pounds of N per acre one would need to apply 161.7 pounds of 34-0-0 fertilizer per acre (55 ÷ .34). If a recommendation is for 20 pounds per acre of P_2O_5 one would need 42 pounds per acre of a 11-48-0 fertilizer (20 ÷ .48). It would also supply 4.6 pounds of N per acre (42 x .11).

Fertilizer Costs

Comparisons made as to fertilizer cost or fertility values generally are more reliable when they are based on the cost of available nutrients such as cents per pound of N, P_2O_5, or K_2O rather than cost per ton of fertilizer. When liquid fertilizers are quoted a price per volume, such as a gallon, the buyer must know the weight per unit volume as well as the analysis in order to compute the cost per pound of nutrient.

The following examples illustrate how to calculate the cost per pound of nutrient for fertilizer materials containing one nutrient. This is done by dividing the cost per ton by pounds of the nutrient in 1 ton.

Example 1: 34-0-0 costs $130 per ton.

Calculation $\frac{\$130}{2,000 \times .34} = \frac{\$130}{680} = \$0.192$ or 19.2¢ per pound of N.

Example 2: 82-0-0 costs $240 per ton.

Calculation $\frac{\$240}{2,000 \times .82} = \frac{\$240}{1,640} = \$0.146$ or 14.6¢ per pound of N.

For mixed materials one can calculate an average cost for the nutrients contained in the material.

Example 3: 18-46-0 costs $190 per ton. The total available nutrient content is 18% + 46% = 64%.

Calculation $\frac{\$190}{2,000 \times .64} = \frac{\$190}{1,280} = \$0.148$ or 14.8¢ per pound of nutrient.

For liquid materials priced by the gallon one must use the weight per gallon in the calculation as illustrated.

Example 4: 10-10-10 costs $2.75 per gallon. It weighs about 11.5 pounds per gallon. The total available nutrient content is 10% + 10% + 10% or 30%.

Calculation $\frac{\$2.75}{11.5 \times .30} = \frac{\$2.75}{3.45} = \$0.797$ or 79.7¢ per pound of nutrient.

Fundamentals of Fertilizer Application

Fertilizers supply the needed plant nutrients not available in the soil. Where soil fertility levels are high, only small amounts of commercial fertilizers may be needed for maximum crop yields. Where the fertility level of the soil is low, fertilizers must furnish a major part of the nutrients needed by the crops. In this case, large amounts of fertilizers must be applied if maximum yields are to be realized.

For example, phosphorus fertilizer applied to a soil testing low in phosphorus will ordinarily produce a large yield increase, while the same amount of phosphorus applied to a similar soil, which has a high test for phosphorus, may produce little or no yield increase.

Maintaining soil fertility at medium or higher test levels is a desirable long-term soil fertility program. Continued high crop yields are more certain when soils contain abundant phosphorus and potassium along with well-balanced supplies of other nutrients.

Fertilizer solutions containing N or combinations of N, P_2O_5, and K_2O have the same effect on plant growth as equivalent amounts of dry fertilizer when applied at equivalent rates and when similar placement is used.

Methods of Fertilizer Application

Fertilizers are applied by broadcasting, row placement, top-dressing, side-dressing, "Pop-Up" method, and foliar application.

Fertilizers should be applied so that:

1. Growing plants can use the applied fertilizer efficiently.
2. There is little or no injury to plants from the fertilizer applied.
3. The application can be accomplished as quickly and easily as is economically possible.

Broadcast

Nitrogen fertilizers may be broadcast and incorporated into the soil.

Fertilizers containing N, P_2O_5, and K_2O may be broadcast when large amounts of all three elements are needed.

Broadcast (corrective) applications of phosphorus and/or potassium can supply large amounts of these nutrients if they are needed to raise the soil fertility level.

Advantages: Fertilizer can be applied in the fall ahead of tillage and at the time when labor requirements are low. Fertilizer is usually 10 to 15 percent cheaper in the fall. If weather turns dry during the growing season, the N is already in the root zone.

Disadvantages: If applied to a sandy soil or if there is an open winter, some N may be lost through leaching. In wet seasons, sizeable N losses may also occur by denitrification.

Row Placement

Most grades of fertilizers used in North Dakota can be row applied at planting time. This "starter", when properly placed, stimulates rapid seedling growth. Amounts of fertilizer which can safely be applied and methods of placement vary with crops.

The specifics of rates and methods of placement for various crops are discussed in the crops section of this guide.

Topdressing

Grasses and forage crops may be topdressed with nitrogen, phosphorus and/or potassium during the late fall or in early spring or between cuttings.

Small grains may be topdressed with nitrogen. These topdressing applications should be made before early heading stage.

Sidedressing

Sidedressing is one way to apply additional nitrogen to corn or sunflowers. In general, plow-down or row applications of nitrogen are preferable to sidedressing. When sidedressing these crops with nitrogen, apply the fertilizer in bands 3 to 4 inches below the soil surface between the rows. Make this application when the plants are 6 to 12 inches tall. Deep sidedressing close to the plants will damage roots and may reduce yields.

Advantages: Fertilizer can be applied close to the time of greatest need by the crop. The cropping plan can be changed up to planting. This is a good method of applying N on sandy soils.

Disadvantages: Wet soil may prevent timely application. When the weather is dry after sidedressing, the roots may not be able to absorb the N if it is placed above the root absorption zone.

"Pop-Up"

Small amounts of fertilizer applied in contact with the seed is called "Pop-Up". The term "Pop-Up" is a misnomer because this method may delay germination and emergence as much as three days. Research, in general, has shown no benefit from "Pop-Up" fertilizer; therefore, "Pop-Up" is not recommended for use under North Dakota conditions.

Foliar Application

Foliar application of N, P_2O_5, and K_2O solutions is not recommended for agronomic crops. Foliar sprays of the primary plant nutrients are seldom practical because of the large amounts needed. Micronutrients and some of the secondary nutrients can be satisfactorily applied in solutions to the foliage since only small amounts are needed.

Time of Application

Nitrogen:

Nitrate-nitrogen (NO_3^-) moves with soil moisture and can leach out of the root zone if there is sufficient water movement. Ammonium-nitrogen (NH_4^+) is absorbed on the exchange sites of the clay particles and is relatively immobile until converted to the nitrate form. Losses of N applied in the fall for crops to be grown in the spring will be minimized if the following precautions are observed:

1. Use an ammonium (NH_4^+) N carrier or one that changes to the ammonium form shortly after application. Some ammonium form of N carriers are anhydrous ammonia, which changes in the soil to the ammonium form; aqua ammonia; urea, which is hydrolized to the ammonium form; and ammonium nitrate or ammonium sulfate.

2. Apply only on medium- and fine-textured soils (silt loams, silty clay loams, etc.).

3. Do not apply in the fall on sandy soils.

4. Do not apply in the fall on soils which are poorly drained.

Extension Bulletin No. 21, "How Fertilizer Moves In Soils" contains additional discussion regarding fertilizer movement as influenced by time of application.

Other Fertilizer Materials and Soil Amendments

There are on the market many other forms of fertilizer materials and so-called soil amendments. Although some of these products have agricultural value, *many are over-priced and of questionable value. Before investing money in* products which have not been recommended, it would be wise to consider the following points:

1. If you decide to try the product, buy just enough to treat a small test plot. *(Compare results with an adjoining plot in the same field on which the product is not used but on which all other operations and conditions are identical.)*

2. Carefully evaluate all new products. Demand adequate proof of their value under your own conditions of operation.

BEFORE YOU INVEST - INVESTIGATE, AFTER ALL IT'S YOUR MONEY.

Animal Wastes

Farm manure is an excellent amendment for soil improvement. It is a valuable complete fertilizer containing all essential plant nutrients. On the average, cattle manure contains 10 pounds of nitrogen, 5 pounds of phosphate, and 10 pounds of potash per ton. Chicken or hog manure may contain up to five times as much nitrogen and phosphorus and ten times as much total salt as cattle or horse manure.

To avoid possible pollution, the indiscriminate use of manure without proper incorporation into the soil should be avoided.

The greatest benefits from manure will result on saline soils, eroded soils, knolls and ridges, and the grayish-colored soils of upland depressions. Manure is best applied directly from the barn or feedlot onto the land. Ten tons per acre are sufficient, except on saline areas, where substantially higher amounts can be used. This is approximately equal to 25 cubic yards per acre. For chicken or hog manure rates of application should be reduced by a factor of five.

Additional information regarding the value and use of manure may be found in Extension Bulletin No. 14, "North Dakota Crop Rotations For Profit". Extension Bulletin No. 2, "Salt Affected Problem Soils In North Dakota" contains information regarding manure use on saline areas.

Legumes

Legumes can be managed to increase the nitrogen supply in the soil. With fertilizer nitrogen in short supply and at present high prices, legumes may be a source of nitrogen to consider.

Farmers are quite dependent on nitrogen for good yields of non-legume grain and forage crops. During the past years of adequate nitrogen fertilizer supply and low cost of commercial nitrogen fertilizer, it was used to supply nitrogen needs of non-legume crops. With the present fertilizer situation farmers need to look at possible alternative sources of nitrogen and legumes offer one alternative.

One must keep in mind that only a part of the nitrogen added by legumes represents a gain in nitrogen. About one-half to two-thirds of the nitrogen contained in the legume is fixed from the atmosphere. The rest comes from soil sources and is not a true gain in supply. Table 34 and 35 give some idea of the nitrogen yield from different legumes.

TABLE 34 - NITROGEN YIELD FROM SEVERAL CROPS

Crop and Management (Legumes Properly Inoculated)	Nitrogen Pounds Per Acre
Oats underseeded with legume, oats removed, plowed fall or spring	20 to 40
Sweetclover plowed second year at hay stage	120 to 150
Alfalfa sod plowed after one crop year	120 to 150
Red clover sod plowed after one crop year	120 to 150
Soybeans drilled solid and plowed under at hay stage	60 to 80
Field peas and oats plowed under at hay stage	60 to 80
Soybean-sudan mixture plowed under at hay stage	40 to 60

Source: Agron. No. 11 Farm and Home Fact Sheet - Univ. of Minnesota.

TABLE 35 - NITROGEN YIELD IN POUNDS PER ACRE OF LEGUME GREEN MANURE CROPS

	1/ Iowa (1955-1957 Determined Fall of Year Seeded			2/ Nebraska 1952 Total Nitrogen Produced
	Tops	Roots	Total	
Madrid Sweetclover	74	72	146	181
Arizona Alfalfa	--	--	---	76
Indian Alfalfa	49	31	880	---
African Alfalfa	48	27	75	87
Ladak Alfalfa	--	--	--	83
Ranger Alfalfa	34	21	55	69
Kenland Red Clover	40	10	50	--
Ladino Clover	31	5	36	--
Hubam Sweetclover	--	--	--	52
Madison Vetch	--	--	--	96
Hairy Vetch	--	--	--	79

1/ Source: Agron. J. 51:135-137, 1959.

2/ Source: Agron. J. 48:127-131, 1956.

The management of the legume in terms of when plowed influences the nitrogen yield as is illustrated in Table 36.

TABLE 36 - NITRATE NITROGEN IN 36 INCH DEPTH OF SOIL AND AVERAGE WHEAT YIELDS SWEETCLOVER MANAGEMENT PLOTS, FARGO STATION.

Management The Prvious Season	Lb/A Nitrate Nitrogen April 1955	May 1956	Ave. of 2 years	Ave. Yield Wheat 1919-56
Regular Fallow, No Sweetclover	70	165	117	30.8
Sweetclover Plowed Early Cropped to Flax	41	72	56	23.2
Sweetclover Plowed Early Fallowed	110	256	183	30.7
Sweetclover Plowed at Bud Stage Fallowed	159	209	184	31.9
Sweetclover 1st Crop Hay 2nd Crop-Plowed Down at Bud Fallow	110	189	149	29.3
Sweetclover 1st and 2nd Hay Crops Fall Plowed	38	103	70	24.6
Sweetclover 1st Hay Crop 2nd Seed Crop Fall Plowed	35	63	49	23.1

Source: Unplublished data NDSU Soils Department.

One must also keep in mind that the benefical effect of increased available nitrogen in the soil profile as a result of the legume may be largely cancelled by the removal of water by the legume. Some data regarding this along with other discussion regarding legumes as green manure is in Extension Bulletin No. 14, "North Dakota Crop Rotations For Profit".

In addition to adding available nitrogen, legumes benefit crops in various ways such as:

1. They add organic matter which a) improves soil tilth, b) makes soil easy to cultivate, c) enables the soil to take up and hold water and d) permits crops to benefit to the fullest from other nutrients.

2. They protect the soil surface from erosion.

3. They influence beneficially the numbers, kinds and activities of various desirable soil organisms that are important in the decay of organic matter.

4. They help control weeds, plant diseases and insects when used in a crop rotation.

5. They protect the soil against leaching of nutrients.

6. They are excellent hay and pasture crops.

7. They are the only crop that can add soil nitrogen for the benefit of succeeding crops in a rotation or for the benefit of crops grown with them.

8. They can be used to help one live with salinity problems.

9. They offer help in prevention and control of saline areas.

Circular R-584, Forages For Salt-Affected And Wet Soils" contains additional information regarding items 8 and 9.

HOW CROPS GROW

INTRODUCTION

The section on crop production will present information dealing with the growth and development of plants. The information on weed control, fertilizer needs and use, and diseases will be covered in the sections dealing with those subjects. The yield and variety descriptions will be found in the section on variety comparisons.

SMALL GRAINS

Small grains include wheat, barley, oats, rye and rice.

THE SEED (CARYOPSIS)

The essential parts of cereal seeds are:

1. Pericarp - the protective covering surrounding the endosperm and germ.
2. Germ or embryo - the young dormant plant.
3. Endosperm - stored food.
   a. Aleurone - outer layer of cells which may contain pigments.

In cereals the endosperm is mostly starch, while the embryo (germ) is high in protein, oil, and minerals.

GERMINATION

Seeds placed in soil germinate if sufficient water and oxygen are present, and if temperatures are suitable. In the germination process, the embryo, which was dormant in the dry seed, resumes growth.

Several factors influence germination:

1. Water absorption is the first step in germination. Since water comes from the soil, the seed must be in close contact with moist soil particles to absorb water. A well prepared, firm seedbed conserves soil moisture. Placing seed in moist soil is necessary for good germination.

   Water absorption by seed also is influenced by concentration of chemicals (principally salts) in the soil solution. If the salt concentration is too high, the seed cannot absorb enough water for normal germination. This is why "fertilizer burn" occurs if high concentrations of fertilizer are placed close to the seed. Seed also may fail to germinate in highly saline soils.

2. Oxygen - must be present in adequate quantities for respiration to provide energy. It may be limiting in water-logged soils, which slow down or prevent germination.

3. Temperature - seeds will not germinate if the temperature is too low. Various kinds of seeds will germinate at different soil temperatures. See Table 1.

Table 1. SOIL TEMPERATURES FOR GERMINATION

Crop	Degrees Fahrenheit Minimum or Threshold	Optimum Range
Wheat	34 to 36	59 to 65
Barley	34 to 36	59 to 65
Oats	34 to 36	59 to 68
Rye	34 to 36	59 to 65
Corn	48 to 50	80 to 90
Sorghum	48 to 50	80 to 90
Millet (assumed to be like corn and sorghum)		

Source: Idaho Agricultural Science

These differences in temperature requirements for germination help explain why some crops can be sown earlier in the spring than others. The danger of frost after growth begins also is a factor to consider in deciding when to seed, since some crop seedlings are more frost-tolerant than others.

4. Light - cereal seeds will germinate either in light or darkness, but other seeds such as bluegrass germinate faster in light.

5. Seed Viability - the embryo (germ) must be alive if the seed is to germinate. The viability of seeds can be determined by a germination test. Some live seeds are more vigorous than others and will germinate faster and produce more robust seedlings.

6. Seed Size - the larger the seed, the more food and energy it can provide to the young seedling. Several experiments have shown that larger seeds germinate faster and produce more vigorous seedlings than do smaller seeds. Large seeds will emerge from greater depths than small seeds. Early seedling vigor and rapid growth provides better crop competition against weeds and seedling diseases. Removing small kernels in seed cleaning is desirable.

7. Breaks in the seed coat (pericarp) may decrease germination in cereals. Broken seeds often have low viability. Injury to the embryo usually is the most serious. Broken seeds often show more mold growth than do whole seeds. Seed treatment protects against mold and fungus growth on the seed surface.

8. Immature seeds are attacked more easily by mold growth than mature seeds. Because of less food reserve in the endosperm they also produce smaller sprouts. Good quality seed comes from well matured plants.

9. Microorganisms - many kinds of fungi and bacteria in the soil can attack seeds and cause them to rot. Seed treatment protects the seed and seedling against soil borne disease infection.

10. Diseased seed - some seed borne diseases cause small, shrunken kernels that should be removed in seed cleaning. Other seed borne diseases such as loose smut and viruses do not affect germination.

11. Dormancy - seeds of some cereals may be dormant when newly harvested. They need a storage period for conditioning before they can germinate. Dormancy in wheat, barley and oats often disappears in 20 to 30 days after harvest but may persist for 60 days in wheat. Durum wheat tends to have a longer dormancy than Hard Red Spring wheat. A higher per cent of dormancy also has been observed in wheat harvested before it is mature. Freshly harvested oats and barley kept at a temperature of

36°F. in a relatively high humidity will stay dormant for three years. Dormancy is less common in corn and sorghum than in oats and barley. Varieties of the different cereals differ in dormancy. Temporary dormancy of cereal grains is desirable where prolonged moist weather conditions occur at harvest. There is no dormancy problem in rye or winter wheat. Newly harvested seed can be sown the same fall.

EMBRYO STRUCTURE AND GROWTH

The embryo is composed of several distinct parts each having a separate function in the developing plant.

The coleoptile, the internodes, and the radicle are involved in the emergence of the seedling during and following the germination process. The first embryo structure to enlarge is the radicle which grows downward, provides anchorage and absorbs water and nutrients. Next the coleoptile reaches the surface of the soil, but usually will become no longer than 3 inches. When it has emerged through the soil surface, the third leaf (first foliage leaf) breaks through the tip of the coleoptile and becomes a functional seedling leaf. All subsequent leaves and the growing point emerge through the coleoptile. These foliage leaves have little or no soil penetrating power. If the coleoptile fails to reach the soil surface, the foliage leaves do not emerge and a poor stand results. They continue growing for a while but remain below ground folded and crinkled because they are unable to penetrate the soil.

The first internode of wheat, barley and rye for all practical purposes does not elongate and this limits the depth of seeding to the length of the coleoptile. In contrast to wheat, barley and rye, the first internode of corn and oats does elongate and pushes the elongating coleoptile up through the soil much like a spear. Hence corn, and to a lesser extent oats, can emerge from greater depths than other cereals.

RESPIRATION

Respiration, transpiration, photosynthesis and reproduction are four of the major life processes of a plant. Respiration, which is at a very low level in viable seed, increases rapidly during the early stages of germination and continues throughout the life of the plant, providing a source of energy for all growth processes.

Seedling plant growth begins in the embryo (germ) as food is transported from the endosperm to the embryo cells during the process of germination.

As the seed absorbs water the starch, which is the stored food in the endosperm, is broken down into sugars which are simpler chemical compounds. This conversion of starch into sugars is brought about by the action of chemicals called enzymes, contained in the seed embryo. Enzymes influence chemical changes without being changed themselves.

The sugars are further broken down into very simple chemicals (carbon dioxide and water) by a process called respiration. This breakdown of sugars releases energy which is used by the germinating seedling for its life processes.

The breakdown of starch (respiration) which provides energy is shown by steps below:

(1) starch $\xrightarrow{\text{(enzyme)}}$ sugar

(2) sugar + oxygen $\longrightarrow$ H_2O (water) + CO_2 (carbon dioxide) + energy

Seeds need large amounts of energy to germinate. It has been estimated that the germination of a bushel of wheat seed requires as much energy as plowing an acre of land.

GROWTH STAGES OF SMALL GRAINS

A. Growth stages, of plants are commonly known as:

1. Seedling - a young plant grown from seed to the stage when tillers emerge.
2. Tillering - shoots arising from the crown.
3. Jointing - nodes can be felt in the lower portion of the stem but the head is not prominent in the leaf sheath.
4. Boot - the head is prominent inside the upper leaf sheath and the flag leaf is developed.
5. Heading - spikes or panicles are emerging but pollination has not begun. The exception is barley which pollinates before emerging from the boot.
6. Flowering - florets open and pollen is shedding (anthesis).
7. Filling - the fertilized ovary is enlarging and the kernel assumes full size.
   - Milk - endosperm can be squeezed from the kernel as a white liquid.
   - Soft dough - endosperm is becoming firm.
   - Hard dough - endosperm is firm and the kernel changing color.
8. Mature seed - kernel is firm and contains 35% or less moisture.
9. Fully ripe - kernel has about 13% moisture.

B. The growing point

The growing point is composed of a group of closely packed nodes, internodes and the embryonic inflorescence (head, ear or panicle). These component parts of the growing point finally develop into the above ground parts of the mature plant. The growing point is differentiating during the late seedling stage and prior to tillering. The potential plant development, including number of spikelets as a yield factor, is therefore, determined at this very early growth stage. Growing conditions at this early growth stage do influence final crop yield. For example, early season drought or high temperatures may limit the final yield. Cultural practices such as early seeding and soil moisture conservation usually help to avoid such yield limiting factors.

The growing point (terminal bud) is <u>always</u> located above the uppermost node of each stem in cereals. Generally the growing point is <u>below</u> the soil surface until nearly 30% of the mature plant height has been reached. As soon as node (joint) tissue can be felt near the soil surface, the growing point is above the soil surface. Tillering generally is completed before the growing point is above ground. This delayed emergence of the terminal bud is a valuable protective mechanism and should be considered when investigating frost, wind or hail damage. Cereals will survive extensive damage to the leaves and crown if the terminal bud is not killed. Maturity, however, is delayed following extensive loss of early foliage leaves.

PLANT PARTS AND THEIR FUNCTION

A. <u>Roots</u> - anchor the plant and absorb water and plant nutrients from the soil. There are two main types of cereal roots, <u>seminal</u> (primary) and <u>crown</u> (secondary). A third type called <u>brace</u> roots may develop above ground in corn.

<u>Seminal roots</u> - develop first. They originate from the embryo when the seed germinates, growing downward from the lower end of the embryo. The radicle develops first, followed by three, five or seven additional seminal roots. Sorghum and millet produce only a single branched seminal root. Seminal roots sometimes erroneously are called "temporary roots," the belief being that they function only in early stages of growth. Seminal roots may function until the plant matures. In corn they penetrate to a depth of five to six feet, but frequently they die soon after the crown roots are formed. In a well tillered wheat plant they may serve as the chief support of the main stem of the plant.

<u>Crown roots</u> - develop after the seedling emerges. They originate from stem tissue (adventitious) and develop after the young plant unfolds a few leaves. They arise from basal stem nodes which remain underground and develop into an elaborate root system. Crown roots usually develop about one inch below the soil surface even though the seed was planted deeper. Internodes below the crown elongate, bringing

it up near the soil surface.
Brace roots - may arise in whorls from nodes above the soil surface in corn and sorghum. When entering the soil, they function as ordinary roots.

Root hair - a "work horse" simply an enlarged epidermal cell in close contact with the soil particles, soil water and soluble ions. Root hairs have a life span of only a few hours but new ones are formed continuously during active plant growth.

Root growth: Growth in a root is due to cell division and enlargement at the tip of the root. Roots do not "search" for water or nutrients, they only "intercept" water and nutrients present in the pore space of the soil with which they happen to come in contact. There is some movement of water and nutrients in the soil and therefore movement towards the root.

With ample space, the roots of a single plant may have a total horizontal spread of four feet in wheat, eight feet in corn and twelve feet in sorghum. Roots of small grains, corn and sorghum normally penetrate downward three to six feet but most of the weight is in the upper 6 to 12 inches of soil.

Some cereal roots may elongate as much as a half-inch or more a day; seminal roots of winter wheat may grow at that rate for 70 days. Corn roots may grow from 2 to 2 1/2 inches a day for three or four weeks. The mature root system of a corn plant may occupy 200 cubic feet of soil.

Roots of cereal plants do not extend into water-logged soil. A moist topsoil with cold or dry subsoil in the early stage of plant growth promotes a shallow root habit that may cause the plant to suffer in later drought. Roots penetrate dry soil only slightly beyond available moisture supplies. They do not "search" for water or nutrients. This is why a firm seedbed without air pockets or thick layers of dry straw is desirable.

Soil temperature affects root development of a growing crop. During the growing season temperatures near the soil surface are considerably higher than temperatures at lower soil depths. The optimum soil temperature for root development of spring sown small grains is reported to be in the range of 68-72^{o}F. Studies of soil temperatures at the Fargo Experiment Station show that these optimum soil temperatures are not reached in the surface soil until the middle of June. If the 60^{o} isotherm is the temperature at which root growth of spring sown small grain crops is slowed considerably, roots may not extend much beyond the 2½-3 foot depth in soil by the time the plant has completed growth.

Since the soil temperatures in the lower depths are sub-optimum for root development, the small grain crop with a rather shallow root system may suffer from drought during the drier part of the growing season (July and August). Soil water available to the crop is, therefore, limited to that in the top three feet. During periods of high temperature or drying winds, crops may suffer from drought even though there is good subsoil moisture at the 4 to 5 foot level.

Absorption by roots: Plants absorb water and mineral nutrients through the root hairs. The roots absorb water and nutrient ions by osmosis. The semipermeable membrane of the cell wall is the selective tissue that restricts the free entry or exit of nutrient ions. Water, however, moves freely through this membrane independent of nutrient ion exchange.

The more a plant needs water the more rapidly it absorbs available soil water. Water taken up in excess of the ability of the plant to transpire water vapor through the stomata is forced out through pores in the leaf. Wilting occurs when transpiration (water loss) of the plant exceeds water uptake. Wilting may be only temporary if it results from hot, dry winds, or it may be permanent if due to a prolonged drought or saline soil condition. Temporary wilting is not considered injurious to vegetative crop growth but usually reduces yield and delays maturity.

Nutrients are absorbed as ions into root hair cells in response to the metabolic needs of the plant. For instance, potassium nitrate (KNO_3) dissolves and becomes dissociated into $K+$ (positive) and NO_3- (negative) ions. These ions are transported through the semipermeable membrane independent of water uptake. Thus it is possible for mineral nutrients to be absorbed even when the plant is not actively taking up water. Mineral nutrients may be concentrated in the cell sap at concentrations far above that in the external soil solution.

Stems (culms) hold the leaves up to sunlight and air. Cereals have a single main culm and tillers each divided into a series of nodes (joints) and internodes. At first the internodes are very short but later each elongates, the length depending upon its position and the species. The basal stem internodes are short while the upper internodes tend to become progressively longer. The uppermost internode is the longest and terminates in the flower part (inflorescence).

The very young internodes are filled with pith cells but except in corn, sorghum, and solid stem wheat varieties the pith disappears as the internode elongates, leaving it hollow. The nodes, however, remain solid.

The growth area of each above ground internode is always at the base. This area contains the meristematic tissue made up of young and actively dividing cells. Stem elongation takes place in this area by both cell division and enlargement. Growth in diameter of the stem is also a result of cell enlargement.

Dwarf varieties of cereal crops are due to less elongation of the internodes, rather than a reduction of the number of nodes, internodes and leaves of the stem within a given maturity range.

Tiller stems usually are slightly shorter and produce shorter spikes or panicles than does the main stem. They also produce fewer and smaller kernels per spike. There may be more sterile florets in a tiller spike than in the main stem spike. The ability of small grains to produce or lose tillers in response to growing season conditions is an important yield and crop quality factor.

Leaves carry on photosynthesis, which is the manufacture of food from raw materials secured from the soil and air using light energy from the sun. Leaves of cereals arise from stem nodes. Each node produces one leaf. A bud is generally present in the axil of each leaf. In small grains the lower buds may produce tillers while the upper buds remain undeveloped. In corn these upper buds develop into ear shoots. Leaves are arranged in rows on opposite sides of the stem.

The flag leaf is the uppermost foliage leaf on small grains. The lower plant leaves die first due to shading, drouth, disease or normal maturity. The flag leaf is the last to remain green and accounts for about 80 per cent of the filling of the grain crop.

TRANSPIRATION

Transpiration is the evaporation of water from within the aerial parts of plants, especially the leaves. Often over 99 per cent of the water absorbed by plants is transpired, but a plant is unable to grow unless it has sufficient water. Most of the water that evaporates from the leaves passes out into the air through the stomata, but a small amount of water vapor diffuses through the epidermal cell layers. Liquid water changes to vapor in the transpiration process.

Light, temperature, humidity, wind velocity and soil moisture conditions influence the rate of transpiration in plants. The stomata open in response to light, therefore transpiration is greater in the day time than at night. High temperatures, low humidity and wind movement increase transpiration. When soil water is readily absorbed, the transpiration rate is higher than when soil water is limited and absorbed with difficulty. Cereal plant modifications that reduce excessive evaporation are decreased leaf surfaces, thickened cuticle, and waxy bloom on the cuticle of leaves and stems. A waxy bloom is conspicuous on sorghum, wheat and barley.

The ratio of the total water absorbed to the total amount of dry matter produced by the plant is termed the "water requirement" or "transpiration ratio". It is usually expressed as the number of pounds of water required to produce one pound of dry matter. The mean water requirements of cereals investigated at Akron, Colorado were as follows: oats 635, barley 521, wheat 505, corn 372, millet 287, and sorghum 271 per pound of dry matter. All of these water requirements were based upon the total dry matter in the plants above. The water requirement is not necessarily a measure of the drought resistance of a crop.

A more practical measure of the water requirement for crops is "consumptive use" which includes evaporation from the soil surface as well as transpiration through the plant. This is frequently referred to as "evapotranspiration". The "drought resistance" of crops depends on (1) drought evasion, i.e., ability to complete maturity before soil moisture is depleted, e.g., early maturing small grains. (2) drought tolerance, i.e., the ability of a plant to go dormant during a drought and to recover later when soil moisture becomes available, e.g., sorghum. (3) ability of a plant to adjust its growth and development to the available moisture supply, i.e., initiation or loss of tillers and the loss of lower leaves when moisture is limiting, e.g., small grains.

PHOTOSYNTHESIS

The manufacture of food substances from carbon dioxide, water and nutrient elements in the presence of light and chlorophyll in living green plant tissue is photosynthesis. The green plant differs from most organisms since it has the ability to reduce atmospheric carbon dioxide to carbohydrate via radiant energy and chlorophyll.

When light of appropriate wave lengths is absorbed by chlorophyll, carbon dioxide and water are converted to sugar and oxygen is released. The process is exactly the reverse of that accomplished by respiration.

The water required for photosynthesis is absorbed into the roots and transported via the xylem tissue in the veins to a green cell. Once in the leaf tissue the water moves from cell to cell on diffusion gradients and most is lost by transpiration.

The sugar produced by photosynthesis accumulates rapidly in the green cells and is translocated to other parts mainly as sugar. Most of the sugar is then converted to starch and proteins and deposited in storage tissues of the plant. The stem, roots and seed generally serve as the storage tissues. This stored plant food is available for future plant growth or reproduction by release of energy through the process of respiration.

REPRODUCTION

A. Inflorescence

Seed is produced on a spike (wheat, barley and rye), a panicle (oats, sorghum and grain millet), and on a compound spike called an ear (corn). In small grains the entire seed head is known as the inflorescence. In corn the comparable inflorescence is the ear. In cereals the inflorescence is composed of spikelets which contain individual flowers.

B. Flower parts

A cereal flower is small and not colorful or showy. It is composed of three stamens (male organs) and one pistil (female organ). A floret includes the flower plus the lemma (outer bract around kernel) and the palea (inner bract around seed). In awned varieties the lemma tip is extended as an awn.

C. Pollination

Naturally self-pollinated cereals (wheat, oats and barley) are more than 96% self-pollinated, the amount being dependent upon variety and environment. Pollination takes place before the floret opens and before the anthers emerge.

Often cross-pollinated cereals include sorghum and the foxtail and proso millets. In these crops the majority of flowers are normally self-pollinated but several are cross pollinated by pollen from another flower either on the same plant or from another plant. Cross pollination among the cereals is done mostly by airborne pollen. Sorghums are usually 90 to 95 per cent self-pollinated.

Naturally cross-pollinated cereals include corn and rye. Cross-pollination is essential to seed production in rye because many flowers are self sterile. Corn produces male flowers in the tassel and female flowers on the ear, allowing considerable natural crossing. Sunflowers are cross-pollinated.

D. Fertilization

The fusion of the pollen sperm with the egg cell in the ovary is called fertilization. After a viable pollen grain falls on the stigma it germinates and grows down the style and enters the ovary. There the male sex cells unite with the egg nuclei to produce a new seed.

Pollen grains are sensitive to high temperature. In self-pollinated crops high temperature may sterilize pollen grains within the floret, resulting in no seed set. Pollen grains also are sensitive to desiccation and therefore hot, dry winds during pollination may cause a poor seed set especially in cross-pollinated crops. Drought or mechanical injury also can sterilize pollen and result in poor seed set.

E. Plant Breeding and Variety Development

Three general methods of crop improvement are: (1) introduction, (2) selection, and (3) hybridization. These methods are not wholly distinct because selection must be used at some place in all three methods.

Introduction of varieties or lines from some other country is used in present-day breeding programs for the introduction of germ plasm into the breeding program rather than usable varieties. Crested wheatgrass, Russian wildrye grass, Balbo rye and Ladak alfalfa are examples of introductions that have become established crops.

Selection is used in all phases of variety development. The successful plant breeder is one that is able to select the desired type of plant and either use it in hybridization or as a variety. Sundak sunflowers and Nowesta hard red spring wheat are examples of using selection as a method of crop improvement.

Hybridization, the only effective means of combining the desirable characteristics of two or more crop varieties, offers the greatest possibility of crop improvement of the three methods. The varieties of crops most widely grown today originated by hybridization.

Crossing is done during the flowering stage of plant growth. In self-pollinated crops the florets are opened and the pollen sacks (anthers) are removed by hand, (emasculated) before pollen is shed--this plant becoming the female. Two or three days later pollen from a selected male plant is gathered and transferred by hand to the stigma of the emasculated female. The head is then covered to prevent entrance of foreign pollen. If fertilization is successful, a cross has been made and a seed is produced carrying genes from both parents. Several generations later the cross begins to breed true and one or more lines having desirable characteristics from both parents may be selected as a new variety.

New varieties of cross-pollinated crops, such as corn, are accomplished by covering the emerging ear silk before pollen is shed and then transferring pollen by hand from a selected male parent.

Commercial hybrids are produced by first crossing the female with a plant that will make it male sterile (no viable pollen). Planting this male sterile female next to a normal flowering plant with bred-in male restorer induces natural cross pollination and the hybrid seed is harvested from the female rows only. Corn hybrids sometimes are produced by detasseling the female rows before they shed pollen.

THE FUNCTIONING PLANT SYSTEM SUMMARIZED

The plant is a coordinated system which is composed of cells organized into tissues, tissues into organs, and finally the organs functioning as a whole plant. The ultimate objective of all plant growth is reproduction of the species. The various plant organs function in relation to one another.

Four basic plant functions resulting in reproduction are:

Respiration is a continuing process which is required in all living plants. Periods of very slow respiration are called dormancy. A stored seed, for example, is dormant. Seed germination is the resumption of rapid metabolic activity which converts stored organic food to simpler compounds, thereby releasing energy. This process continues throughout the life of the plant. This energy is chemical in nature and is used throughout the plant, particularly in the meristems, in nutrient uptake and finally in reproduction.

Transpiration occurs whenever the wet cell surfaces inside the plant are exposed to the atmosphere through the stomata. Water vapor moves from areas of high concentration to areas of low concentration through the stomata. The plant receives fresh dry air containing carbon dioxide in exchange for the moisture-laden air, which is low in carbon dioxide. This exchange is vital to photosynthesis, but generally is wasteful of water. The stomata open and close in response to light or the plant-soil water relationship. Closure of the stomata due to wilting effectively stops most photosynthetic acitity.

Photosynthesis is a photo-chemical reaction in which light energy is transformed into chemical energy within the chloroplast cell containing chlorophyll, water and carbon dioxide. The products of photosynthetic activity are energy stored as carbohydrates, oxygen and water. This process occurs only in living green plants. The rate of photosynthesis exceeds the rate of respiration by 10 to 20 times and results in a net dry weight gain of the plant. Every cell, tissue and organ in the plant is directly related to the photosynthetic activity including manufacture, transportation or storage.

Absorption involves the very specialized root hair cells and the cytoplasmic semipermeable membrane inside the root hairs. The rapid absorption of water and certain nutrient ions is important to proper plant growth and development. Water moves freely into or out of the root hairs in response to solution concentration gradients from regions of high water concentration to regions of low water concentration. Nutrients are absorbed as ions. The plant is selective in nutrient ion uptake and must expend energy in the uptake and transport of these nutrient ions. It can take up ions without absorbing water. Absorption involves both underground and above ground plant parts. The chlorophyll in green plant cells absorbs light rays from the sun, supplying the energy needed for photosynthesis. Carbon dioxide (CO_2) an essential element in photosynthesis, is taken in through the stomata as a gas and is absorbed by wet cell surfaces within the leaf.

SPECIFIC CROP PRODUCTION ITEMS

Growth processes in cereals - the length of the vegetative period of any cereal is determined largely by the temperature, photoperiod, plant nutrition growth hormones, and genetic factors that affect reactions to these conditions. Each cereal species has an approximate minimum, optimum, and maximum temperature at which growth occurs, although varieties within a species may differ. When the average temperature is 18°F below the optimum, the time required to grow a crop to maturity is approximately doubled. Temperature largely determines the length of time a cereal plant takes to reach flowering and to mature after the floral structure has been formed.

The long day cereals--wheat, oats, barley and rye--flower earlier when nights are short and days long.

The short day cereals--corn, sorghum, millet--flower earlier when the nights are long and days short.

High temperatures reduce small grain yields. -High temperatures during the growing season influence final yield. Ninety degree temperatures or perhaps a few degrees lower reduce final wheat yields even under favorable soil moisture conditions.

Small grain seedlings may sometimes show sun scald resulting from high soil line temperatures on bright sunny spring days. A light colored line appears across the leaves. This burn occurred when that part of the seedling was at the soil line. This may delay maturity slightly but has not injured the growing point.

Growing days required - the number of growing days required to reach maturity by each kind of spring sown cereal crop grown in North Dakota will vary depending on (1) variety, (2) date of seeding, (3) temperature, (4) moisture and (5) fertility conditions. High temperatures and drought tend to force early heading. Drought may be only severe enough to cause a plant to slow its normal rate of development. Ample rain following such a drought stress period may hasten heading or maturity. Seeding too late may force the crop into the short days and cooler temperatures of early fall, thus delaying maturity of day length sensitive crops. The following table gives the approximate number of growing days for each crop.

APPROXIMATE NUMBER GROWING
DAYS FOR NORTH DAKOTA SPRING
SOWN CEREAL CROPS

	Emergence to Heading Days	Heading to Ripe Days	Total Emergence to Ripe Days
Barley	38 - 46	32 - 38	70 - 74
Oats	36 - 46	38 - 43	75 - 86
HRS Wheat	42 - 49	35 - 42	83 - 88
Durum Wheat	45 - 52	38 - 42	84 - 94
Millet	30 - 35	30 - 35	60 - 70
Corn	50 - 60	50 - 64	90 - 120

Source: N. Dak. Experiment Station. Unpublished Agronomy Dept. Field Notes.

Winter hardiness of fall sown crops - Rye is the most winter hardy crop, followed by winter wheat.

Vernalization changes a plant from winter to spring habit of growth. Winter rye sown in the spring fails to produce heads unless the sprouting seed or the young plant is subjected to freezing or near freezing temperatures for a two or three week period. Rye may sprout in the fall but not emerge until spring and produce a satisfactory crop. Rye which fails to germinate in the fall must germinate early in the spring, and a prolonged cold spell must follow to produce a crop. Winter wheat also requires vernalization.

Lodging in cereals - there is no single factor that can be used as a measure of standability. Large stem diameter often has been associated with lodging resistance in small grains, but straw size and stiffness may not be a reliable guide to the lodging resistance if the plant has a weak root system. More important plant characteristics related to lodging resistance are length of straw, leaf area, and resistance to bending. Short, heavy stems with thick walls are characteristics which resist lodging.

Abundant soil nitrogen may produce a lush growth of cereals that leads to increased lodging. Lodging usually has been decreased in small grains by applications of phosphorus and potash on deficient soils because these nutrients promote root development. Thick stands keep much of the sunlight from reaching the base of the stems and shade causes the cell walls of the stems to be thin and weak.

When a cereal stem lodges before maturity it usually straightens up. The nodes contain a gravity sensitive hormone which induces cell growth on the lower side, causing the plant to become erect again.

The chief external factors responsible for lodging are:

1. Shading--causing weak straw.
2. Unbalanced nutrition--heavy applications of nitrogen and excess of water may stimulate lodging. Lack of potassium induces weakness in the mechanical tissues.
3. Temperature--warm temperatures can promote lush weak vegetative growth.
4. Disease--several fungus diseases may directly induce stem weakness.

Tillering - varieties of small grain vary in their tendency to tiller. The extent of tillering for any one variety is influenced by environmental factors such as moisture, soil fertility, temperature and sunlight. Seeding too thick, using small seed and seeding too deep will decrease the amount of tillering. Barley tends to tiller the most, followed by hard red spring wheat, durum wheat and oats in that order.

Leaf stages - counting leaf stages in small grains is important in determining safe crop stages for herbicidal applications. The leaf number refers only to those leaves which are fully expanded and those on the main shoot. It does not refer to tillers or leaves on tillers. A leaf is considered fully expanded when the tip of the next leaf is just visible.

Salt tolerance - decreasing order of cereal crop salt tolerance from most to least tolerant.

Barley
Rye
Oats
Wheat (HRS)
Wheat (Durum)
Sorghum
Corn-poor
Flax

Roots of cereal plants will not grow into water-logged soils. Adequate soil moisture near the surface in the early stages of crop growth promotes a shallow root system. The crop may suffer later from drought even though subsoil moisture seems adequate.

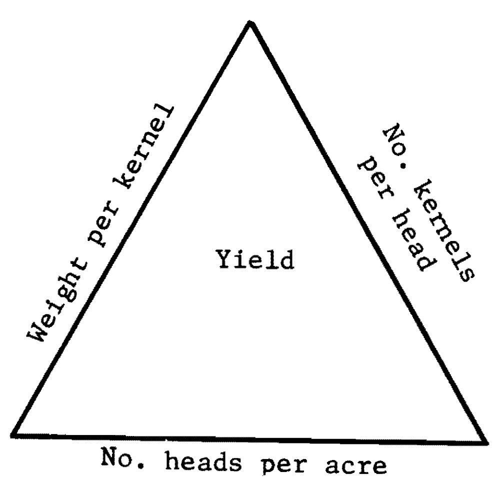
Plant roots will not extend through a dry soil zone to reach moisture that may be available in deeper subsoil. Roots don't "search out" moisture or nutrients. They only intercept those with which they come in contact. There is some movement of soil moisture and nutrient ions towards actively absorbing root parts.

Ratio of grain to straw - the ratio will vary with such factors as variety, rate of planting and productivity of soil. As a rule of thumb, however, the following ratios prevail.

Barley,	1 pound of grain to 1 of straw;	1 T straw =	41.7 bu.
Wheat,	1 pound of grain to 1½ of straw;	1 T straw =	33.3 bu.
Oats,	1 pound of grain to 2 of straw;	1 T straw =	62.5 bu.
Rye,	1 pound of grain to 2 of straw;	1 T straw =	35.7 bu.
Corn,	1 pound of grain to 1 of straw;	1 T straw =	35.7 bu.

The yield triangle - total yield per acre is the combined effect of (1) weight per kernel (2) number of kernels per head and (3) number of heads per acre as represented in the yield triangle. Any crop production factor which limits the maximum contribution of any one or more of the yield triangle sides results in decreased yield.

THE YIELD TRIANGLE



Each crop variety has a genetically determined yield potential; environment determines how closely actual yield approaches genetic potential. It is fairly certain that full yield potential is never achieved, because at some time during the growing season one or more of the environment factors are limiting.

Normal Germination Standards

MINIMUM GERMINATION
STANDARD FOR GOOD SEED

HRS wheat 85%	Oats 85%
Durum wheat ...85%	Rye 80%
Barley 85%	Corn 90%

Hail damage - effects of defoliation on cereals during active growth reduces the photosynthetic area of the plants and may result in serious yield reduction. The effect on yield depends largely on the stage of plant development at the time of injury. Experiments with corn have shown that the most serious yield injury results when defoliation occurs at the flowering stage. Earlier defoliation causes less serious yield injury.

Leaf removal was inflicted on oats, barley and wheat in Iowa at weekly intervals from the seedling stage to the hard dough stage of the grain. Cutting off all leaves above the growing point reduced yields about in proportion to the percentage of leaf area removed at each weekly interval. Other experiments have shown that removal of leaf blades also reduces the protein content of grain.

Four trials at the Fargo Station have shown that spring wheat which was beaten fairly severely by hand to simulate hail damage at various stages of growth showed losses.

YIELD LOSSES FROM SIMULATED
HAIL DAMAGE TO SPRING WHEAT
AT FARGO

	Per cent Yield Loss	Days Delayed in Maturity
Check - no treatment	0	0
Plants beaten at:		
4 leaf	36	9
jointing	55	12
boot	65	12
headed	84	11
All stems broken at:		
jointing	30	8
boot	41	6
headed	38	4
milk	40	4
nearly mature	12	3

Source: Simulated Hail Injury to Wheat and Flax, North Dakota Report No. 12, July 1964.

These results indicate that hail damage occurring in the boot through the milk stage is the most severe. There was no rain following these treatments such as normally accompanies a hail storm. When estimating field hail loss apply the per cent yield loss from the table only to the percentage of damaged stems in the field.

Recovery may seem to be terrific but final yield is often disappointing because delay in maturity makes the crop more subject to disease, late season drought and sometimes frost injury.

Fall Frost - The effect of fall frost on wheat is dependent on (1) stage of plant maturity (2) degrees of frost and (3) length of the frost period. Canadian data indicates that a light frost of 28°F. lasting 4 hours and occurring prior to the dough stage will severely injure both germination and yield. Such a frost may wrinkle the bran coat but have no effect on germination and little or no effect on yield when occurring at or after the dough stage. In general, the earlier the stage of crop maturity the easier frost damage affects both yield and germination. During late maturity stages even severe frost may not affect yield or germination but can affect market quality. A light frost of 28° to 30°F. may cause sterility in wheat that has just headed or is about to head.

BUSHEL WEIGHT, PER CENT GERMINATION AND SOIL EMERGENCE OF THATCHER WHEAT

Frost Damage[1] Type of	Test Wt. Lbs/Bu.	Germination Per cent	Emergence Per cent
A	60.0	95.0	87.5
B	57.5	88.0	78.5
C	53.0	74.0	68.5
D	42.5	48.0	27.0

[1]Type A - Sound seeds showing no frost damage.
Type B - Bran coat frost damage only.
Type C - Deep seated frost damage. Kernels with or without slight shriveling and usually dark in color.
Type D - Shriveled and shrunken kernels. Bushel weight low.

Source: The effect of Frost on Germination and the Vitality of Seedlings from Frosted Wheat. Bulletin No. 128 University of Saskatchewan, Sask., Canada.

SEED INCREASE PROGRAM

OBJECTIVES OF THE PROGRAM

The seed increase program for new varieties of field crops in North Dakota requires the cooperative efforts of the Experiment Station, Extension Service, county crop improvement associations or crops committees, qualified seed increase growers, the North Dakota Seed Trade Association and the North Dakota State Seed Department in a well planned and organized program. The objectives of this program are:

1. Increase breeder, foundation, registered and certified seed of new adapted varieties of field crops as rapidly as possible to provide seed for commercial production.

2. Keep this seed pure during the increase stages by requiring certification.

3. Make pure seed available to commercial growers on an equitable basis and at a reasonable price.

4. Maintain pure seed stocks of common varieties for seed growers.

THE STATEWIDE SEED INCREASE PROGRAM

Several carefully supervised seed increases are necessary to provide pure seed of a new variety to commercial growers. The procedure varies slightly with the variety and kind of crop, but operates within the following guidelines.

Introduction of New Varieties - The North Dakota Agricultural Experiment Station develops new varieties through breeding programs or obtains seed of new varieties from other states, the Agricultural Research Service of the United States Department of Agriculture, or Canada. These new or introduced varieties are performance tested for a number of years at several locations in North Dakota. If they appear adapted and of value to North Dakota farmers, they are included in the seed increase program for release to growers.

Experiment Station Increase - The increase of breeder and foundation seed of these new lines is made under the control and supervision of plant breeders and Seed Stocks personnel of the Agronomy Department. Facilities of the Agronomy Seed Farm at Casselton and the Branch Experiment Stations are used for summer increase in North Dakota.

When a more rapid increase is desirable, seed of new varieties is increased in the south (Arizona, California, Mexico) during the winter months and returned to North Dakota for further increase the same year.

When there is not enough suitable Experiment Station land available to increase a variety to anticipated needs the county agent and the county crop improvement association or county crops committee of selected counties may be asked to recommend experienced growers who will increase the seed under 100 per cent contract to the Experiment Station. This contract increase is not an allocation of seed to the county. When only a few growers are needed for this increase, the Experiment Station may select and contract such growers with county suggestions and will keep the counties concerned posted. Allocation of the crop produced by all such growers is controlled by the Experiment Station.

Increase Under County Supervision - This important step in the seed increase program occurs after the decision to name and release the variety and after there is sufficient seed available so that county increase is necessary. Allocation of a definite number of bushels, based on recent historical crop production, is made to each county in which the variety is considered adapted. The County Crop Improvement Association or County Crops Committee acting in behalf of the State Seed Increase Program then implements the established program in the county. This includes selection of experienced producers of certified seed for seed increase under contract to the county organization and responsible supervision of the program within the county.

Seed increase continues under county organization contract and supervision until sufficient seed is available to provide seed at reasonable prices to all interested commercial growers. All production that is usable as seed shall be accounted for and reallocated for seed increase. Any "cleanout" not usable as seed shall be disposed of as feed or otherwise destroyed.

Based on supply and demand, the State Seed Stocks Project will advise counties when it thinks that grower contracts should be released or are no longer needed for a given variety. After release County Associations may continue or release increase grower contracts depending on the local situation.

The North Dakota Agricultural Association usually is allocated a limited amount of seed at the same time and on the same terms that allocations are made to counties. It is the responsibility of the Seed Allocation Committee of the North Dakota Agricultural Association to select seed increase growers who do not or will not have an allocation of the same variety for increase from a County Crop Improvement Association, and follow the same increase regulation as applicable to counties.

Distribution to Commercial Growers - Seed becomes available to commercial producers directly from the last county seed increase growers, who by then are not under contract or have been released from their contract. County association programs should be concerned only with seed increase and should not be involved in distribution to commercial growers.

FUNCTION OF THE COUNTY CROP IMPROVEMENT ASSOCIATION

County Administration - County Crop Improvement Associations or County Crops Committees act as county administrators of the Seed Increase Program and have very important functions in the seed increase of new varieties.

County committees should become familiar with the statewide program as outlined by the Experiment Station and Extension Service for seed increase of each variety. The program should be fitted to local situations but must be uniformly administered in all counties so that all increase growers in the state are treated the same. County committees perform an important service to their county by carefully selecting qualified producers of certified seed who obtain the maximum possible increase of pure seed. The following points will be helpful to county committees in achieving program objectives.

1. Follow the program as outlined by the Experiment Station for the specific variety increase. The County Agent, the Extension Agronomist, and Seed Stocks Agronomist will assist and advise as requested and needed.

2. Select producers of certified seed who have demonstrated their ability to produce and make available for further increase the highest possible number of bushels of good, pure seed.

3. Only the more experienced producers of certified seed should be used in the first year of seed increase. A list which includes experienced and qualified seed increase growers for each field crop has been provided and should be kept up to date. This list will provide names of growers to be contacted for increase of new varieties when only a few growers are needed. Avoid publicity during the early stage of seed increase when only a very limited amount of seed is available.

4. Select good producers of certified seed in a fair, impartial and equitable manner. A sample grower application form is shown at the end of this circular.

5. Furnish each contract grower with an up-to-date copy of Bulletin 51 (revised) "North Dakota Seed Certification Rules and Regulations".

6. PROVIDE CLOSE SUPERVISION TO THE PRODUCER SO THAT ALL CONTRACT OBLIGATIONS ARE FULFILLED, ESPECIALLY CERTIFICATION, AND SEE THAT GROWERS ARE KEPT INFORMED.

7. When producers are contracted to the county organization they should not be released from their contract without approval of the Experiment Station. Release will be granted when it is apparent that seed supplies equal or exceed demand at the maximum contract price.

Selecting County Increase Growers and Fields - Experience is required to grow pure seed. Therefore, county committees should select producers of certified seed who have proven their interest, demonstrated their ability, and have the production facilities for the maximum increase of pure seed. The following requirements should be met by any grower who is asked to increase seed under contract for the county organizations.

Grower Qualifications

1. He should have past experience as a producer of certified and/or registered seed and be familiar with requirements as listed in Bulletin No. 51 (revised) "North Dakota Seed Certification Rules and Regulations" issued by the State Seed Department, Fargo, N. Dak. If the amount of foundation seed to be allocated exceeds the availability of qualified certified/registered seed producers, additional highly qualified producers may be selected by the County Crop Improvement Association committee and county agent to receive allocations of seed for increase. (Each county maintains a current list of growers who have produced certified seeds.)

2. He understands the objectives of the seed increase program.

3. He will sign and fulfill the contract requirements and cooperate fully with the county committee.

4. He will pay for the seed on delivery and pay for field inspection, cleaning and final certification costs.

5. He will apply for field inspection, provide for proper cleaning, complete certification and distribute the seed produced as directed.

6. He will clean the drill, combine, trucks, bins, etc., thoroughly to avoid any possible crop or variety admixture.

7. He understands that the production contract gives the county committee an option for allocation of the entire crop produced. And that:

   (a) the contract does not guarantee that the crop will be sold at the maximum price suggested in the contract.

   (b) he must request an allocation, if desired, for the following year's production on his own farm.

Field Requirements

8. The field available should have a high production potential and be suitable for increase of the variety.

9. The field to be used for seed increase must not have been planted to the same kind of crop unless the previous crop was grown from certified seed of the same variety. A field that was in summerfallow or clean row crop the year previous is most desirable.

10. The field should be free of prohibited noxious weeds, namely, field bindweed (creeping jenny), leafy spurge, Canada thistle, sowthistle, Russian knapweed and perennial peppergrass.

11. The field also should be relatively free of annual weeds.

12. Commercial fertilizer should be applied as needed on the basis of a soil test or experience.

13. The crop should be planted in good season. Later than normal seeding may be necessary for planting seed increased in the south but the field should be ready for planting as soon as the seed is available and weather permits.

14. Isolation as required for certification must be maintained.

15. Spraying with selective weed control chemicals and insecticides as needed should be required.

Harvesting, Cleaning and Storage

16. Harvesting equipment and storage facilities must be cleaned thoroughly to avoid the possibility of other crop and variety admixtures.

17. The crop should be harvested in good season to produce as high quality seed as possible.

18. The grower should have adequate seed cleaning equipment of his own or be prepared to make arrangements with an approved certified seed cleaning plant.

19. Seed should be cleaned to the highest practical class of certification.

20. The grower must provide storage until seed is allocated or the contract released.

FUNCTION OF THE EXPERIMENT STATION

After new varieties become available through the various breeding programs or by introduction from other states or countries, and are evaluated to determine their usefulness to North Dakota farmers, they are increased and allocated under the Seed Stocks project and program of the Agronomy Department. Some responsibilities and functions of the Agronomy Department are:

1. To estimate the amount of seed needed to supply anticipated demand based on adaptability and usefulness of the new crop variety.

2. To increase foundation or registered seed of the new variety for allocation to counties in areas where it is adapted.

3. To determine the size of allocation to counties on the basis of available seed and average production of the crop in the county.

4. To establish a minimum and maximum amount of seed that may be allocated by counties to any seed increase grower. Exceptions must be cleared through the Seed Stocks Office.

5. To establish a statewide uniform price for seed increased and sold under contract with either the Experiment Station or the county organization.

6. To prepare a grower contract that will be executed between the grower and county organization or the Experiment Station.

7. To establish a uniform statewide seed increase program that will be cooperatively administered with the Extension Service and keep cooperating counties informed on the progress of the program.

8. To establish policy for southern increase of new varieties by grower groups or individuals.

FUNCTION OF EXTENSION SERVICE
The Extension Service cooperates with the Experiment Station, county crop improvement associations or crops committees, local growers and local seed dealers in this program.

The county extension agent represents the Experiment Station at the county level and assists the County Crop Improvement Association or Crops Committee in carrying out the increase program as outlined by the Experiment Station for each new variety.

FUNCTION OF STATE SEED DEPARTMENT
The State Seed Department will accept for certification all new varieties recommended by the North Dakota Agricultural Experiment Station in accordance with variety standards established by breeders or originators of the variety. This department cooperates with the Seed Stocks Program and assists in formulating policy concerning certification standards.

FUNCTION OF THE NORTH DAKOTA AGRICULTURAL ASSOCIATION
The Seed Trade as represented by both distributors and local dealers serves a very important function in the introduction, promotion and adoption of any new variety. Their major roles in this program are to:

1. Learn the characteristics and usefulness of new varieties before they become available for general sale.

2. Offer approved certified seed cleaning facilities for increase growers.

3. Promote the sale of high quality North Dakota grown seed both within and outside the state.

4. Cooperate with the Seed Stocks Program.

INDIVIDUAL CROPS

This section is not intended to be a complete discussion for each individual crop.

Wheat - Wheat is a cool season crop. It requires a longer growing period and a somewhat higher minimum heat requirement than other small grains.

Optimum preharvest mean temperature for wheat appears to be approximately 60° to 70° F. whereas the annual growing season temperature should be about 12° to 16° F. lower. Annual as well as preharvest daily mean temperatures significantly above 65° F. appear to be associated with low wheat yields. Warm temperatures during the late seedling and tillering stage of wheat may retard heading. Daily maximum temperatures above 90° F. during the three or four weeks after flowering may ripen the grain prematurely. Above average temperatures are beneficial at the time of sowing, detrimental during the tillering, flowering and early dough stages and beneficial during ripening.

Germination - as water enters, the seed swells and increases in weight by about 60 per cent. The optimum temperature for germination is about 64° F. The minimum is about 34° F. Much above the optimum causes irregular germination. In soil, under favorable conditions, germination begins in 4 to 5 days. There may be variety differences in speed of germination. Semidwarf wheats in general cannot emerge from the depth as can normal height wheat due to a short coleoptile.

Seedling - when the seedling reaches the soil surface, the kernel is rapidly becoming a mere sack containing diffusable food substances. The coleoptile has grown upward and its tip projects above the soil surface. Seminal roots are developing at this stage. The first foliage leaves appear through the coleoptile and normally are rolled clockwise.

The appearance of seedling leaves is due primarily to the growth of the third internode which brings the growing point near the soil surface. The buds on the fourth and fifth nodes which have been developing gradually now swell. The internodes remain very short. This whole area constitutes the crown, which is located just below the soil surface. Adventitious roots and tillers develop from the crown nodes.

Roots - Wheat roots are of two major kinds, seminal and crown.

The mature system has a depth of 3 1/3 to 4 feet and a maximum depth of 5 to 7 feet. Sixty per cent or more of the whole root system is in the top 12 inches of soil. Winter wheats in general are deeper rooted than spring wheats.

Stems - once at ground level, the stem remains comparatively short for some time, later elongating to full height of the wheat crop. The elongation occurs in the growing region at the base of each internode. The lowest internode elongates first, followed by the others in succession. The number of nodes ranges from 5 to 7. Each node is solid. The internodes generally are hollow but in certain varieties they are solid. The internodes become progressively longer from the bottom to the top of the plant. A crop may, therefore, be short at heading time but tall enough when mature to facilitate harvesting. The lower internodes, and parts of the top internodes, are entirely covered by leaf sheaths.

Tillering - tillers develop from the buds in the axils of the basal stem nodes. In grain sown at a normal depth it is usually the second and third nodes which produce tillers followed by the fourth and fifth nodes. In deeper sown grain (3 inches and over), the second and third nodes generally remain dormant, with the first tiller arising from the fourth node. Hence sowing too deep tends to reduce the amount of tillering.

Several other factors influence tillering: (1) varietal characteristics (2) thin seeding promotes tillering while thick seeding reduces it; (3) plants from large seeds tend to tiller more than those from small seeds; (4) tillering tends to increase with good fertility; (5) adequate soil moisture and cool early season soil and air temperatures favor tillering.

Leaves - the normal wheat leaf is divided into two main parts, the sheath and the blade, which are separated by the collar.

Inflorescence - the inflorescence of wheat is a spike with two rows of spikelets and a single terminal spikelet. The initial inflorescence can be seen in the late seedling stage, but the head does not emerge from the enveloping leaf sheaths until some 6 to 7 weeks later.

The number of florets in a spikelet varies. The lower two florets usually are fertile; the upper and especially the terminal are sterile. As a rule, two grains mature, but three grains may form and very exceptionally four, depending on growing conditions. Thus, we say the heads are filling four rows, six rows or eight rows.

Flower opening and pollination - the floret opens a few days after heading. The first head to flower is that of the primary stem, followed by those of the tillers in order of origin. The first spikelet of the head to flower is situated about one third of the way down from the top. Flowering then proceeds upward and downward from this point. In each spikelet the basal floret opens first and the others in succession upward.

Under ordinary conditions the wheat head completes flowering within two to three days after the first anthers appear. Under certain conditions, such as drought or high temperatures, some of the lower as well as the top spikelets of the head may fail to set seed.

Function of awns - the presence of awns on the florets of wheat has tended to result in the production of heavier kernels. In semi-arid regions awned wheats have rather consistently outyielded awnless types, but usually there has been little or no yield superiority of awn types over awnless types under humid or cool irrigated conditions. Awned heads transpire more than do awnless heads, but the water lost through the awns account for no more than one to five per cent of the total transpiration of the plant. Awns carry on photosynthesis. Under drought conditions the awns may continue photosynthesis even after the flag leaf dries up. Under some circumstances the contribution of the awns to the total kernel dry matter may comprise as much as 12 per cent. The tips of awned spikes dry less rapidly under hot dry conditions because of the shading or other effects of the awns.

Winter Wheat - The growth and development of the winter wheat plant is very similar to the spring wheat. The winter wheat, plant, however, must be vernalized to produce heads. The winter wheat requires a very firm seedbed to reduce winter injury. Any operation that is used in seedbed preparation should provide firmness and as much cover to hold snow as possible.

Harvesting - the translocation of material from the straw to the kernels ceases when the moisture content of the kernel drops below 40 per cent. Since field ripening and drying are not uniform some increase in dry matter of the grain continues until the average moisture content drops to 30 to 35 per cent. Wheat that stood in the field for two weeks after it was fully ripe in Nebraska suffered an average loss of 3 to 5 per cent from shattering. The alternate wetting and drying from exposure to rain and dew during this period caused the kernel seed coat to wrinkle after swelling and drying. This lowered the test weight of the grain two pounds per bushel.

Barley

Germination - Most of the water required for germination enters the seed through the base of the kernel, which is known to possess a semipermeable membrane.

Seedling - the radicle is visible within 24 to 30 hours after germination begins. It is followed by 5 to 8 other roots which, together with the radicle, form the seminal root system. The coleoptile becomes apparent somewhat later, delayed because it does not break through the lemma but forces its way upward beneath it and thus is first seen at the tip of the kernel. The appearance of the coleoptile above ground is mainly due to the elongation of the coleoptile. The length of the coleoptile depends on the depth of seeding. Once above the soil surface the coleoptile tip stops growing, opens and the first foliage appears, followed rapidly by the second and third.

The young leaves of the seedlings are smooth; the yellowish green color is conspicuous and the auricles prominent and clasping. Before development of the first tiller, crown roots appear from a thickening node near the ground surface. This is the start of the crown.

Roots - the radicle, which is the first seminal root, grows downward and may penetrate to a depth of 5 to 6 feet. It is branched throughout.

Differentiation into a shallow growing upper region and a more deeply penetrating lower region is often marked. Soil moisture and fertility influence the development. In heavy soils and under drought conditions, the roots may be very shallow and widely spreading.

Stem - the stem has 5 to 8 nodes and internodes. Elongation at the stem occurs in the growing region at the base of each internode. The last internode terminates in the spike.

Tillers - develop in the same manner as wheat, but usually are greater in number.

Leaves - the foliage leaves resemble the leaves of the wheat plant but vary in number, color, length and width. The ligule is well developed and the auricles are clasping and more conspicuous than in any other cereal.

Inflorescence - the inflorescence is a cylindrical spike with alternating spikelets, strongly compressed on a zigzag rachis. At each joint of the rachis there are 3 spikelets, each one containing a floret. In 6 row barley all three spikelets are fertile and develop kernels. The center floret produces a straight kernel while the two outside florets produce slightly twisted kernels. In two row barley only the central spikelet contains a fertile floret. Side spikelets are sterile. Six-row varieties usually have 25 to 60 kernels, while 2 row varieties have 15 to 30 kernels per spike.

Development of the kernel - pollination of the floret is normally completed before the head emerges from the boot. After fertilization the endosperm commences to develop and is followed almost immediately by the embryo. The outside layer of endosperm cells is called the aluerone. This aluerone layer may contain a colored pigment, such as in blue barley. The lemma and palea (hull) in barley adhere to the outer epidermis of the pericarp due to the secretion of a sticky substance apparently secreted by the pericarp, which, as the grain dries out, more or less glues them to the pericarp. The hull usually accounts for about 15 per cent of the kernel weight, although it may vary up to 25 per cent or more depending on variety and kernel plumpness.

After pollination, increase in kernel length is very rapid and is completed in about 7 days. Thereafter the lateral (side to side) diameter increases and continues until about the 15th day. On the other hand, the growth of the dorsiventral (front to back) diameter is slower and its growth is maintained until near maturity. This is why thin barley nearly always has good length. The secretion of the substance which causes the lemma and palea to adhere to the kernel occurs about the 9th or 10th day after pollination. About the 15th or 16th day the kernel begins to toughen and the lemma begins to lose color on the back side. This stage also approximately ends the period of most rapid increase in dry matter and ash. The per cent of water in the kernel falls almost uniformly from about 80 per cent to about 40 per cent at the rate of 1 to 2 per cent a day, depending on climate.

Mature grain - the hulless kernel of barley is similar to that of wheat but both ends are pointed. The complete barley kernel, however, includes the lemma, palea and rachilla. The kernels in two-row barley are symetrically developed and broadest near the middle. The center kernels of six row barley are symmetrical and generally broadest above the middle; the side kernels, however, are not symmetrical and are slightly twisted. The rachilla is a continuation of the axis of the spikelet and adheres to the threshed kernel. It lies within the kernel crease and may have either short or long hairs, a character often used in variety identification.

Oats

Germination - in germinating cereals the first node stays right at the germ portion of the seed and actually divides the embryo into the radicle and the stem. In oats elongation of the first internode carries the elongating coleoptile upward. The coleoptile originates at the second node. The first foliage leaf originates at the third node. The fourth node then becomes the crown node. This is different than in wheat and barley and is similar to corn. The second internode is short, and therefore the second and third nodes remain close together.

Roots - increase in proportion to variety maturity. Late season varieties tend to have a deeper root system than early maturing varieties. Oat roots are small, numerous, fibrous and densely covered with fine root hairs.

Stem - the oat stem has 4 to 8 internodes and is generally thicker and softer than wheat. The leaf sheath of certain varieties is somewhat hairy at or below the nodes. Oats hay is of better quality than hay made from other small grains.

Tillers develop as in wheat but are fewer in number. Oats retain greater ability to tiller late than other small grains. A field of oats may therefore green up and sometimes even head after harvest, especially when drought forces early maturity and rains follow.

Leaf - the leaf sheath closely envelopes the main stem and is united at the base. The ligule is well developed, oval in shape, and ends in a number of fine teeth. There are no auricles.

Inflorescence - the flowering head of oats is called a panicle. The main axis is either erect or pendulous, terminating in a spikelet. Along the main axis are four to nine nodes (average 5 to 6) and at each node main lateral branches develop on alternate sides.

Spikelets - the spikelet consists of from two to seven florets enclosed in a pair of bracts called glumes. The average number of florets is three. The basal floret plus one (occasionally two) may be fertile and develop a kernel. Generally the upper florets are sterile.

When an awn is present on oat kernels, it arises from the back of the lemma and is an extension of the midrib. In wild oats an awn is found in all kernels of the spikelet, is strongly developed and twisted below the knee (bend). A few cultivated varieties also have awns but in the majority of these the awn is found on the basal kernel only and is usually small, curved or straight and not twisted.

Pollination - blooming begins at the top of the panicle and progresses downward, lasting 3 or 4 up to 8 days. In any one spikelet the lower floret opens first, followed by the second and third. All panicles of a single plant usually complete blooming in about 10 days, but plants with many late tillers may bloom for a month when the weather is cool.

Oats is naturally self pollinated. Cross-pollination can occur, but much less frequently than in wheat.

Mature grain - except in hulless oats the lemma and the palea tightly enclose the kernel. The lemma and the palea together form the "hull". The hulless kernel, called the "groat", makes up 65 to 75 per cent of the whole kernel. The groat is covered with moderately long, fine, silky hairs.

The basal kernel of a spikelet is the largest; it has a higher percentage of hull than the upper kernels; it may be awned; its base is blunt and has a short rachilla which varies in length, shape and hairiness in the different varieties. The second kernel, if formed, is smaller, has a lower per cent of hull, no awn, a pointed base and may have a rachilla. If a third grain is formed, it resembles the second but is smaller.

"Fatuoids" or false wild oats, occasionally appear in some cultivated varieties and resemble the common wild oat. A tendency for occurrence of fatuoids in a variety is generally included in the official varietal description.

RYE

There are two types of rye. Fall rye, a winter type sown in the fall, and spring rye, sown in the spring.

Germination begins at a temperature as low as 33° F., but the optimum temperature ranges from 55 to 65° F. Northern rye varieties often cease germination above 85° F. Rye usually germinates after it has absorbed water equal to about 56 per cent of the kernel weight.

Roots - seminal roots are few in number, the radicle and usually only three other seminal roots. They are followed by the crown roots in whorls from the basal nodes. All are functional throughout the life of the plant and a few may penetrate to considerable depths. Rye roots usually spread 6 to 10 inches at a working depth of about 4 feet and a maximum penetration of 5 to 6 feet. Environmental conditions influence the habit of root development. Compared with the other small grain cereals, rye roots are in general more profusely branched, especially near the soil surface.

Stems - the stems are erect and slender, tougher and longer than those of wheat. A purplish pigmentation is common.

Leaves - the sheaths are smooth and tight; the ligules are very short and rounded but may be absent in certain spring ryes; the auricles, when present, are white and narrow, tending to wither early. Most leaves and stems have a waxy covering.

Inflorescence - the inflorescence is a long uniform spike. The rachis is generally tough, with 20 to 30 joints which are somewhat irregular in outline and densely hairy on the edges. Each joint bears a fertile spikelet but there is no terminal spikelet. The number of spikelets averages about 37.

Spikelet - Each spikelet has two narrow pointed glumes. There are normally three florets, the two lower fertile and the third sterile. The lemma of each fertile floret is broad and keeled with long hairs on the keel, especially the upper third. It terminates in a medium long awn.

Flower opening and pollination - the first florets to open are those about one third below the top of the spike, anthesis preceeding thereafter both upward and downward.

Rye is crossed-pollinated - 96 to 99 per cent of the individual flowers of rye are self-sterile. Cross pollination is accomplished largely by wind borne pollen. Insects are not important pollen carriers in rye.

Mature grain - the ripe kernel is threshed free from the lemma and palea. It is longer, more slender, more sharply keeled, more pointed at the base and darker in color than wheat. The kernels also are less uniform in shape, size and color.

Temperature and growth - fall rye makes faster growth under cool temperatures of both fall and spring than winter wheat.

Under normal conditions, winter rye tillers mainly in the fall. Appreciable growth ceases in the fall when mean temperatures drop below 40°F and begins again in the spring when temperatures rise above 40° F.

MILLETS

The term "millet" is applied to a number of warm weather annual grasses used both as forage and cereal crops.

Foxtail Millets

Roots - there are three seminal roots. The crown roots are numerous, thin and wiry, developing from the lower nodes near ground level. All roots appear to function throughout the life of the plant but they are shallow and the plant is subject to drought injury. The crop may escape drought injury due entirely to its short growing season.

Stems - the stems are erect, slender, leafy and hollow except at the nodes, which are solid and somewhat swollen below. The internodes are short at the base of the stem, becoming longer in the middle region and again shorter above. The last internode, which ends in a spike-like compressed panicle, is the longest. Tillers develop from the buds of the basal nodes.

Leaves - the leaf sheafs are in most cases longer than the internodes. The ligule is short, thick, and has fringed edges, but auricles are lacking. The blades are long, broad and tapered gradually to an acute point; the upper surfaces are smooth and the lower are ridged, with a prominent midrib. Leaves extend well toward the top of the stem.

Inflorescence - the inflorescence is a dense, cylindrical, bristly panicle.

Spikelets and florets - there are 1 to 3 bristles at the base of each spikelet. These bristles are about twice the length of the spikelet, which gives the whole spike a bristly appearance. Self-pollination is the rule, though some cross-pollination occurs. The first florets may open when three fourths of the panicle has emerged from the sheath. Flowering proceeds from the top downward. A large head may require 8 to 16 days to complete flowering. Flowering is hastened by high temperatures and low humidity.

Mature grain - the lemma and palea firmly enclose the mature kernel. The color may vary from yellow, pale straw, orange, red, pink, brown or black.

Proso Millet

Stems - proso millet stems are stout and erect but the lower part may tend to lie on the ground, erecting itself at the lower nodes. Stems are hairy.

Leaves - are covered with hair. The leaf sheath is open and extends well up the stem.

Inflorescence - the proso inflorescence is an open panicle similar to oats. The panicle base is more or less enclosed in the sheath and is usually nodding and rather compact. The numerous branches are rough and bear spikelets near the tips.

Mature grain - when threshed, most of the seed remains enclosed in the hull (lemma and palea). The hulls are of various shades and colors, including white, cream, yellow, red, brown, gray and black. The seed coat of all varieties, however, is a creamy white.

CORN

Corn is an annual cereal known only as a cultivated crop and almost certainly of Central and South American origin.

Germination - some authors state that corn germinates in from ten to twenty days at 43.7°F.; in from five to ten days between 48.6° - 58.5°F. The optimum temperature is given as 86°F.

Water appears to penetrate with equal rapidity over the whole surface of the kernel during germination. There is no evidence of a localized semi-permeable membrane as in barley. About 40 per cent of water by weight is required for germination.

Seedling - when the coleoptile appears above ground, the seedling normally possesses four seminal roots, one primary, which is the radicle, and three lateral. Additional laterals may form later.

The elongating first internode is largely responsible for the appearance of the coleoptile above the soil surface. The length of the first internode depends upon the depth of planting. At normal planting depths of 2 to 3 inches, it is about twice the length of the coleoptile. When planted deeper the first internode increases in length until the node from which the coleoptile grows is within about 2 inches of the soil surface.

This elongation of the first internode occurs to some extent in oats, sorghum and millet, but not in other small grains. It is one reason that corn can be planted deeper than small grains and still emerge. When the tip of the coleoptile is past the ground level, it splits into two lobes and the first of the foliage leaf emerges through this split, followed rapidly by the second, third and fourth leaves. Meantime, the node which gave rise to the first true leaf begins to thicken and in a short time the first crown roots emerge, usually in a whorl of four. The later formed crown roots develop from the nodes above.

Roots - the roots are fibrous and of three types.

Seminal roots - the primary seminal root is the radicle. It appears early and, after growing to a considerable length, branches. The seminal roots are typically three in number. Some workers have found the number of seminal roots to vary from 3 to 10.

Crown roots - develop from the nodes near the ground level. They form about an inch below the soil surface no matter how deep the planting. Crown roots develop in whorls from several nodes crowded together at the base of the stem, forming the crown. The early formed crown roots (in plants up to 5 weeks old) may number 10 to 15. They grow almost parallel to the soil surface or at a slight downward angle and are confined almost entirely to the surface foot of the soil. They vary in length from 1 to 2.6 feet and are branched profusely. In older plants the above roots and certain newer ones from the same nodes spread laterally for a distance of 2 to 4 feet and then turn sharply downward. They penetrate the soil from 1.5 to 4.6 feet. The later formed roots may number 20 to 35. They grow straight downward or outward for about 2 feet. Others are much longer and may reach a depth of 7 feet or more. All are profusely branched. In general, corn appears to have a lateral spread of 3½ feet and a penetration of from 5 to a maximum of 8 feet.

Brace or prop roots - at the time of rapid elongation of the stem, several of the nodes just above the ground level may send out whorls of branch or prop roots. These roots are thicker than normal roots and often deeply pigmented. Most of the brace roots enter the soil and function as other roots.

Stems - have easily recognized nodes and internodes. The lower internodes are short and thick, the upper ones become gradually longer and thinner. The result is a stem tapering gradually upward to the tassel. Both nodes and internodes are solid. On the side next to the leaf the stems are furrowed, the position of the furrow alternating at each node. The last node ends in the tassel.

Tillers and branches - a branch bud is present in the axil of every corn leaf. The lower buds may develop into tillers (suckers) while the buds in the larger foliage leaves produce ears.

Leaves - foliage leaves arise from nodes, which vary in number from 8 to 20 depending on relative maturity of the plant. The greater number of leaves indicate the longer maturing hybrids.

Inflorescence - the stamens and pistils are borne on the same plant. The staminate flowers are borne terminally on the tassel and the pistillate flowers on the ear.

The tassel is a terminal panicle which has a variable number of spirally arranged lateral branches. On the central axis the spikelets are arranged in rows, varying in number from 4 to 11. Each row consists of a pair of spikelets, one above the other. On the laterial branches the spikelets, also in pairs, are reduced to two rows.

The ear is a modified spike and consists of a thickened central axis called the cob, bearing a series of paired spikelets in longitudinal rows. Since each row of paired spikelets develops two kernels (one from each spikelet) the regular occurrence of an even number of kernel rows is inevitable.

Flower opening and pollination - on the tassel the first flowers to open are those of the older spikelets near the tip of the central axis. Thereafter blooming spreads upward and downward, reaching the tip of the tassel long before it reaches the base. A tassel continues to produce pollen for several days, depending on the variety, the relative development of the tassel and weather conditions. Under favorable conditions pollen discharge commences at sunrise and is more or less complete by noon. Dry bright weather favors the shedding of the pollen; cold weather delays it.

Insects frequently visit the flowers of corn but as agents of pollination they are almost negligible. Wind and gravity are the key distribution agents.

From the corn tassel, the pollen showers down on a calm day over an area with a radius of some three to four feet. In a high wind the pollen may be carried several hundred feet. Thus isolation is necessary to prevent cross pollination in pure seed production of open pollinated varieties. Controlled cross pollination, however, is necessary for hybrid corn production.

The oldest spikelets on the ear are those at the base; the youngest at the tip. The silks of the older spikelets begin to elongate as much as seven days before the silks toward the tip. These older silks have to travel a much greater distance and this reduces silk emergence from the ear to from two to five days. A silk is receptive to pollen whenever it emerges. It remains receptive for nearly fourteen days, and during that period it may continue to elongate until pollinated. As the silks do not emerge simultaneously, but in succession over a period of from two to five days, it follows that the pollination of every silk on an ear takes place over a period of several days. An average plant produces about 25,000 pollen grains for each silk. Usually a corn field will shed pollen over a two week period, thus assuring good pollination under most field conditions.

Mature grain - the corn kernel is a caryopsis with a thick pericarp enclosing a single seed. The mature kernels vary in shape due to variety and position on the ear. The tip end of the kernel may readily be broken off, exposing a small pigmented spot. The embryo is visible beneath a shallow groove on the side of the kernel facing the ear tip. The soft area just above the embryo is a convenient place to visually check kernel maturity. Milkiness or firmness of the endosperm indicates degree of maturity.

Growing temperature - corn is a warm weather plant that requires high temperatures day and night during the growing season. The crop is seldom grown for grain where the mean summer temperature is less than 66^{o} F or where the average night temperature for the three summer months falls below 55^{o}F.

Plants are quite susceptible to injury from high temperatures at the tasseling stage. Pollen may not be produced or may dry up before pollination takes place, resulting in poor kernel set.

Corn plants can be injured by freezing temperatures any time during the growing season. Generally corn is able to recover from freezes that occur before the plants are six inches tall. Frosts early in the fall before the grain is mature kill the leaf tissue and reduce both yield and quality.

SORGHUMS

The discussion of sorghums will be divided into two groups: (1) grain sorghums and (2) grass sorghums.

Grain Sorghums

Grain sorghum is a warm season row crop. It will yield well only in years of favorable spring and summer temperatures, with adequate growing season moisture and sufficient frost free days to mature. Sorghum has a tendency to stay green until after a hard frost. Following frost, plants tend to lodge and must be combined before the seed is dry. This requires artificial drying.

Roots - at germination a single primary seminal root, the radicle, is produced which grows almost vertically downward and produces numerous lateral branches throughout its length. No additional seminal roots are produced.

The crown roots develop in succession from the basal nodes situated just below or at ground level. Their directional growth is very similar to corn roots. The root system is very abundant, as plants with 6 to 8 leaves may have a lateral spread of 3 feet. Later the roots may have working depths of 3 to 4 feet and maximum depths of 4½ to 6 feet. They are more fibrous than roots of corn and, according to one authority, develop more than twice as many laterals at any stage of their development. This would mean that the root system of the sorghum plant is about twice as extensive as the root system of a corn plant.

The profuse branching and wide distribution of the root system is one of the main reasons why the sorghums are so drought resistant. Other factors of importance are: (1) the plant grows slowly until the root system is well established; (2) the plants have approximately half the leaf area of corn; (3) the lower transpiration rate reduces water demand; (4) the plant can remain dormant during a prolonged drought period and resume its development following rainfall.

It is well known that sorghums influence the yield of succeeding crops. This was formerly attributed only to the depletion of soil water and available nutrients by the extensive root system and late summer growth. This depression also is due to the rapid buildup of microorganisms that feed on the high sugar content of sorghum stubble and roots. These organisms require large amounts of soil nutrients, especially nitrogen which is "tied up" temporarily but becomes available later in the season as the microorganism population declines.

Stems - the stems are erect, solid and slightly furrowed on alternating sides. The nodes are somewhat thickened, the internodes are short at the base, becoming longer toward the top; those of the middle region are nearly equal in length but the terminal internode which ends in the head, is the longest of all.

The buds at ground level may develop as tillers, the number depending partly on the variety and partly on environmental conditions. Up to 15 tillers may develop on certain varieties. These tillers are, in the majority of cases, shorter than the main stalk; they all develop heads which are smaller and mature later than the main stalk. Above ground there is a bud at each node except the terminal node. After the main stem has headed and often not until its seeds are half ripe the uppermost bud may elongate to form a true lateral branch which may develop a late maturing head.

Leaves - the foliage leaves vary somewhat in different varieties. The sheaths are long, in most cases exceeding the length of the internodes but considerable variation is found in different varieties. The ligule is short, membranous and fringed. The leaf blades are very similar to corn. They are, however, more erect and the midrib is more prominent and the edges are smooth. The total leaf area of sorghum is less than of corn.

Flower opening and pollination - the first flowers to open are those near the top of the main stalk. Thereafter, flowering proceeds downward. The whole process of flower opening is within minutes of its inception. Flowering usually takes place between midnight and early morning. The total duration of flowering on the panicle usually is from 6 to 9 days. Self pollination does occur and pollination between flowers on the same panicle is very frequent. Cross pollination also occurs readily.

Grass Sorghums

The term "Grass Sorghums" was first used by Piper to include the grass-like sorghums which are annual in habit, the most important of these being sudangrass. The name sudangrass was given to *Sorghum vulgare sudanense* when it was introduced to the USA from Africa.

Germination - sudangrass germines over a wide range of temperatures, but best at 86°F.

Roots - the root system is similar to that of the other sorghums.

Stems - the stems are slender, solid and slightly furrowed on one side, the position of the furrow alternating at each node. Buds develop at all the nodes, those at the base develop as suckers, a few of those above as lateral branches.

Leaves - are 6 to 24 inches long by 1/2 to 3/4 inches wide. The sheath overlaps strongly at the base, but in the lower leaves is open nearly the full length of the internode. The blades have a distinct midrib. The ligule is long.

Inflorescence - the inflorescence is an open panicle, erect, 6 to 14 inches long, and up to 10 inches wide at the base. Spikelets appear in pairs, one above the other.

Mature grain - the kernels vary from light reddish-brown, with occasional light color or almost white. In outline they are more or less elliptical, flattened on one side, slightly convex on the other.

FLAX

Although flax is not a grass and not a cereal, it is sometimes included in the small grain group because of its general production characteristics.

North Dakota produces seed flax harvested for seed, as distinguished from fiber flax harvested for fiber.

Seeds - flaxseed is a true seed because the pericarp is a part of the boll and is removed in threshing. The embryo is surrounded by a thin layer of endosperm. Cotyledons make up a large portion of the seed and are the first leaves to emerge above ground as the seed germinates. Seeds start germination as low as 38-40° F. Seeds have a smooth, shiny surface resulting from a mucilaginous seed coat covering. One bushel (56 pounds) of flaxseed produces about 19 pounds of linseed oil. The oil percentage usually is lower when drought occurs within 30 days after blossoming and to the extent that it results in shriveled seed. Differences in seed size, shape and color are important characteristics in distinguishing varieties.

Roots - flax has a single taproot with numerous branches. The root system is relatively short, so that flax is largely dependent on moisture in the surface 2 feet of soil.

Branching habit - the flax plant has a distinct main stem but branches freely from the crown near ground level when grown in thin stands. Such basal branching is partly or entirely suppressed in thick stands. The upper part of the stem branches freely, with each branch terminating in a flower bud or boll.

Growing point - the growing point is exposed at the tip of each stem. Damage to the growing point of very small flax seedlings can kill the plant. When damage occurs after a few true leaves have emerged, buds in the main leaf axils will develop new stems but crop maturity is delayed.

Stems - three principal tissue areas are recognized in the stems - pith, wood and bark. The bark contains the comparatively long flax fiber cells that constitute the linen fibers. The woody cylinder surrounded by the fiber bundles gives the flax stem its strength and resistance to lodging. Flax in the green boll stage is the most susceptible to lodging. The pith disintegrates as flax matures and the stem becomes hollow.

Leaves - stalks, (petioles) are nearly absent; leaves are linear and may be erect or spreading. They have three veins, with the mid-vein prominent. The leaves are arranged spirally around the stem except at the base of the stem, where they are opposite.

Flowers and bolls - the flax flower has 5 petals which vary in size, color and shape, depending on variety. The petal color may be blue, pale blue, white or pale pink. Petal colors may be a lighter shade of color under droughthy conditions. The flowers open at sunrise on clear warm days, the petals falling before noon. Flowering is indeterminate and continues until growth is stopped.

The boll is 5 celled, each cell containing 2 seeds. When completely filled, the boll contains 10 seeds. The bolls of our varieties are semi-dehiscent but rarely dehisce (shatter).

Growing conditions - flax requires moderate to cool temperatures during the growing season. Drought and high temperatures (about 90° F.) during and following the flowering stage reduce the yield, the seed size, oil content and oil quality. This is why the oil content and quality of northern grown flaxseed is generally higher than when grown further south.

Frost damage - flax just emerging is easily killed by frost. Flax in the seedling stage when several true leaves may not be damaged even when temperatures are as low as 18° F. but a light freeze of 30° F. may cause injury in the blossom or green boll stage. Between these stages, plants generally are not injured even at temperatures of 15° F.

Salt tolerance - flax is less tolerant to alkali or high saline soils than corn.

SUNFLOWER PRODUCTION

The cultivated sunflower is a native of America and was taken to Spain from Central America before the middle of the 16th Century. It was grown in America by Indians for food.

North Dakota is currently the leading sunflower producing state. Other major producing states include Minnesota, California and with lesser acreage, Missouri, Illinois, Kentucky, Texas. The major sunflower producing countries of the world are the Soviet Union, Argentina, Bulgaria, Romania, Turkey and South Africa, all of whom produce considerably more than the United States.

Commercial sunflower seed production started to increase in North Dakota in the late 1940s but did not exceed 10,000 acres until in 1957. Most of this production has been confined to the Red River Valley and adjoining counties. Until 1967 production was primarily the large seed varieties suitable for the birdseed and confectionery market. The acreage of high oil content varieties for oil production has been increasing rapidly in the past few years.

ADAPTATION. Sunflowers grow quite well on a great variety of soils. Soils that are well adapted to good corn or small grains would be suited to sunflower production. Heavy, low lying soils that are poorly drained and known to be slow in warming up in the spring should be avoided.

Sunflowers are a long-season crop requiring adequate moisture supplies during late July, August and September to fill well. Seed normally is planted during May, plants bloom during late July or early August and the crop matures in September but is not dry enough for combining until early October. The young plants will withstand some freezing until they reach the 4- to 6-leaf stage. The fully developed seeds generally are not damaged by frost, but between these stages the plants are quite sensitive to frost.

SUNFLOWERS IN ROTATION. Sunflowers yield best on summerfallow, but this acreage is normally used for cereal grains. Planting sunflowers as a third or fourth crop following summerfallow is satisfactory. A common practice is to plant them on land that would normally be summerfallowed, thus extending the rotation by at least one year.

It has been commonly believed that sunflowers are hard on the soil and that crops following sunflowers do poorly. Results at the Crookston and Rosemount experiment stations in Minnesota do not substantiate this belief. Some farmers on heavy soils with adequate moisture and fertilizer indicate that small grains following clean sunflowers yield nearly as well as after fallow. Sunflowers do volunteer, and fields following sunflower production should either be fallowed or planted to a crop that can be sprayed with 2,4-D or MCPA.

Rotations also are important to disease and insect control. A four to five year rotation should be used.

SEEDBED PREPARATION. To insure even germination, the seedbed should be firm. A firm seedbed brings soil moisture near the surface and permits shallow planting to give rapid and even emergence. Sunflowers are grown in cultivated rows and do not cover the soil surface as quickly as solid seeded grain crops; therefore, some attention should be given to leaving a rough or trashy soil surface if there is danger of soil drifting.

PLANTING RATE AND PLANT SPACING. Sunflowers usually are planted with a corn planter in rows 30 to 42 inches apart or with a beet planter 22 inches apart. Special planting plates are used and sizes usually are listed on the seed tag as for corn. A grain drill properly calibrated can be used, but watch for seed damage. Reasonably close spacing in the row will produce smaller heads and higher yields and the crop tends to stand better and is easier to combine. Seeds should be placed as uniformly as possible to prevent unequal spacing and competition.

Oilseed varieties may be planted about two seeds per foot of row in 30 to 40-inch rows and about one and one-third seeds per foot of row in 22-inch rows. This would give a plant population of about 25,000 to 27,000 plants per acre. This requires 4½ to 5½ pounds of seed per acre. In areas with adequate moisture and high fertility this could be increased slightly, while on very dry soils, the population should be reduced by 20 to 30 per cent.

Varieties grown for the birdseed and confectionery market should be spaced 8 to 14 inches apart, thus producing somewhat larger heads and larger seed. A population of 15 to 18,000 plants per acre is desirable. These varieties are larger seeded and require 3½ to 4½ pounds of seed per acre.

If the crop will be harrowed for weed control more than twice, an extra one-fourth pound of seed should be planted for each extra harrowing. Likewise, if the crop comes up too thick, it can be thinned by harrowing.

TIME AND DEPTH OF PLANTING. Plant sunflowers from May 10 to 25 in northern areas and from May 10 to May 30 in southern areas. Should planting be delayed beyond this, early maturing varieties are recommended. Sunflower seeds often take longer to emerge than small grain crops because the seed has a thick hull and requires a good supply of moisture for germination. Seed will emerge from depths of three inches or more, but one inch is a better seeding depth if soil moisture is available near the surface. Don't plant deeper than necessary to reach moisture because colder soil at the lower depths slows germination.

HARVESTING. Good combining days in October when the seed is dry enough for storage are limited, so the combine should be ready, test runs made and moisture content determined before combining the field. Nine per cent moisture or less is a safe level for storage. Seed with a moisture content of over 11 per cent may spoil and harvesting should be delayed or the crop artificially dried. Seed lots containing many dehulled seeds are more difficult to keep in good condition during storage.

Straight combining is the only practical way to harvest sunflowers. Sunflower seed is easily threshed. The cylinder speed should be reduced to about 300 RPM and the concaves opened wide. Excessive cylinder speed or close concave setting breaks up the heads so that the sieves and return become overloaded. High cylinder speed also causes serious dehulling. If the combine is properly adjusted and operated, there is almost no hulling and dockage is relatively low.

Long metal pans spaced three inches apart are attached to the cutter bar. The pans guide the stalks and catch most of the seed that is shattered from the heads as they are moved to the feeding auger. In operation this equipment acts somewhat like a stripper. The stalks passing between the pans are pushed forward by the shield. As the heads pass under the shield, they are drawn to the sickle by the reel, cut off and thrown into the feeding auger.

DRYING SUNFLOWERS. The availability of grain drying equipment, either owned or custom operated, is important to the sunflower grower. Harvesting at moisture contents higher than the 9 per cent moisture content required for storage normally results in higher yields. Less bird damage, head dropping and head shattering occur with higher moisture harvesting.

Sunflower seeds dry easily and bin, batch and continuous flow dryers have been used successfully. The large kernels allow air to pass easily and because of its low bushel weight, relatively small quantities of moisture are removed per bushel. Most dryers were originally designed for corn, which has a higher bushel weight. Consequently, when drying sunflowers the unloading equipment may become the limiting factor to drying rate.

High drying temperatures do not appear to have an adverse effect on the sunflower's oil yield or its fatty acid composition. Limited tests have shown no apparent damage at drying temperatures up to 220° F. Farm and commercial continuous flow dryers operated at 160° F to 180° F over several seasons have not caused discernible damage.

A severe fire hazard exists in dryers being used on sunflowers. Very fine hairs and fibers from the seed coat are rubbed loose during handling and commonly are found floating in the air around the dryers. The hairs or fibers, when drawn through the drying fan and open burner, ignite. Unless these small flaming particles or sparks burn themselves out before hitting sunflowers, a fire may result. The fire hazard is increased by higher drying temperatures, which result in drier sunflowers against the inside plenum wall. For this reason many farmers have stayed with lower drying temperatures.

The fire hazard is decreased when the fan can draw clean air, not containing the fine hair or fibers. This may be accomplished with portable dryers by turning the fans toward the wind. On stationary dryers an intake duct may be built to above the top of the dryer to cut down the amount of material drawn in.

Guidelines for drying sunflowers are:
1. Keep good housekeeping practices. Clean around the dryer and in the plenum chamber.
2. Do not overdry.
3. Insure continuous flow for all sections of recirculating batch and continuous flow dryers.
4. Do not leave drying equipment unattended.

SOYBEAN PRODUCTION

Soybeans in recent years have become an important cash crop in southeastern North Dakota.

Soybeans are a long season crop. Their need for favorable temperatures, a long growing season, and generally satisfactory moisture throughout the summer and early fall limits their westward and northern expansion in the state. They are grown mainly in southeastern North Dakota, which is also the commercial grain corn area. Two counties, Richland and Cass, harvest nearly 94% of the total soybean acreage in the state. Very early maturing varieties are available that can be grown farther north in the Red River Valley. But these have limited yield capacity and quickly run into strong competition from other row crops such as potatoes, sugar beets and field beans, and from other well-adapted crops.

SOIL PREFERENCE. Soybeans need about the same soil conditions as corn. A mellow, fertile, medium-textured loam soil usually is best. Heavier soils should have good drainage. Sandy loam soils warm up faster, and this can help soybeans develop in a cool or short growing season when enough rain falls.

A soil relatively free of weeds is very desirable to avoid serious weed competion. Effective weed control is important for profitable soybean production.

ROTATION. Soybeans fit well into a small grain rotation to replace summerfallow or other row crops. They are a late season crop and leave less soil moisture reserve for next year's crop than fallow or early harvested small grain. Soybeans mellow the soil and plowing soybean ground in preparation for next year's crop is not necessary except where the straw is very heavy or the weed situation is bad.

While well-inoculated soybeans produce most of their own nitrogen requirements they do not leave a nitrogen carryover for next year's crop.

SELECT VARIETIES FOR SOYBEAN MATURITY AREAS. Choose a variety of soybeans that will mature under average local growing conditions and produce a satisfactory yield of high-quality beans. In general, the farther north or west in the soybean area of North Dakota, the earlier the variety you need.

SEED TREATMENT. Treating soybean seed generally does not increase yield when high quality seed is planted. Seed treatment benefits most when the seed used is low in germination (below 80 per cent) due to age, frost, weather, kernel damage (broken seed coats), or when germination and emergence are slow due to cold soil.

INOCULATION. Inoculate soybean seed with "soybean bacteria" before planting. This provides the necessary bacteria in the soil that let the soybean plants function as a legume, utilizing and storing nitrogen from the air. This inoculant is different from that required for alfalfa, sweet clover, and other legumes.

Inoculate soybeans close to planting time and after fungicide treatment if the seed is treated. Applying inoculum is cheap insurance of good nodulation which benefits the soybean crop and may be a small benefit to crops that follow.

SEEDBED PREPARATION. Soybeans respond to good seedbed preparation. Shallow spring tillage to kill weeds before planting is effective on fall plowed fields. On soils where spring plowing is practical, plowing is usually done just before planting. Prepare a firm, moist seedbed, as free from weed seed as possible. The sooner you plant soybeans after the last cultivation the better their chance to compete with weeds.

PLANTING. Plant soybeans after the soil has warmed up and air temperatures are favorable, usually around corn planting time. Delayed seeding gives you time to kill early weeds before planting soybeans.

On good land where weeds are not a serious problem, plant as early as favorable temperature conditions permit so the beans can take full advantage of the entire growing season and produce top yields. Four years' data from "date-of-planting" studies made at the Fargo Experiment Station show that plantings made after the middle of May had lower seed yield, poorer seed quality, lower oil content, shorter plant height, pod set closer to the ground and more lodging. Late planting may be justified only where weed control is of primary importance.

Planting in rows is the most common method used and permits cultivation for weed control which is important in getting good yields. A corn planter with the proper plates, a grain drill or a sugarbeet planter may be used. Plant about 1½ to 2 inches deep to place the seed in moist soil. Planting too deep, or in a soil which crusts, may result in poor emergence.

Row spacing down to 22 inches have not decreased yields even when planted early. Growers faced with late planting in some seasons and who have equipped themselves with narrow-row planting and cultivating equipment or have this equipment on hand for other crops can use this same equipment when planting early. Increased yields from early planting in narrow rows may occur in some years.

HARVESTING. Straight combining is the most satisfactory and commonly used method of harvest. It is important to follow the combine manufacturer's recommendations for necessary adjustments to prevent splitting and breaking of the beans. Open cylinder concaves or bars as necessary and reduce cylinder speed by about half.

Harvest soybeans when the plants mature and the beans are dry, containing not more than 14 per cent moisture. When the beans are very dry (8 to 10 per cent moisture), harvesting will generally cause more shattering and seed injury. Under these conditions, you may have to combine only in the morning or evening when humidity is high. About 40 shattered beans per square yard represent a loss of one bushel an acre.

STORING. Soybeans may be stored safely for short periods during the fall or winter with a moisture content as high as 14 per cent. For safe storage during the spring or summer, soybeans should not contain more than 12 per cent moisture. Sound beans, free of foreign material and split beans, store better and stay in condition longer.

FIELD BEAN PRODUCTION

Dry, edible beans are grown commercially in several states but a large proportion of the crop is grown in five states. North Dakota ranked 6th among producing states.

Field beans are a concentrated direct human food and are high in protein, phosphorus, iron and Vitamin B_1. They are readily stored after processing and can be transported easily.

Processing facilities have developed along with increased crop production.

Field beans are a specialty crop and require special cultural practices, know-how and attention on the part of a producer. It is not a crop that can be successfully grown by the farm operator who is not willing to give it some special attention.

GROWING REQUIREMENTS. Field beans are a warm season annual adapted to a rather wide variety of soils. They are sensitive to very alkaline and very acid soil conditions but are not sensitive to the character of the soil so long as it is reasonably fertile, well-drained and of such a nature that it does not interfere with germination and emergence of plants.

Alkali symptoms are yellow, stunted plants that later may actually show some corrosive action of the salts on the leaves. The leaf edges of the affected plant will be browned and dead and often accumulations of salt may be seen on the leaf surfaces.

The optimum growing temperatures for field beans is 65 to 75 degrees F. They are a warm season crop and usually are not affected by high temperatures if adequate soil moisture is present. Cool, humid or rainy weather is unfavorable to field beans but even so, they are adapted to a fairly wide range of temperature. Bean production is more successful in areas where the rainfall is light during the latter part of the growing season. Good moisture throughout the growing season and dry harvest weather favor a high yield and high quality crop.

Field beans are not tolerant to frost in either spring or fall or to prolonged exposure to weather that is near freezing.

PLACE IN ROTATION. Field beans are a short season crop and will fit into a variety of rotation plans. They are commonly grown following alfalfa, clover, potatoes, sugarbeets, peas and small grain crops. Field beans are not good weed fighters, even though they are a cultivated crop. If weeds are controlled, beans are a good replacement for summerfallow in the rotation. Sugarbeet growers may find that field beans are one of the best crops to follow beets. Field beans should not be planted on the same field year after year nor on sunflower ground because it can multiply disease and insect problems.

While field beans are a legume and produce most of their own nitrogen requirements, they do not leave a carry-over for next year's crop. They do mellow the soil, and plowing for next year's crop is usually not necessary.

SEEDBED PREPARATION. Fall plowing is preferable for field beans on heavy soils unless they follow a row crop. A deep, firm seedbed free of clods and coarse debris is essential for field beans.

SEED SELECTION. The use of certified blight-free seed is necessary because some blight (mosaic) diseases are seed-borne.

When field beans are planted under unfavorable soil and weather conditions, treating the seed may help to control rotting of the seed or damping-off of the seedlings. Seed treatment with insecticide-fungicide combinations may be advisable where an infestation of wireworm is present.

METHOD AND RATE OF PLANTING. Field beans should be planted in warm soil after all danger of frost is past. The time of planting is a little later than for corn. Field beans should not be planted until the soil has reached a temperature of 50^{o}F. at planting depth. Planting too early in cool, wet soil is likely to result in low germination. The most common planting time is from May 15 through June 7.

Field beans are grown in rows from 22 to 42 inches apart. The recommended row spacing for dryland production is 28 to 30 inches. The crop may be planted with an ordinary grain drill with some of the seed cups plugged to plant rows the desired distance apart or with a corn or field bean planter. Most field beans in the Red River Valley are planted with bean planters. Seeding rates vary from 40 to 80 lbs. per acre, depending largely on row spacing. The most common seeding rate is 60 lbs. per acre.

Normal planting depth is about 2 inches. Deeper planting should not be made unless the topsoil is dry. Seeds should be planted in moist soil.

HARVESTING. The vines are cut below the soil surface with special four-row or six-row field bean cutters that leave the plants in a single windrow. Two windrows are then put together with a side delivery rake or a special windrower designed to eliminate dirt and reduce shattering. Windrowing should be done immediately after cutting. A good small grain pickup or a special field bean pickup attachment on the ordinary grain combine is used for threshing field beans from the windrow.

Field beans should be harvested before killing fall frost. Frozen immature field beans are almost impossible to separate in processing but unfrosted immature field bean seed will shrink when drying so that it can be separated.

Field beans are ready for harvest when some of the pods are dry and when most of them have turned yellow. The nearly mature field beans in the yellow pods will continue to ripen after they are cut. Too many dry pods will result in heavy shattering when the field beans are harvested. Field bean cutting and windrowing can be done at night or early in the morning when the plants are damp with dew in order to reduce shattering loss. It is advisable to make field bean windrows as large as can conveniently be threshed. The larger windrows offer the seed more protection from injury, wind disturbance and shattering.

Field beans are ready for threshing when the moisture content is 15 per cent and there are no green beans present.

They mustbe threshed carefully to avoid damage to the seed. The cylinder speed should be reduced as much as possible and long seed drops in the separating, loading, and handling operations should be prevented to avoid injury or splitting. The cylinder speed should be between 150 and 300 rpm for most threshing conditions. There must be sufficient clearance between the cylinder and the concave bar to allow the seed to pass through without injury. If there is evidence of injury or splitting of the seed, immediate adjustment should be made. For extended safe storage, the moisture content should not be over 13 per cent.

SUGAR BEETS

SOILS

Sugarbeets are grown on a wide variety of soils in the United States and most soils in the Red River Valley and in the sugarbeet producing regions of southwestern Minnesota are suitable for sugarbeet production. In fact, sugarbeets have been grown on most soil types in the beet production areas of North Dakota and Minnesota. Most sugarbeets, however, are presently grown on soils with a silty clay loam or clay loam texture. With the exception of stony soils, the sand and sandy loam soils are the least desirable because of their droughthy nature while the clay and some silty clay soils present problems in achieving good seedbeds because of their greater tendency to crust, form clods, and stay wet in the spring which can often result in a delayed planting date. The silty clay loam and clay loam soils have good water holding capacity essential to dryland beet production and are easier to till than clay and silty clay soils in preparing a good seedbed.

CULTURAL PRACTICES

Crop Rotation

Growing sugarbeets on a field every three or four years is a popular and recommended rotation in North Dakota and Minnesota. Three and four-year rotations are important in minimizing the incidence of soil borne diseases when crops susceptible to the same disease are separated by 2 or more years. A rotation also accommodates other agriculturally important crops such as soybeans, dry edible beans, potatoes, sunflowers, and small grains. A rotation often includes one year of summerfallow that conserves moisture, which can become important in moisture deficient years, reduces weed problems, and allows an accumulation of nitrate nitrogen through mineralization. With herbicides for weed control, fertilizer nitrogen, and high food prices from world shortages, summerfallow acres are decreasing. An 8-year rotation study conducted by workers at the University of Minnesota, Northwest Experiment Station - Crookston indicated that when including the cost of leaving land idle (summerfallow) one year in four, the largest net return was realized from a non-fallow rotation.

Crop sequence in rotations varies among growers. The most common crop sequence has been small grain - small grain - summerfallow - sugarbeets but present trends, due to changing government programs and research findings, lean slightly to sugarbeets following small grains, potatoes, or beans.

Field Selection and Seedbed Preparation

Field selection is often dictated by crop rotation with few alternatives available. If a field or farm is selected for sugarbeet production by choice or if a last minute decision must be made to change fields due to wet soil conditions, access to chemical fertilizers, or change in government farm programs, good field characteristics for sugarbeet production should be kept in mind. A field selected for sugarbeet production should have good surface drainage, have adequate internal drainage, be free of any serious weed or chemical residue problems, should not have been in sugarbeets the previous two years, and should not contain excessive nitrate-nitrogen levels as determined by a soil test.

Seedbed preparation should start during the summer months if sugarbeets are going on summerfallow and in the fall if old cropland is to be used. Spring seedbed preparation should take place as soon as weather and soil moisture conditions permit.

The preparation of summerfallow land for sugarbeet production in the Lake Agassiz Basin should include land planeing for good surface drainage, earlier spring planting, uniform planting depth, and uniform field distribution of seasonal precipitation. If cropped land is to be used for beets the following year, cultivate or till the soil as soon as the crop is harvested. At this time or preferable just prior to this operation, soil samples should be taken and analyzed at a reputable soil testing laboratory for fertilizer recommendations. The basic fertilizer application should be applied and incorporated according to recommendations at this time. Recommended herbicides for fall application should be applied and incorporated as close to freeze as possible. Protection of the soil from winter wind erosion should be given strong consideration and can be accomplished by winter cover cropping, leaving crop residue on the surface, or by ridging the soil in a northeasterly-southwesterly direction perpendicular to prevailing winter winds. Maximum tillage is a recommended practice for fall while minimum tillage is suggested for spring to conserve as much seedzone moisture as possible.

A good seedbed is firm, level, and free of stones and clods with adequate seedzone moisture for uniform and complete germination. It is also free of serious weed, insect, and disease problems with appropriate nutrient levels for producing an optimum sugar yield.

Row Width and Plant Population

Row widths from 18 to 30 inches have been investigated by a number of researchers. Maximum yields were obtained in equi-distant plant spacings (equal distance between rows and between plants within rows) of less than 15 inches. Since such a row width would be impractical with large scale field mechnization and large tractor tires, the popular 22 inch row was adopted. A harvest population of 25,000 to 27,000 plants per acre in row widths greater than 20 inches resulted in similar root yields, however, a loss of approximately 400-500 pounds of sugar per acre resulted from increasing the row width from 20 or 22 inches to 28 or 30 inches. These losses are associated with less efficient use of the available space per plant which results in a lower sugar percentage, more impurities, and less recoverable sugar per acre. Obtaining a uniform population in wider rows can be even more difficult than in 22 inch rows because of the in-row spacing required. (In-row spacing must be 8.4 inches in 30 inch rows versus 11.4 inches in 22 inch rows for a population of 25,000 beets per acre.) Growers interested in row widths greater than 22 inches must weigh the anticipated advantages against a probable sugar loss.

A good sugarbeet plant population at harvest time should be from 25,000 to 27,000 uniformly spaced plants per acre. In 22 inch rows this is 105 to 114 beets per 100 feet of row. This population under dryland production can produce a very good root yield of high sugar beets with good quality. For other population figures based on beets per 100 feet of 22-inch rows, see following table.

PLANT POPULATION - 22 INCH ROW WIDTH

Plants Per 100' of Row	50	60	70	80	90	100	110	120
Plants Per Acre	11,880	14,256	16,632	19,008	21,384	23,760	26,136	28,512

Seeds and Seeding

A number of sugarbeet varieties are available from sugarbeet companies and from commercial seed companies. These varieties vary widely in disease resistance and in potential tonnage and sugar yields. Most sugarbeet companies have a list of varieties which have been shown to produce satisfactory yields and sugar contents in their respective growing areas. For information on specific varieties, recommendations, costs and availability of seed, contact your agricultural fieldman, sugarbeet cooperative office, or seed company field representative.

Sugarbeets should be planted early in the spring as soon as weather and soil conditions permit. An April planting date is considered early and the probability of freezing temperatures following planting is very high. However, early planted sugarbeets have survived air temperatures as low as 20 degrees in previous years and the risk of frost should not be a deciding factor in determining planting date. Most sugarbeet acres are planted from mid-April to mid-May.

Sugarbeet seed should be planted uniformly 3/4 to 1½ inches deep for maximum and more uniform germination and emergence. Sugarbeet seed planted in April and early May when evaporation of soil water is low and seedzone moisture is optimum should be placed about 3/4 inch deep. Sugarbeet seed planted at a later date when days are longer, temperatures warmer, and surface evaporation is higher should be planted deeper than 3/4 inch or close to soil moisture. However, seeding deeper than 1½ inches is not recommended since sugarbeets do not emerge well from such depths. If seed is planted in a dry seedzone and precipitation is essential to germinate the seed, plant shallow (about 3/4 inch deep) to assure complete and uniform germination with minimum amount of rainfall.

Except for shortness of growing season, lack of timely precipitation during the growing season is often the principal factor limiting sugar yields in North Dakota and Minnesota. Another important factor limiting sugar yield is poor populations. Root yields of sugarbeets tend to be similar over a large range of populations but recoverable sugar yields per acre (sugar recovered in processing) peaks out at uniformily spaced populations of 25,000 to 27,000 plants per acre. Consistantly obtaining a population of 25,000 plants per acre under dryland conditions in North Dakota and Minnesota is very difficult for growers.

Several factors can contribute to poor populations. Lack of adequate seedzone soil moisture at planting time for complete and uniform germination is often a serious problem confronting growers each year. Crusting of the fine textured soils, wind damage to young plants, seedling disease, and insects often seriously reduce plant populations. Many acres are replanted annually due to one or more of the problems associated with getting good stands, or even more often, growers must be satisfied with less than desirable populations.

Planting rate in pounds of seed per acre varies with row width, in-row spacing, and seed size. A beet seed should be placed every 2.4 to 3.5 inches in 22 inch rows for a population of 81,463 to 118,800 plants per acre and thinned back to a desired harvest population of 25,000 to 27,000 plants per acre.

Planting rate is reduced substantially when planting to stand but because of previously mentioned long-time and well-recognized problems often encountered in obtaining optimum and uniform sugarbeet populations in the Red River Valley of North Dakota and Minnesota, planting to stand is not a widely recommended practice. The few growers that have tried planting to stand have, for the most part, used coated seed.

Coated seed is a more spherical form of seed which can be planted with more precise in-row spacing by some planters. The coating must be saturated and broken down by soil moisture before germination of the seed can occur and in years when seedzone moisture is marginal, sugarbeet germination and emergence may be slowed or even reduced by a seed coating. Consequently, coated seed is not generally recommended for dryland production in North Dakota and Minnesota.

Growers interested in planting to stand and/or using coated seed should do so on a limited acreage under the ideal conditions of a good seedbed, good seedzone moisture, and early planting date. If planting date is delayed, planting to stand should not be practiced and uncoated seed should be used since seedzone moisture is more likely to be limited in a late planting. A 53 to 57 percent survival is necessary when planting to stand at a 6 inch spacing in 22 inch rows to obtain a harvest population of 25,000 to 27,000 plants per acre. Even if this type of survival is experienced, the resulting population is often non-uniform and sugarbeet quality is reduced.

Planting rates and seed spacings for 22 inch rows are found in the following table.

Inches Between Plants	Plants Per Acre	Pounds Seed Per Acre by Seed Size					
		No. 1	No. 2	No. 3	No. 4	No. 5	Coated
4	71,280	.99	1.58	2.04	1.21	2.85	7.9
3.5	81,463	1.12	1.81	2.32	1.38	3.26	9.1
3	95,040	1.32	2.11	2.72	1.61	3.80	10.6
2.4	118,800	1.65	2.64	3.39	2.01	4.75	13.2
2	142,560	1.98	3.17	4.07	2.42	5.70	15.9
1.7	166,320	2.31	3.70	4.75	2.82	6.65	16.5

Planting speed is often 2½ to 3 mph, however, recommended operating speeds for specific planters should be available from the manufacturer or dealer. Planting speed should be determined by the ability of the planter to place sugarbeet seed at a uniform depth with uniform spacing between seeds in the row. Improper operating speeds for the planter or soil conditions may result in uncovered seed, non-uniform planting depths, and erratic seed spacing.

In summary, sugarbeet seed should be placed at a uniform depth and in-row spacing in a firm seedbed in contact with soil moisture and compacted with a press wheel to assure good, firm, seed-soil moisture contact for maximum, uniform germination and good harvest populations.

Thinning

An increasing number of growers are producing sugarbeets without hand labor by utilizing good chemical control of weeds and complete mechanization of the thinning operation. The percentage of acres machanically thinned increased from 25 percent in 1972 to 45 percent in 1973. Mechanical thinners of various types that remove sugarbeets at random have been used for some time but the introduction of electronic thinners which remove beets selectively has significantly increased the acres of sugarbeets being grown without hand labor. Electronic thinners presently are used on 76 percent of the mechanically thinned beets.

Regardless of the thinning method used, excess beets should be removed leaving a uniformly spaced population of 105 to 115 beets per 100 feet of 22 inch row. A once-over operation by labor following mechanical thinning is often used by growers to remove weed escapes and to improve the plant spacing.

Fields that already have less than desirable populations should not be thinned. A thinning operation makes a poor stand poorer. A field that has approximately the desired number of plants per 100 feet of row before thinning, usually will not show an increased yield from thinning. A field where the existing plant population is closely bunched together would be an exception.

FERTILIZATION

Determine fertilizer needs for your sugarbeet crop by carefully relating the current fertility level of the soil, as determined by soil tests, and the expected yields of sugar and roots to the nutrient needs of sugarbeets.

Nitrogen

Nitrogen is the most critical element in producing good quality sugarbeets and optimum sugar per acre. Sugarbeets that have access to excessive amounts of nitrate-nitrogen during the growing season produce good root yields of sugarbeets that contain less than optimum sugar percentages and undesirable amounts of impurities. High nitrogen sugarbeets usually stay green and healthy looking up to and often through the harvest season. Sugarbeets that have access to too little nitrogen begin yellowing and showing nitrogen deficiencies prior to the desirable September 1 date and usually produce less than optimum tonnage but produce sugarbeets that are of very good quality.

The proper amount of nitrogen, phosphorus, and potassium fertilizer to apply for maximum sugar production, based on a soil test, can be found in the Fertilizer Recommendation section on pages 58 and 59.

Fertilizer Application

All nitrogen and potassium fertilizer materials should be broadcast and incorporated. Nitrogen and potassium material applied down-the-row in contact with the seed can reduce germination and emergence.

Fall applications of nitrogen are not recommended on coarse textured soils, soils with a high water table, or on soils subject to water ponding in the spring. On such soils, apply nitrogen as near to planting time as possible. Although sidedressing nitrogen on sugarbeets is generally not recommended, application of nitrogen before planting is not always possible. If sidedressing is necessary, apply nitrogen before the sugarbeets have reached the 4 or 6 true leaf stage. When sidedressing sugarbeets, reduce the recommended rate 10 pounds of nitrogen for each week beyond May 20 that the fertilizer is being applied. No nitrogen fertilizer material should be applied after the 4 or 6 true leaf stage or June 15. Nitrogen applied after planting becomes unmanageable and increases the risk of excess late season nitrogen at the time when a nitrogen deficiency in sugarbeets should appear.

Phosphate fertilizers have a low salt index and can be placed safely in contact with the seed. When phosphate is banded with or near the seed, its availability and efficiency is usually improved, especially for early season growth. Apply at least 10 to 20 pounds per acre of P_2O_5 with or near the seed at planting time. Use of starter phosphate fertilizer is especially important on soils testing very low in phosphorus.

All NDSU phosphorus recommendations for sugarbeets assume that the phosphorus will be applied in bands with the planter. If all phosphorus fertilizer is to be broadcast, double the recommended rate and for very low, low and medium testing soils, apply it ahead of plowing or the deepest tillage operation. On soils testing high and very high, apply all phosphorus material with the seed or if material is broadcast, a shallow incorporation is adequate.

If part of the P_2O_5 recommendation is to be broadcast with the remainder going on with the planter, increase the broadcast portion 1.5 times and apply the phosphorus ahead of the deepest tillage operation to place it in a more favorable position in the soil and to help prevent possible losses through runoff and/or eroding soil.

For more information on fertilizer recommendations and application, see Circular S-F 4 "Fertilizing Sugar Beets".

DISEASE CONTROL

Incidence of disease in North Dakota and Minnesota sugarbeet fields is usually low but the potential for a serious disease outbreak exists each year. The best preventative control measures against potential disease problems are growing disease-resistant varieties and establishing a crop rotation that separates crops susceptible to the same diseases by at least three years.

Seedling diseases caused by fungi such as Aphanomyces, Pythium, and Rhizoctonia are responsible for substantial stand reductions annually. Seed treatment with a fungicide, crop rotations, and cultural practices are important in keeping incidence of seedling disease to a minimum.

Recognized foliar diseases in sugarbeets include cercospora leaf spot, Ramularia, Alternaria, Phoma, and foliar Rhizoctonia. Cercospora leaf spot is the most important foliar disease but effective foliar applied fungicides are available.

For information on fungicides and fungicide recommendations, see Plant Diseases section, pages 207 and 211.

WEED CONTROL

The most serious weed problems in sugarbeets in North Dakota and Minnesota are wild oats, redroot pigweed, foxtail species, and wild mustard. A grower must use all available weed control methods to consistently keep these weeds and other less common weeds under control. Proper herbicide applications, timely cultivations, good weed control in other crops in the rotation, and hand labor are all needed in a total weed control program. Although new herbicides and new uses for old herbicides have been and continue to be developed, weed control still is one of the most serious sugarbeet production problems. For more information on herbicide rates, methods of application, and weeds controlled, see Chemical Weed Control section on page 213.

INSECT CONTROL

The most important insect problem in sugarbeets in North Dakota and Minnesota is the sugarbeet root maggot. In the past, the root maggot has been found primarily in the northern sections of the Red River Valley on the coarser textured soils. The maggot has migrated however, and now can be found to some extent in most soil types and in the central and southern areas of the Red River Valley. The sugarbeet root maggot caused severe yield reductions before effective insecticides were registered and can still cause severe yield losses in unprotected fields.

Other insects such as cutworms, grasshoppers, flea beetles, and webworms are generally of minor importance to the sugarbeet production areas of North Dakota and Minnesota as a whole, but these insects can be a serious problem to individual growers or on individual fields.

For information on how to control these insects see Crop Insecticide Recommendation section, page 182.

POTATOES

COMMERCIAL PRODUCTION

The first record of potato production in North Dakota was about 1814. Commercial potato production in North Dakota is synonomous with production in the Red River Valley, which encompasses also the northwest corner of Minnesota. Commercial production as an economic factor commenced in the early 1900's. Since that time North Dakota has ranked fourth or fifth nationally in production. Some irrigated potato production is found in the Oakes and Bismarck areas.

Since World War II and the advent of processing the use of the potato crop today is about 45 percent for processing, 30 percent for seed production and the balance is for fresh use. The red skinned potato (Red River Reds) was once the trade mark of potato production. With the swing to processing, color is no longer the important variety factor it once was.

Marketing is an important factor in the movement of the crop. Today potatoes are one of the major crops in the state's economy.

VARIETIES

The most popular potato varieties grown in the Red River Valley are Kennebec, Norchip, Norgold Russet, Norland, Red Pontiac, Red LaSoda, La Rouge and Russet Burbank. Chieftain, Cascade, Irish Cobbler, La Chipper, Superior and Viking are also grown but in smaller acreages.

Kennebec - developed by the USDA and introduced in 1948. Maturity medium to late. Tubers elliptical to oblong with shallow eyes, white skin and flesh. High yield and good processing quality. Resistant to late blight.

Norchip - developed by the North Dakota Agricultural Experiment Station. Introduced in 1968. Maturity is medium early. Tubers are round - oblong and have a white skin. Total solids are very high and yield is medium high. Excellent chipping variety. Scab resistant and field resistant to certain common insects.

Norgold Russet - developed by the North Dakota Agricultural Experiment Station. Introduced in 1964. Maturity medium early and yield about medium. Tubers are oblong and have an attractive russet skin. Excellent baking and boiling potato. Resistant to common scab but susceptible to hollow heart under certain growing conditions.

Norland - developed by the North Dakota Agriculture Experiment Station. Introduced in 1958. Maturity is very early and yield about medium. Tubers are oblong to round with fairly attractive red skin color. Resistant to common scab. Excellent early market potato.

Red Pontiac - this variety which is a mutation of Pontiac was selected by Mr. J. W. Weston in 1949. Late maturing. Tubers round to oblong with smooth flaky light red skin color. High yield and low specific gravity.

Red LaSoda - developed by the Louisiana Experiment Station and the South Dakota State Seed Department. It is a mutation of the LaSoda variety and was introduced in 1958. Maturity is medium and yield high. Grown mainly as a seed variety in the Red River Valley.

La Rouge - developed by the Louisiana Agriculture Experiment Station and was introduced in 1962. Maturity is medium and tubers have a bright red skin color with shallow eyes. Specific gravity is low and yield is medium high. Grown mainly as a seed variety in the Red River Valley.

Russet Burbank - a mutation of the variety Burbank which was introduced by Luther Burbank in 1876. Late maturing. Tubers long, cylindrical with russet skin. Good cooking quality, particularly baking. Medium yield and high specific gravity.

SEED HANDLING

All potato growers should start with certified seed each year. The additional cost of certified seed is small in comparison to the total cost of producing potatoes and the higher risks involved in using non-certified sources.

Tubers 8 ounces or less in weight make better seed than larger tubers. By using small tubers seed pieces are more uniform in size, have less fresh-cut (injured) surface and are more likely to have one or more eyes. Tubers should be cut into blocky seed pieces 1½ to 2 ounces in size. Smaller seed pieces generally do not perform as well, resulting in lower yields and sometimes poorer stands. Large seed pieces result in higher seed costs without additional yield increases.

Ideally seed should be firm and just beginning to sprout at the time of cutting and planting. The sprout should not be over ¼ inch in length to prevent injury in handling and planting. Warming the seed at 55-65 F for 10 to 14 days before planting will initiate sprout activity resulting in earlier emergence as well as promoting better wound healing.

Most growers treat seed with a dust containing a fungicide after cutting. A dust applicator should provide uniform dust coverage over the cut surface. The dust may help in reducing surface infection by fungi and bacteria resulting in stronger plants and better stands. Dust treatments however are no substitute for good handling practices.

Most seed is planted immediately after cutting and when cut seed is hauled from the storage to the field it should be tarped. The wound healing mechanism in the seed piece is adversely affected by drying and exposure to sunlight. Some seed is now pre-cut and "healed" in storage weeks or months before planting. This practice is still limited however and requires additional handling facilities and involves additional cost.

SOILS AND FERTILIZERS

The fertilizer needs of a potato crop are best determined by taking into account the present fertility status of the soil and the yield goal for each field. The following is a summary of soil test calibration research with potatoes.

Yield Goals

Yields are a reflection of soil type, climate, variety, and management. However, for the purpose of determining fertilizer requirements a yield goal can be based mainly on the highest yield that you have produced on that field in the past, which of course is a reflection of all of the above factors. If you are a new grower use the area average as your field goal. Fertilizer recommendations based on soil test and yield goal assure that the required amount of nutrients will be present in proper balance for yield and quality. They are not a guarantee that you will reach your goal. Yields of 250 hundredweight(cwt) of marketable potatoes are common on the fine textured soils of the Red River Valley. Potatoes grown on coarse textured soils without irrigation generally yield less than 200 cwt per acre. Under irrigation yields of over 400 cwt are possible.

A 300 cwt crop of potatoes will use, on the average, the following amounts of nitrogen, phosphorus, and potassium for vines and tubers:

Nitrogen	200 lbs.
Phosphorus (P_2O_5)	60 lbs.
Potassium (K_2O)	300 lbs.

About one-third to one-half of this is found in the vines. The rest is found in the tubers and is removed from the field. The actual amount of nutrients used by a 300 cwt crop can vary from the above figures depending on the amount of nutrients available to the crop. On a highly fertile soil a 300 cwt crop of potatoes could use much more than the above amounts.

Fertility Status of Soils

Often in the past fertilizer experiment results were used to make general recommendations. In other words the fertilizer treatment that gave the highest yield on a particular field was used as the recommendation for an entire area. If the trial happened to be conducted on a very infertile field the resulting general recommendation for the whole area was for a large amount of fertilizer. In contrast, fertilizer recommendations based on soil tests take into consideration the fertility level of individual fields (Tables 26 & 27). If the soil in a particular field is already high in a particular nutrient as determined by soil test, recommendation would be low and vice versa. In this way limited capital or resources can be used on fields where they will do the most good.

Fertilizer Placement for Potatoes

Fertilizer applied at the time of planting should not be in direct contact with the seed pieces. The recommended method is placing fertilizer in two bands; each band two inches to the side and two inches below the seed pieces. However, broadcasting and plowdown is acceptable on soils with medium or high phosphorus soil test ratings.

Many growers are applying fertilizer in blind rows before the seed is planted. This method has given good results.

Fall application of nitrogen fertilizer is not recommended on coarse textured soils because of the danger of loss by leaching. Also avoid fall application of nitrogen on soils with a high water table and on soils subject to ponding or flooding in the spring. On such soils it is best to apply nitrogen as near to planting as possible.

PLANTING

The planting season for potatoes in the RRV extends from May 1 until the end of June, with the major part of the crop usually planted the last two weeks in May and first week in June. May planting is preferred since the extending growing season usually results in higher yields, better maturity, and lower sugars.

Generally the center of the seed should be planted 3 to 4 inches below field level and covered with 2 to 3 inches of soil for best stands. Shallow covering usually results in quicker emergence with less blackleg and rhizoctonia attacking the sprouts. However, the best depth will vary with soil moisture and temperature.

Row widths generally average 38 inches in the RRV while in-row spacings may vary from about 8 to 18 inches. Seed spacings varying from 6 to 15 inches have had only a modest effect on total yields. However a major result of closer spacing is an increase in small and a decrease in large tubers. Therefore the comparative market value of the various sizes of potatoes should be considered when deciding on the best spacing. Other effects of spacing are on maturity, hollow heart and tuber shape. All of these factors are considered in making spacing recommendations. Wider spacing is recommended for varieties with heavy tuber set, early maturity, smooth tubers and resistance to hollow heart.

Heavy yielding and poor setting varieties should be spaced closer to reduce the yield of oversized tubers. Close spacing is a simple, effective way to reduce hollow heart where conditions favor its development. Closer spacings also usually result in slightly earlier maturity which should help reduce skinning and bruising at harvest. Large tubers make poor seed, so closer spacings are recommended for certified seed growers.

No spacing recommendation will always be best for a given variety because of year to year variations in weather conditions. Under dry conditions wide spacings are best while the opposite is true in wet years. Temperature also plays an important part. Cool temperatures at the time of tuber set usually increases the number of tubers per hill so wider spacings are satisfactory. However a generally cool growing season may increase yields so closer spacings are best.

TILLAGE AND WEED CONTROL

The primary means used for controlling weeds in the Red River Valley has been by tillage. The principal summer tillage implements are cultivators, harrows and weeders. The first tillage operation following planting is usually "blind" cultivation and harrowing. While the number of tillage operations will vary with the severity of the weed problem, three cultivations and two harrowing or weeding operations are common.

The use of herbicides for controlling weeds are increasing and are available for either pre- or post-plant application. Those currently recommended are listed in yearly circulars published by North Dakota State University.

VINE KILLING AND HARVESTING

Killing potato vines is an essential practice in most potato operations. Vine killing helps hasten maturity of the potato tuber assuring better "skin set" thus resulting in reduced bruising and skinning damage at harvest. Killing vines too early may result in reduced yields and lower specific gravity. However, potato top killing if practiced as a "slow kill" may result in increased specific gravity of tubers. Vine killing also is helpful in preventing the spread of Late Blight spores from vines to tubers at harvest. Most potato varieties require 10 to 14 days from vine killing operations to harvest to assume proper tuber conditions for minimum handling damage. Vine killing may be done by mechanical, chemical or flame methods, however the use of chemicals is the predominant means of killing potato vines. Several chemicals have been cleared by the Environmental Protection Agency for use as potato vine dessicants. The annual Extension Pest Control Guide for Potatoes should be consulted for current approved materials and rates.

Mechanical injury to potatoes during harvest is one of the most important problems in the production of potatoes. Damage reduces the value of potatoes, causes weight loss and decay in storage, and may result in complete abandonment of whole bins in storage. The harvester must be mechanically ready to do the harvest job with a minimum of damage. In operating the harvester consider blade depth, travel speed, apron speed and agitation, and spill out.

SPROUT INHIBITOR

The development of long term storage to provide full season marketing of potatoes for table stock and processing utilization has made sprout inhibition an essential production operation. Some processing forms, such as potato chips, require that potatoes be stored at high temperatures very conductive to tuber sprouting.

The sprout inhibitors presently used are: Maleic Hydrazide (MH-30), Isopropyl N-(3-Chlorophenyl) Carbamate (C.I.P.C.) and 2, 3, 4, 6-Tetrachloronitrobenzene (TCNB). MH-30 is usually formulated as a 58 percent liquid and is approved for potato field spraying at 3.0 Pounds active ingredient or one gallon per acre applied 4-5 weeks before harvesting when tubers approach No. 1 size. Vines must be vigorously growing, lush and green at the time MH-30 is applied for proper translocation to the tubers.

The presence of severe wilting blighted foliage or Rhizoctonia damage to underground stem and stolon areas will delay or prevent the accumulation of adequate residues of the chemical in the tuber. Tolerances of MH-30 have been established at 50 parts per million in fresh potatoes and 160 p.p.m. in potato chips. Generally, residues of 12-15 p.p.m. in the stored tuber will completely inhibit sprouting.

C.I.P.C. is approved for sprout inhibition as an application to stored potatoes at a rate of 1 pound actual C.I.P.C. per 60,000 pounds of potatoes as an aerosol, 1 pound per 96,000 pounds as a dip or brushed-on emulsion, and 1 pound per 100,000 pounds when applied as a dust. The dip and brushed-on emulsions are used on potatoes as they are removed from storage to prevent sprouting during the marketing period. A Federal tolerance of 50 p.p.m. on or in fresh or processed potatoes is established. C.I.P.C. must reach all buds in each eye to be effective. Buds not adequately covered by C.I.P.C. may enlarge and produce appressed rosette-type sprout clusters from which growth may turn inward to produce ingrown or internal sprouts. C.I.P.C. is made by Pittsburgh Plate Glass Co., and applied by franchised applicators.

TCNB is a weak inhibitor or sprout suppressant. At 50^{o} F., it may control potato sprouting for several months. At higher temperatures, especially in storage frequently ventilated with outside air, sprout-free time is often reduced to 2 or 3 weeks. TCNB is applied at 1 pound of 6 percent dust per 600 pounds of potatoes as potatoes enter storage. TCNB volatilizes into storage atmosphere to reach potato eyes and inhibit sprouting. After TCNB vapor dissipates, potatoes can sprout. Federal tolerance is 25 p.p.m. of TCNB in or on potatoes from postharvest application. TCNB is made by Sterwin Chemicals, Inc., and is often promoted for late season application to seed to prevent sprouting until seed can be planted.

STORAGE

Potato storage is an important part of potato production and marketing. In the Red River Valley approximately 85 to 90 percent of the crop goes into storage for some period of time. Both on-the-farm, off-the-farm trackside and commercial storages are used. A trend towards longer storage seasons are apparent with some storages now holding potatoes for 11 to 12 months.

The potato must be protected from freezing yet high temperatures encourage moisture loss, rot and sprouting. The condition of the potatoes going into storage determine to a large extent how well the potatoes will store and what their condition will be coming out of storage. The first step towards good storage is good potatoes. A mature tuber, free from excessive bruising, scald, late blight or field rot and reasonably free from dirt is a necessity for long-term storage. All a storage can do is help maintain quality. An improvement in quality will not take place. Diseased, chilled or badly bruised potatoes going into storage will likely suffer a significant quality loss during storage.

Because of their high water content, approximately 78 percent by weight, moisture loss from potatoes is critical. Moisture loss is weight loss and is comparable to a reduction in yield. However, a greater consideration may be the quality factor. Shrink affects the appearance and firmness of the tubers.

To reduce moisture losses from potatoes in storage, high relative humidities are recommended. For all practical purposes the inside of a potato is assumed to be at 100 percent relative humidity. Anytime the atmosphere around this tuber is below 100 percent RH moisture will attempt to leave the potato through transpiration. The lower the relative humidity, the higher the moisture loss and the greater the shrink.

The greatest weight loss from potatoes occurs during the first two to three weeks of storage. During this "sweat" period, high respiration rates, high moisture loss, and high heat loss occurs. To minimize the amount of weight loss or shrink during early storage proper <u>suberization</u> or wound healing must occur. Excellent conditions for suberization are high temperatures, 60^{o} - 70^{o} F. and high relative humidities. Under these excellent conditions wound healing may occur in two to three days. At lower temperatures and lower relative humidities, longer periods of time are required. A supply of oxygen during suberization is very important. Because of the high respiration, a carbon dioxide buildup may occur. High carbon dioxide contents adversely affect potato quality and storability.

To supply oxygen during suberization at least occasional air circulation is recommended. One practice which works satisfactory is to run the circulation fans briefly once per day. Circulate air in the evening or early morning when outside relative humidities are high. When fans are sized for ventilation rates of 1 to 1.5 CFM (cubic feet per minute) of air per CWT of potatoes, five minutes of running time should be sufficient.

In general, temperature recommendations for long-term storage are table and seed potatoes, 38^{o} - 40^{o} F.; French fries, 45^{o} - 50^{o} F., and chip potatoes 50^{o} - 55^{o}F. At temperatures of 40^{o}F and lower reducing sugars normally start forming in the potato tuber. The actual temperature reducing sugars began to form depends upon variety and growing conditions. Although reducing sugars seldom build to the point of causing appreciable sweetness in table potatoes, they are very important in the quality of chipping potatoes. Reducing sugars in chipping potatoes cause an undesirable color (brownness) to the fried chips. At higher temperatures reducing sugars do not occur.

The color of chips from stored potatoes in general shows a decline during storage. This occurs faster at lower temperatures, but also occurs at higher temperatures.

Higher temperatures increase the respiration rate of potatoes and increase the likelihood of sprouting once dormance has been broke, if sprout inhibitors have not been applied.

DISEASES

Bacterial Diseases

Disease and Casual Organism	Chronologic Symptom Development
Black Leg Erwinia atroseptica See Control: 1,2,3,4,5,6,15	1. Poor stand - missed hills due to seed decay, soft rot. 2. Dry rot often occurs due to a secondary infection. 3. Foliar chlorosis, leaf bronzing, rolling and wilt. 4. Shiny, black lower stem, followed by complete collapse of plant. Plant easily pulled from soil. 5. Aerial tubers form when disease progress is slow. 6. New tubers may be symptomless or various degrees of rot may occur at stem end. Lenticel infections may occur. 7. Soft rot during storage.
Ring Rot Corynebacterium sepidonicum See Control: 1,4	1. Symptoms begin to form when temperatures exceed 70^{o}, young plants stunted. 2. Wilt - with night time recovery. 3. Veins green, interveinal area of leaf chlorotic then necrotic. 4. Leaf margins curl up and vascular tissue discolored. 5. Creamy bacterial exudata may be squeezed from the vascular tissue of cut stems and tubers (Squeeze Test). 6. Yellow discoloration of vascular tissue of tubers develops, giving the appearance of a ring around the tuber. Later this tissue decays and separates from other tissue providing a cavity. 7. Positive squeeze test plus gram stain test are necessary for positive diagnosis.
Soft Rot Erwinia carotovora See Control: 1,2,3,4,5,6,15	1. Often associated with black leg and dry rot. 2. As with black leg, poor stands and missed hills develop. 3. Lenticel infections may originate new tuber blotches. 4. Wet, slimy, odorous rot of tubers and sometimes other plant parts; generally only those tubers that are injured by cultivation, frost or harvest procedures are generally infected. Important in storage.

Fungal Diseases

Disease	Symptoms
Dry Rot *Fusarium roseum* *F. solani*; other *Fusaria* See Control: 1,2,3,4,5,6	1. Infected seed pieces show various stages of dry rot. 2. New tubers are seldom infected at harvest; lenticel infections may be noticed as a slight sunken area; if skin is removed at this point various stages of white fungal mycelium may be apparent. 3. New infections occur from lenticel infections and more often through harvest injuries. 4. After harvest the degree of rot depends on the amount of harvest injury and storage conditions, the higher (above 90%) the humidity the wetter the rot. Hollow pockets form within the tuber after infection and white to pink mycelia and spores of the fungus form which help to distinguish dry rot from bacterial soft rot.
Early Blight *Alternaria solani* See Control: 5,7a.7b,7c,8, 10,11,11a	1. Dark brown, circular, lesions with concentrically arranged rings resembling a target develop initially on the lower older leaves and stems. 2. Lesions enlarge, coalesce and increase in number. 3. Plants show early senescence and mature early. 4. Tuber symptoms may be confused with leak, late blight and soft rot. Affected areas are brown to purple, irregularly shaped and sunken with a raised and well defined border. Lesions do not extend deeply into the tuber as in late blight, a yellow discoloration occurs just beyond the decay.
Late Blight *Phytophthora infestans* See Control: 7,7a,7c,7d,7e, 7f,11a,12,13	1. Water soaked, dark green, purplish to brown, leaf spots occur on foliage. Spots enlarge and encompass entire leaflet including petioles and small stems-not restricted by veins as in early blight. 2. Under high humidity the organism may produce a downy mildew growth and when observed with a hand lens individual structures appear to twist in response to a gentle air current. 3. On the tuber the blighted area may cover any or all of the tuber surface. The surface of the infected area is reddish-brown, purplish-brown or almost black in color. Unlike early blight, the infected area penetrates deeply and to irregular depths and without a yellow border.
Rhizoctonia Disease Black scurf Cortical Rot *Rhizoctonia solani* See Control: 1,8	1. Symptoms are often non-specific and variable, they include delayed emergence, stem lesions or cankers, rhizome(stolon) lesions, root rot, tuber russetting, formation of aerial tubers, stunt, chlorosis, leaf roll, crinkle, wilt, and poor vigor. The observance of light brown lesions on newly formed rhizomes and stems of young plants is very diagnostic. 2. The observation of black sclerotia resembling shiny specks of dirt when wet and which are difficult to wash off are also diagnostic. 3. A cortical and root rot often occurs in conjunction with Fusarium wilt and causes chlorosis and wilt and may result in poor yields. The lower stem, cortex, becomes fissured, dark in color and develops few secondary roots, many of which are also dark in color and rotted.

Scab
Streptomyces scabies
See Control: 8,9,14

1. Infections occur on rapidly developing tuber tissue (stems, rhizomes, and roots may be affected).
2. The degree of infection is in response to environmental factors including variety susceptibility and ranges from a roughened or russeted area to a raised scab or to a shallow or deep pitted form. The scabs are usually quite distinct and appear as rough or corky spots on the tubers.

Wilt
Fusarium solani
F. oxysporum
F. roseum and others
See Control: 1,8

1. Chlorosis of lower leaves and leaf mottling and bronzing may occur. This is often coincidental with vascular discoloration.
2. Wilt may or may not occur but generally does in hot weather, however, leaves which are not chlorotic may also wilt.
3. Secondary roots develop poorly and aerial tubers often form.
4. Premature death may result; cortical and vascular tissue may be desiccated as well as badly discolored.
5. Tuber symptoms range from symptomless to variable degrees of vascular browning, especially at the stem end and generally extend some distance into the tuber away from the stem end.

Wilt
Verticillium albo atrum
V. dahliae
See Control: 1,8,8a,9

1. Initially leaflets of lower leaves roll along the mid rib while entire leaves curl down and become chlorotic.
2. Dark green color of healthy plants disappear and this is followed by browning and necrosis.
3. Vascular elements are plugged with fungal tissue and become brown to reddish brown.
4. Tuber vascular tissue discoloration occurs but is not as extensive as in Fussarium wilt.

Control Methods

1. Use disease-free certified seed.
2. Warm seed out of storage, seed treat, plant in warm soil, do not use large mother tubers or tubers with dry rot for seed.
3. Suberized cut seed is best to plant; suberization is encouraged by temperatures above 60°F, high oxygen and high humidity levels; if planting is delayed, hold cut seed under those conditions. Heavy rains after planting may often cause problems, thus if such weather is forecast it may be well to hold seed if good suberization conditions are available.
4. Disinfect all equipment - cutters, planters, trucks, bags, bins, etc. with a quaternary ammonium compound, lysol or sodium hypochlorite solution in warm water.
5. Reduce harvest injuries by use of slow forward speed and correct chain speeds, dig only when soil conditions are favorable and tuber skins have set, kill vines in advance of harvest in order to reduce skinning, feathering and bruising.
6. Provide and maintain ventilation in storage and reduce storage temperature slowly, hold at 36-38°F.
7. Apply fungicides to foliage at periodic intervals beginning in early July.

7a. Make periodic observations of foliage in order to determine when foliar fungicide applications should be initiated.
7b. Watch for first lesion development on lower leaves and begin applications immediately.
7c. Time fungicide applications with spore production as observed by lesion development and with short periods of wet foliage (12 hours).

7d. Keep records of temperature and humidity beginning as soon as the first cultivation.
7e. If average maximum and minimum temperatures for any consecutive five days is less than 80^{o}F and total rainfall for a 10-day period exceeds 1.2 inches or less if humidity is over 90% for long periods, apply foliar fungicides.
7f. Temperatures above 80^{o} and humidity below 90% with little or no rain for three weeks kills the fungus, no fungicide is necessary.
8. Crop rotation.
8a. Do not include sunflowers in rotation.
9. Use resistant varieties if avilable.
10. Use early maturing varieties.
11. Kill vines long enough before harvest so that they are thoroughly dry and dead before harvesting.
11a. Allow time for infected tubers to rot in the soil between vine killing and harvest. Periodic hand digging will determine the progress of skin maturation and rotting.
12. Destroy cull piles-do not depend on herbicides to kill culled tubers, sporulation may occur on non-sprouted tubers.
13. High hilling to divert rain and spores away from new tubers.
14. Do not use manure as fertilizer, apply Nitrogen if necessary.
15. Provide general insect control.

FORAGES

INTRODUCTION

North Dakota has approximately 14 million acres of native or prairie grassland in private and federal ownership. In addition, 3 to 4 million acres of seeded tame grasses and legumes are used for hay and grazing. Greater use of tame grasses and legumes should be given consideration in farm and ranch hay and grazing programs to supplement the native grassland resource. In general, tame forages produce more forage per acre and provide earlier spring grazing than native grasslands.

PERENNIAL AND BIENNIAL LEGUMES

ALFALFA is the most widely grown perennial legume in North Dakota. Its primary use is for hay, but is also used for pasture, silage and soil building. The acreage harvested for hay(Table 37) has increased steadily since the early '60's and now occupies approximately 70 percent of the tame grass and legume acreage used for hay production.

Table 37 Acreage of Alfalfa, Tame Grass and Wild Hay Harvested

Year	Alfalfa	Tame Grass Hays*	Wild Hay	Total
		Acres X 1,000		
1950	403	690	2,586	3,679
1955	1,310	479	1,996	3,785
1960	1,261	620	2,006	3,887
1965	1,326	732	1,565	3,623
1970	1,344	739	1,317	3,400
1973**	1,580	746	1,334	3,660

Source: N.D. Crop and Livestock Statistical Reporting Service
* Includes cereal crops cut for hay and tame grasses
** Preliminary

There are many alfalfa varieties available on the market from public and private breeders. New varieties are being released yearly. The most important considerations in selecting an alfalfa variety are forage yield, winter hardiness and bacterial wilt resistance, especially if grown in long term stands and under irrigation.

Ladak and Vernal alfalfa have been tested for the longest period of time and have performed exceptionally well under North Dakota conditions. Ladak, due to its high first cutting yield, is the preferred variety for western North Dakota where moisture is sometimes short for a second cutting. Comparative forage yield data for the newer alfalfa varieties growing under North Dakota conditions is often limited. However, forage yield differences between varieties with similar winterhardiness often are small, making variety selection difficult.

Relative forage yield of alfalfa varieties growing at North Dakota Experiment Stations, winterhardiness, and bacterial wilt resistance ratings are presented in Table 38. These comparative forage yield data indicate the number of test years a variety yielded significantly more than (+), equal to (=), or less than (-) the variety Vernal in the same forage yield test. The producer should select the variety Vernal or varieties that have yielded equal to or more than the variety Vernal for the greatest number of years. Relative forage yield comparisons for several recent varietal releases are shown in Table 39.

Table 38 Winterhardiness, bacterial wilt rating and relative forage yield of several alfalfa varieties as compared to Vernal at six North Dakota Experiment Stations. 1972.

Variety Winterhardiness	Bacterial wilt rating*	Number of test years variety yields MORE (+), EQUAL (=), or LESS (-) than Vernal							
		Fargo	Carrington Dryland	Carrington Irrigated	Dickinson	Langdon	Minot	Williston	All Stations
		+ = -	+ = -	+ = -	+ = -	+ = -	+ = -	+ = -	+ = -
Very Winterhardy									
Norseman	R	0 11 0	0 3 0	0 2 1	1 5 2		2 5 1	0 2 0	3 28 4
Teton**	R	0 8 6		0 2 0	5 10 0	0 2 2	0 5 1	0 5 6	5 32 15
Travois**	R	0 8 4			3 4 1		1 5 1		4 17 6
Winterhardy									
Dawson	R	0 7 0	0 3 0	0 2 1	0 3 1		0 1 2	0 2 0	0 18 4
Ladak	MS	2 31 1	1 2 0	0 4 1	6 8 1	2 2 0	1 6 0	1 10 2	14 63 5
Ladak 65	R	0 3 0	0 3 0	0 3 0			0 3 0	0 2 0	0 14 0
Rambler**	MS	0 1 5		0 2 0	1 6 0	0 2 2	0 3 2		1 14 9
Ranger	R	0 27 7	0 2 1	0 4 1	0 12 3	1 2 1	0 8 0	0 6 1	1 61 14
Rhizoma	S	0 3 8		0 2 0	2 4 1	0 3 1		0 4 1	2 16 11
Roamer	R	0 5 1			3 1 0		0 3 0	0 2 0	3 11 1
VERNAL	R	4.24 T/A	2.77T/A	5.14T/A	1.98 T/A	3.40 T/A	3.7 T/A	1.9 T/A	
Test years		36	3	5	15	4	8	13	
Cuttings/year		3	2-3	3	1-2	2	2-3	1-2	
Moderately Winterhardy									
Cody	R	0 10 3		0 1 1	0 0 4	0 4 0	0 5 1		0 20 9
DuPuits	S	0 11 11		0 1 1	0 3 8	0 1 3	1 5 0	0 0 5	1 21 27
FD-100	S	1 7 2	0 2 1	0 3 0		0 3 1			1 15 4
Glacier	S	0 5 0	0 2 1	0 3 0					0 10 1
Saranac	R	0 7 1	0 3 0	0 3 0					0 13 1
Warrior	R	0 5 0			0 3 1		0 5 1		0 13 2

* Bacterial wilt rating: VR = very resistant, R = resistant, MR = moderately susceptible and S = susceptible.
** Pasture type alfalfa.

Table 39 - Relative Forage Yield of Several New Alfalfa Varieties As Compared to Vernal at Fargo, North Dakota. 1973

Variety by Winterhardiness	Bacterial Wilt Rating*	No. of Test Years**		
		More (+)	Equal (=)	Less (-)
Winterhardy				
Agate	R		1	1
ATRA 55	MR	1	4	1
BH-22	MR	0	5	0
Dominar	MR	0	3	0
Drylander	R	0	1	0
Fremont	R	0	3	3
Iroquois	VR	0	1	0
KN-33	MR	0	5	0
Progress	R	0	2	0
Nugget	R	0	1	0
Ramsey	R	0	3	0
Scout	MS	0	4	0
Team	S	0	3	0
Titan	VR	1	3	0
Weevlchek	VR	0	3	0
Vernal	R	4.2 Tons	41 Test years	
Victoria	S	1	1	0
WL-216		0	3	0
WL-217		2	1	0
123	R	0	4	0
520	R	2	3	0
525	R	0	2	0
Moderately Winterhardy				
Anchor	R	0	1	0
Apex	S	0	2	0
Bonus	MS	0	1	0
Cardinal	S	0	5	0
Europa	S	0	5	0
Kanza	VR	0	6	3
Orchies	S	0	2	1
PAT 30	S	0	2	0
Saranac	R	0	0	2
Stride	S	0	0	2
Tempo	MR	0	2	0
Thor	VR	2	4	0
530	R	1	1	0

* Bacterial wilt rating: VR = very resistant, R = resistant, MR = moderately susceptible and S = susceptible

** Number of test years variety yielded More (+), Equal (=), or Less (-) than Vernal.

The regrowth of pasture type alfalfas, e.g., Teton, Travois, is slow following harvest and should not be considered for hay production under irrigation or where a 3-cut harvest system is practiced.

ALFALFA MANAGEMENT

Alfalfa is a perennial crop which must store food reserves in the form of carbohydrates (starches and sugars) in its roots for winter survival. Adequate food reserves in roots and crown are essential for development of cold resistance, to maintain the plant during winter and to initiate new growth in spring and following each harvest. A knowledge of the carbohydrate storage pattern in alfalfa roots is fundamental to understanding the plant's response to various management systems.

Stored carbohydrates follow a cyclic pattern throughout the growing season as forage is harvested (Fig.19). Food reserves decrease in uncut alfalfa until mid-May, corresponding with about 6 to 8 inches of new growth. As growth continues, the leaves manufacture carbohydrates in excess of normal growth and development needs, allowing storage of "food" in the roots. Food reserves in uncut alfalfa increase until full bloom in late June or early July, decrease until seed is mature in August and increase again until the first killing frost in the fall.

Alfalfa cut two or three times annually for hay shows a similar cyclic pattern in stored food reserves-decreasing following each cutting until new growth reaches 6 to 8 inches tall, then, increasing until the next cutting or until a killing frost. Note that with proper harvesting or grazing in the fall (Fig. 1) food reserves are maintained at the same level as in uncut alfalfa stands. With adequate fall food storage it is not necessary to allow complete recovery of food reserves following spring growth before the first forage harvest. Therefore, it is possible to remove the forage early (1/10 bloom or before) in order to harvest the highest quality hay and still maintain productive stands.

The productive life of an alfalfa stand is related to harvest and/or grazing management. Frequent forage harvesting at improper growth stages and overuse by grazing animals may result in one or all of the following:

1. Reduced Yields
2. Limited Root Growth
3. Increased Winterkilling
4. Thinning of Stands
5. Grass and Weed Invasion
6. Possible Disease Susceptibility

Fall management of alfalfa is critical in the maintenance of vigorous, productive stands. Alfalfa plants must produce adequate regrowth in the fall before the first killing frost to manufacture and store high levels of carbohydrates in the roots prior to winter dormancy.

Alfalfa fields with good soil moisture supply may produce substantial amounts of fall regrowth. Harvesting fall regrowth after a killing frost when the plant is dormant has little effect on stored food reserves. However, cutting for hay removes stem growth that helps catch and hold snow, providing insulation for the alfalfa's winter protection. If fall regrowth is cut late for hay, uncut strips 2 to 3 feet wide spaced 20-30 feet apart will help hold snow on the field. If pastured in late fall, graze moderately to maintain a minimum stubble height of about 6 inches.

Winter injury will occur some years even with careful management. Winter injury usually results in plants being completely killed, although some plants may be only weakened. Delaying the first harvest until about the one-half bloom stage will provide an opportunity for the injured plants to regain their vigor, however, forage quality will be lower.

If winter injury is not too severe, stands can be maintained a year or more at a lower level of production until new seedings are established. Good yields can be obtained from stands 2 years old or older if there are about five vigorous plants per square foot. If there are two large plants or less per square foot, yield will be reduced substantially. The decision when to plow up these fields will depend on the alternative sources of forage for hay or pasture. Plowing may have to be delayed until new alfalfa fields can be established.

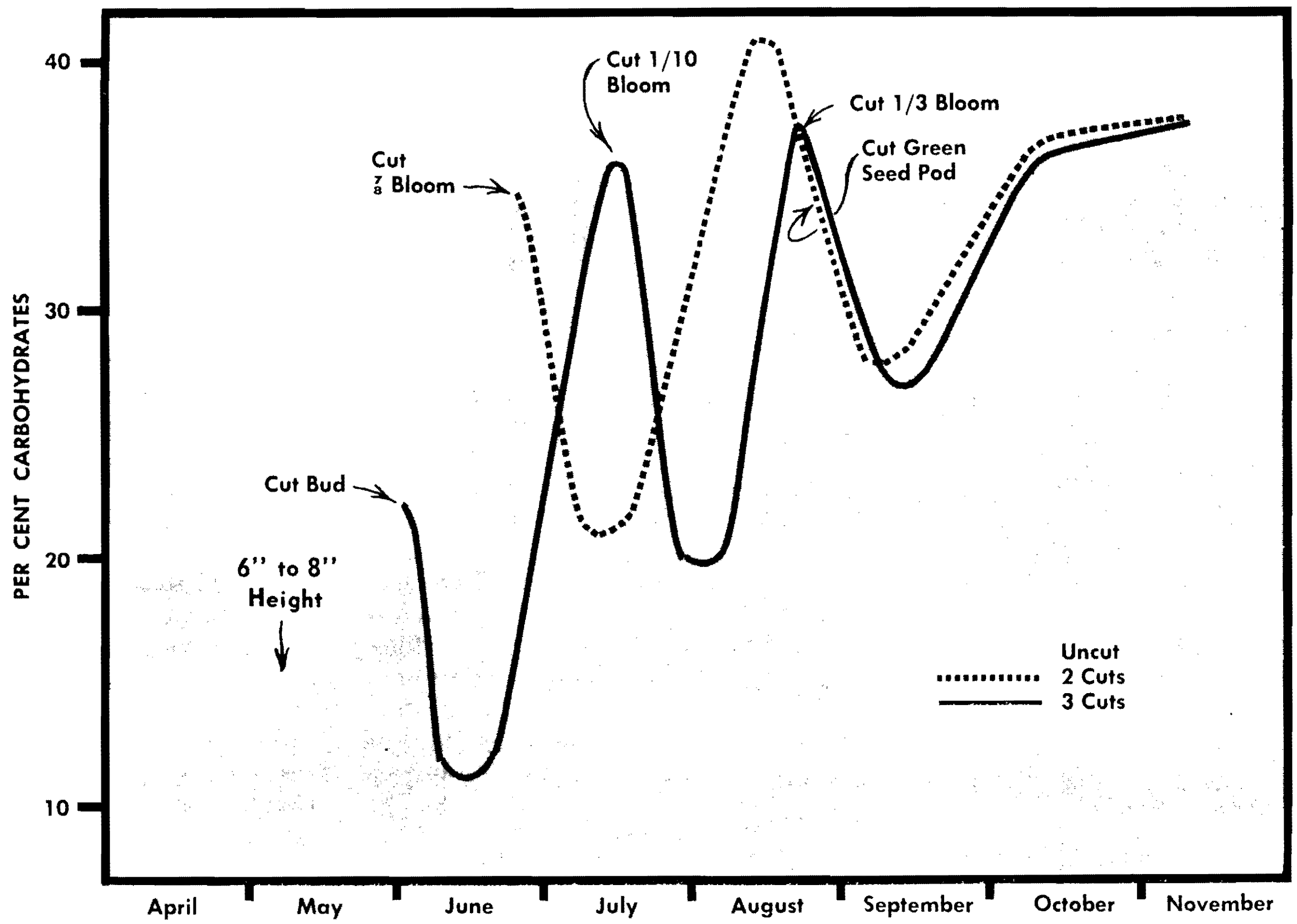


Fig.19–Seasonal trends of total available carbohydrates in roots of Vernal alfalfa with two cuttings, three cuttings and with no cutting. (Adapted from Forage Management In The North, by Dale Smith, 1962.)

SWEETCLOVER is a biennial and must be seeded each year. It is seeded in the spring, becomes established during the growing season and produces a crop the following year. Late summer and fall seedings are not recommended as the new plants may not grow large enough to survive the winter. The principal uses are for hay, pasture, silage and soil building. Madrid, Goldtop, and Yukon are yellow flowered varieties, and Denta is a white flowered variety. The variety Denta is a low-coumarin strain. Coumarin is a compound that is responsbile for "Sweetclover Disease" which may develop from livestock eating molded or spoiled sweet clover hay or silage. Bloat may be a problem when grazing sweet clover. Suggested seeding rate is 6 to 8 pounds of scarified seed per acre.

LEGUME INOCULATION

Inoculation of legume seed with the proper nitrogen fixing bacteria is recommended. Inoculation assures the presence of the correct bacterial strain to produce nodules on young seedlings for nitrogen fixation. Legume bacteria die after 2 to 3 years in light sandy soil. The bacteria are usually present in very limited numbers on fallow fields, poor soil areas, uncropped land or fields not previously seeded to the legume in question.

PERENNIAL GRASSES

BROMEGRASS

SMOOTH BROMEGRASS is a winter hardy, long-lived perennial sod-forming grass introduced from Hungary. There are two distinct types of smooth bromegrass, the "southern type" and the "northern type". Southern types are noted for having an agressive sod formation, whereas the northern types produce more open stands.

Bromegrass provides excellent hay and pasture forage under soil and moisture conditions of the eastern two-thirds of North Dakota. It provides excellent quality pasture from about May 15 throughout the grazing season. It is the best adapted grass for use under irrigation and should form the base for all mixtures.

In addition, bromegrass is an excellent soil binding grass due to its sod forming characteristic. It is widely used in grass waterway seedings.

Blair, Baylor, Fox, Sac and Lincoln are southern types; Carlton is a northern type and Magna and Manchar are intermediate in type between northern and southern varieties.

CRESTED WHEATGRASS

STANDARD CRESTED WHEATGRASS is a hardy, drouth resistant, perennial bunchgrass introduced from Russia. Crested wheatgrass is a valuable forage for hay and pasture in western North Dakota. Growth begins early in the spring and provides excellent pasture from early May until late June. During warm, dry periods growth ceases, but begins again with the approach of cool, moist weather in the fall.

Crested wheatgrass makes a high quality, palatable hay when harvested shortly after the heads appear. Palatability and forage value decline rapidly as the plant approaches maturity.

Nordan and Summit are two distinct varieties of the standard crested wheatgrass type. The variety Nordan appears to have more seedling vigor under North Dakota conditions. Fairway crested wheatgrass, a distinct species, is recommended for dryland lawns, golf fairways, and airports. Fairway crested wheatgrass has lower palatability and less vigorous seedlings than standard crested wheatgrass varieties. Parkway is a variety released by the Canada Department of Agriculture.

RUSSIAN WILDRYE

RUSSIAN WILDRYE is a long-lived, perennial bunchgrass introduced from Siberia. It is especially useful in North Dakota as a pasture grass under intensive pasture management systems. Growth begins in April, similar to crested wheatgrass, but its period of summer growth is longer than other cool-season grasses. Growth will continue following seed maturity provided soil moisture is adequate. Early season growth may be saved for late summer and fall grazing. This grass retains high nutritive qualities and palatability late into the fall.

Russian wildrye requires high fertility to maintain top forage yields. Hay yields are low due to its basal leaf habit of growth.

Stands are more difficult to establish than crested wheatgrass or bromegrass. Excellent stands have been established, however, when seeded on summer-fallow in early fall, or in late fall as a dormant season seeding in clean crop stubble.

The variety Vinall has been shown to equal commercial Russian wildrye in forage yield and produces higher seed yields. Mayak is a variety released by the Canada Department of Agriculture.

SLENDER WHEATGRASS

SLENDER WHEATGRASS is a short-lived native perennial bunchgrass. Principle use in North Dakota is in grass mixtures. The seeds germinate quickly and the seedlings are vigorous and fast growing. Slender wheatgrass loses vigor and generally decreases in grass seedings in two to three years.

Two to three pounds of slender wheatgrass in grass seed mixtures will insure success in establishing an acceptable stand of grass.

Slender wheatgrass possesses tolerance to saline (salty), and sodic (alkali) soil conditions. When grown on relatively dry sites it may be equal to tall wheatgrass in tolerance to saline or sodic soil conditions.

INTERMEDIATE WHEATGRASS

INTERMEDIATE WHEATGRASS is a sod-forming grass introduced from the USSR. It is a vigorous, fast growing grass, similar to slender wheatgrass. Its principle use is in short rotations for hay or pasture. Like slender wheatgrass, it is an "insurance" grass in grass mixtures, or it may be used as the principal grass with alfalfa. Forage production generally declines after three growth seasons.

Varieties available include Chief, Oahe, and Ree.

TALL WHEATGRASS

TALL WHEATGRASS is a tall, coarse, late maturing bunchgrass introduced from Turkey and the USSR. Principal use in North Dakota is in the reclaiming of wet saline or sodic soils. It has the ability to establish stands under these soil conditions. Tall wheatgrass is not tolerant to standing water.

Forage yields are similar to intermediate wheatgrass and pubescent wheatgrass in North Dakota tests. Palatability of the hay is fair.

In recent years, tests have shown that it has a potential use for wind erosion control when grown in wide double row strips spaced uniformly across a field.

Distinct varieties of tall wheatgrass are not readily available. Alkar is a named variety developed and released by the state of Washington in 1959. Orbit is a variety released by the Canada Department of Agricultue in 1966.

PUBESCENT WHEATGRASS

PUBESCENT WHEATGRASS is a sod-forming grass introduced from the USSR. It is similar to intermediate wheatgrass and distinguished from it by the presence of short, stiff hairs on the heads and seeds.

Varieties of pubescent wheatgrass are reported to differ from intermediate wheatgrass in forming a more open sod, more drouth tolerance and adapted to lower fertility soils. North Dakota tests show almost identical performance by intermediate wheatgrass and pubescent wheatgrass.

Mandan 759 is a variety developed at the Northern Great Plains Research Center, Mandan, North Dakota. This variety is reported to produce higher forage and seed yields than other varieties tested at Mandan.

REED CANARYGRASS

REED CANARYGRASS is a broad-leafed, coarse, sod-forming native grass adapted to moist or undrained soils. It is not tolerant to saline or sodic soil conditions. Reed canarygrass is an excellent grass for seeding in shallow ponds or on soils subject to periodic flooding.

Properly managed to maintain palatability, reed canarygrass will provide good hay and pasture. For hay, cut when the first heads begin to appear. A second cutting of leafy forage is possible if harvested in this manner. For pasture, graze heavily enough to maintain a growth no taller than 12 to 15 inches.

It is an excellent grass for use in grass waterway seed mixtures on moist or wet soils because it forms a dense, tough sod.

Varieties available include Frontier, Grove, and Rise.

GARRISON CREEPING FOXTAIL

CREEPING FOXTAIL is a sod-forming grass introduced from Eurasia. The variety "Garrison" was found in the early 1930's growing in sloughs in McLean county, near Max, North Dakota. Garrison creeping foxtail is well adapted to wetland sites. It can withstand spring flooding and standing water as well as reed canarygrass. It is not tolerant to saline or sodic soils.

Field evaluations indicate that Garrison creeping foxtail has high forage palatability when used for either hay or grazing. Tests at Fargo show good forage yields.

Principal use in North Dakota should be for seeding on wet soils or areas subject to periodic flooding. Under these conditions it is well adapted for grass waterway seedings.

GRASS-ALFALFA MIXTURES

Forage yields are generally higher with pure stands of alfalfa. Grasses are recommended in mixtures with alfalfa for pasture. Pasture plantings containing about 60 percent grass and 40 percent alfalfa tend to reduce the bloat hazard, especially with proper grazing management. In addition, grass-alfalfa mixtures are an insurance against an alfalfa stand loss from winterkilling and provide additional protection against soil erosion. Grasses produce the major portion of their growth early in the season, usually permitting only one cutting for hay production. Therefore, pure stands of alfalfa or, if mixtures are desired, stands with more than 50 percent alfalfa should be used for highest annual forage production.

SEEDING PRACTICES

Building a firm foundation requires careful planning or new forage seedings may fail. Primary building blocks include:

1. Selection of high quality seed
2. Use of adapted grasses and legumes
3. Proper seedbed preparation
4. Management of companion crop
5. Correct seeding date
6. Proper planting depth
7. Correct planting method
8. Adequate soil fertility
9. Proper management of new plantings

Numerous grass and legume varieties are available for dryland and irrigated hay and pasture seedings. In general, the forage variety selected will depend on the intended use, area of adaptation, productive potential, season of use if seeded for pasture and soil conditions.

Adding alfalfa to a grass or grass seed mixture usually increases forage production. When seeding grass-alfalfa mixtures try to obtain final stands containing about 60 percent grass and 40 percent alfalfa for pasture. Pure stands of alfalfa will generally provide a higher hay yield than a grass-alfalfa mixture. However, if a mixture is used for hay the initial stand should contain 50 percent or more alfalfa. Planting 1 to 4 pounds of alfalfa in pasture mixtures normally will provide adequate stands. Bloat may be a problem when grazing grass-alfalfa mixtures, especially alfalfa regrowth, requiring careful livestock management. Bloat may also be a problem when grazing sweet clover.

Suggested dryland and irrigated hay and pasture mixtures for North Dakota are listed in Tables 40 & 41. The dryland seeding rates are given for pasture. If a grass-alfalfa mixture is used for hay increase the alfalfa seeding rate by 2 pounds per acre and decrease the proportion of grass in the mixture or use 5 to 8 pounds of alfalfa if seeded in a pure stand. Slender wheatgrass is suggested for use in dryland seed mixtures because seeds germinate quickly and produce vigorous fast growing seedlings. If slender wheatgrass seed is not available, use intermediate wheatgrass or pubescent wheatgrass.

Table 40 - DRYLAND PASTURE AND HAY SEED MIXTURES

Forage Crop	Seed Mixture Pounds/Acre				
		Central			
	West	West	East	East	Statewide
Alfalfa	1-2	1-2	2-3	3-4	
Crested Wheatgrass	7	7			
Slender Wheatgrass	2-3	2-3	2		
Smooth Bromegrass			6-7	7-8	
Russian Wildrye					10-12
Total	10-12	10-12	10-12	10-12	10-12

Smooth bromegrass performs well on good moisture sites throughout the state. Smooth bromegrass and crested wheatgrass may be used in the same seed mixture on hilly or rolling land if desired.

Irrigated pasture seed mixtures suggest the use of grass and alfalfa or pure stands of grass. If a pure stand of grass is seeded under dryland or irrigated conditions annual applications of nitrogen fertilizer will be required for optimum forage yields. Forage plantings containing 30 percent or more alfalfa will usually only require the application of phosphorus depending upon the level of phosphorus in the soil. The level of phosphorus can be determined through a soil test. Fertilizer recommendations are given in Table 33.

Irrigated pasture mix 3 suggest using orchardgrass, a cool-season perennial with a distinct bunch type growth habit, which forms an open sod. Orchardgrass begins growth early in the spring, recovers rapidly following grazing and has a more uniform seasonal distribution of growth as compared to smooth bromegrass. However, available varieties lack adequate winter hardiness to be planted as the only grass under irrigation in North Dakota. Orchardgrass will be better adapted to irrigated pasture mixtures in the southern half of North Dakota. The varieties Avon, Nordstern and Sterling are suggested for trial plantings.

Table 41 - IRRIGATED PASTURE AND HAY MIXTURES

	Seed mixture pounds/acre			
	Mix 1	Mix 2	Mix 3	Hay
Alfalfa		1-2	1-2	10-12
Orchardgrass			3-4	
Smooth bromegrass	14	12	8	
Reed Canary grass or Garrison Creeping Foxtail	2	2	2	
Total	16	15-16	14-16	10-12

Under ideal conditions (good soil moisture, proper seedbed preparation, good seeding methods and proper seeding depth) forage stands can be obtained by using LESS seed per acre than shown in Table 40 & 41. Under field conditions, 50 percent or more of the potential grass or legume seedlings may be lost due to the following factors:

- .Soil Moisture
- .Soil temperature
- .Soil aeration
- .Surface soil crusting
- .Depth of seeding
- .Disease
- .Insects
- .Weeds
- .Soil fertility
- .Soil erosion
- .Winter injury

The approximate number of seeds per pound of various grass and legume species and seeds per square foot when planted at one pound per acre is shown in Table 42.

Table 42 - FORAGE SEED COUNTS

Species	Seeds/lb	Seed/sq.ft. at 1 lb/A. Seeding Rate
Alfalfa	200,000	4.6
Sweet clover	260,000	6.0
Creeping meadow foxtail	610,000	14.0
Crested wheatgrass	190,000	4.4
Intermediate wheatgrass	88,000	2.0
Orchardgrass	650,000	14.9
Pubescent wheatgrass	100,000	2.3
Reed Canarygrass	530,000	12.2
Russian wildrye	175,000	4.0
Slender wheatgrass	160,000	3.7
Smooth bromegrass	135,000	3.1
Tall wheatgrass	79,000	1.8

Increasing individual species seeding rates to above recommended levels will not compensate for poor seeding management.

SEEDBED PREPARATION

A firm seedbed is essential for grass and legume establishment. A well packed seedbed will permit a shallow, precise seeding depth and allow the seed to be placed in close contact with moist soil.

Methods of seedbed preparation depend on individual situations but tillage usually is necessary. Demonstration grass and legume plantings have shown that coarse textured soils (sandy) require packing prior to seeding to obtain satisfactory stands. Seedbeds packed twice with a press drill prior to seeding had better stands than those packed only once. Medium textured soils may require packing, depending upon the amount of soil disturbance during seedbed preparation.

PACK SEEDBED FIRM ENOUGH SO THAT TRACKS MADE BY A MAN WALKING ACROSS IT ARE HARDLY VISIBLE.

The type of seedbed has a marked effect on dryland grass and legume establishment. Field observations of spring and late fall plantings indicate that when seeding directly into crop stubble, the prior crop has an influence on successful stand establishment. Sudangrass stubble was found to provide the best forage stands, followed by sorghum, millet, oats, barley, wheat and flax stubbles.

COMPANION CROPS

Companion crops such as flax, wheat, oats and barley often are used with new grass and legume seedings. The decision whether to use a companion crop should be based on the soil moisture situation in your area, availability of irrigation water and need for soil erosion and weed control. Flax is the least competitive of the companion crops. Wheat is a good companion crop if it does not lodge. Early maturing oats or oats removed for hay or silage are satisfactory, also. Barley is the most competitive at normal seeding rates because of thick tillering and wide leaves. Barley often lodges in areas where moisture is plentiful and where soils are highly fertile. Legumes establish better than grasses when seeded with a companion crop.

COMPANION CROPS ON DRYLAND. Normal seeding rates of companion crops may compete severely with grass and legume seedlings for soil moisture, nutrients and sunlight. Seeding the companion crop in 18 to 21-inch row spacings at the normal drill setting may be desirable in the drier sections of North Dakota. Solid seedings of oats at two-thirds the normal rate or a normal seeding rate of flax may be used in eastern North Dakota or on sites where soil moisture is adequate throughout the growing season. Companion crops are desirable on sites where soil erosion and weed growth may be a problem. If grass seeding equipment is not available, seed the companion crop first, then, seed the forage crop in the opposite direction. If weeds can be controlled, grass and legume establishment will be more succesful if seeded without a companion crop in the western one-half of North Dakota, due to competition for soil moisture.

COMPANION CROPS WITH IRRIGATION. Companion crops usually are planted with new grass and legume seedings in the spring under irrigation. With limited irrigation water available, planting the companion crop at rates similar to that suggested for dryland may be desirable. Research in North Dakota indicates that 1 bushel of oats or barley can be seeded with perennial forage crops without a substantial loss of grain yield or future production provided adequate irrigation water is available. Do not use companion crops with fall seedings unless soil erosion is a major problem. High rates of nitrogen fertilizer plus high companion crop seeding rates in combination will reduce forage yields the following year. Adjust the seeding rate of companion crop and fertilizer application rate to avoid heavy growth and lodging.

Loose straw, especially if in a heavy swath or compacted near the soil surface, should be removed from new plantings within two or three days or grass and legume seedlings may die. Use of straw chopper-spreader or straw catcher is desirable to avoid swath on new seedings.

SEEDING DATES

The best seeding date depends on the area of the state in which you live, soil moisture situation and whether grasses or legumes are being seeded.

Perennial grasses may be seeded when established plants are beginning to grow in open fields (not protected areas) and continue as long as surface soil moisture is available to germinate seed. Grasses require 8 to 14 days for germination.

Spring planting of legumes may begin when established stands begin to grow well in open fields. Legumes may be planted as late as mid July without a companion crop, provided conditions favor immediate germination. Legumes require 5 to 7 days for germination.

The following guidelines for spring, early fall and late fall forage seedings will be helpful.

SPRING PLANTING. Planting forage crops in good clean stubble without a companion crop has been very successful; however, one crop year is lost. The stubble protects the new seedlings from blowing soil without competing for available soil moisture. Plantings on clean tilled land with a companion crop will be most successful provided soil moisture is not limiting. On soils subject to wind erosion plant the companion crop first, e.g., flax, wheat, oats, then after the companion crop is up and controlling erosion, seed the grass or legume in the opposite direction. If oats is used as the companion crop it may be removed early as hay or silage to eliminate competition. Barley, wheat and flax usually are harvested as grain, but if conditions turn dry they should be removed early.

EARLY FALL ON SUMMERFALLOW AND STUBBLE LAND. Early fall (August 10 to September 10) planting of grass on firmly packed summerfallow is one of the best seedbeds for grass under dryland conditions. Planting grass in clean, well packed crop stubble following an early grain crop harvest provides an effective seedbed provided early fall rainfall or irrigation water is available to promote rapid seed germination and seedling establishment. With adequate moisture available the grass seedlings make rapid fall growth and provide productive stands the following season. Plant protective strips of flax on summerfallow for erosion control, moisture conservation and to trap snow to protect the grass seedlings. Do not plant legumes in late summer or early fall on dryland. They will not grow large enough to survive the winter. If it is necessary to plant the legume in the fall on dryland, delay seeding until just before freeze-up or plant early the next spring. Early spring planting of legumes appears to produce better stands than late fall seedings.

LATE FALL PLANTING. Successful plantings have been made by seeding in late fall just before freeze-up in fields where corn, sudan grass or sorghum have been cut for silage. Two rows cut high, 24 to 30 inches, and left every 30 to 40 feet protect against soil drifting and hold snow on the field. Planting in clean, well packed small grain stubble also provides a good seedbed.

Grasses and legumes seeded during late fall are ready for early germination and growth when the soil warms up in the spring. Late fall is an excellent time for seeding on sandy soils throughout the state. However, fall seedings run the risk of fall germination and winter killing or very early spring germination and killing by freezing temperatures.

SEEDING DEPTH

Improper planting depth is the cause of many grass and legume seeding failures. A shallow seeding depth is important in establishing grasses and legumes. Large seeded grasses and legumes should be planted ½ to 3/4 inch deep on medium to heavy textured soils. Due to rapid drying of the surface, it may be desirable to plant at 1 to 1½ inches on sandy soils. The shallower depths are recommended for small seeded grasses and legumes. "Broadcast" seedings of legumes may be successful in early spring provided surface soil moisture is plentiful for about a week. Grass should always be seeded into the soil and followed by press wheels.

SEEDING METHODS

A press drill with grass seed attachment equipped with a seed agitator is satisfactory for seeding grasses and legumes provided a firm seedbed is prepared. If seedbed is not firm enough to regulate seeding depth, the grass or legume seed should not go down the same spouts as the grain. Place the grass and legume seed spouts to drop the seed behind disc openers and in front of the press wheels. Special grass drills with depth control bands are available from a number of Soil Conservation Districts throughout the state.

SOIL FERTILITY

A well planned fertility program is necessary to maintain high forage yields under dryland and irrigation production systems. Take an inventory of your soil fertility needs - SOIL TEST.

Nitrogen and phosphorus are the primary nutrients limiting forage production in North Dakota. However, plant response to phosphorus additions usually is small. Nutrient requirements for stand establishment are different than the fertility needs for maintaining productivity of established stands.

STAND ESTABLISHMENT

Seeds can germinate without the addition of fertilizer. However, once the small amount of nutrients in the seed is used up, the young seedlings depend entirely on soil nutrients for their development.

Nitrogen generally is not needed for successful stand establishment under dryland or irrigation. Moderate to high levels of applied nitrogen at seeding promote the growth of weeds and the companion crop, which may provide too much competition for the new forage seedlings, especially on dryland. Legumes properly inoculated before planting normally do not require nitrogen fertilization.

Phosphorus encourages root development. A well developed root system helps protect seedlings from winter injury and produce vigorous stands the following spring.

Potassium generally is high in North Dakota soils. A soil test will determine the level in your soils.

Recommended rates of phosphorus and potassium for new seedings and established grass stands are listed in Table 33. Nitrogen may be applied at 10 pounds per acre on dryland and 20 to 30 pounds per acre under irrigation if needed by the companion crop. Do not apply more than 10 pounds of nitrogen plus potassium in the row with grass seed or germination injury may occur.

ESTABLISHED STANDS

Established stands of grass have responded primarily to the application of nitrogen fertilizer. However, nitrogen applications at recommended rates on dryland and irrigated grass may require an application of phosphorus to maintain nutrient balance and high forage production (See Table 33).

Response of pure stands of alfalfa to phosphorus and potassium has been variable throughout North Dakota. The greatest potential for increased forage yields due to fertilizer application is on soils testing very low in these nutrients. Leave an unfertilized check strip in the fertilized field to determine the response of alfalfa to fertilization. REMEMBER - A soil test provides an inventory of your soil nutrient status.

Alfalfa and grass-alfalfa mixtures containing 30 percent or more alfalfa are fertilized to maintain alfalfa in the stand. Phosphorus, if limiting production, increases the ability of the alfalfa plant to maintain itself in the mixture. Potassium may be limiting on sandy soils. Nitrogen increases grass yields, but high rates may increase grass growth and eliminate alfalfa from the mixture. Table 32 lists phosphorus and potassium recommendations for dryland and irrigated alfalfa and grass-alfalfa mixtures.

MANAGEMENT AFTER SEEDING

Keep a close watch on new seedings. A crust may form before seedlings emerge. A light irrigation or surface roughening will aid seedling emergence. A rotary hoe pulled backwards has been effective in breaking up a surface crust. Surface residues help to prevent surface drying, break the force of raindrops and reduce soil puddling, thereby holding more moisture near the surface and reducing surface crusting problems. Irrigated seedlings may require frequent light irrigations to keep soil moist in the seedling root zone.

Growth of weeds may be a problem on late fall or spring plantings where companion crops are used. Mow the weeds only if they offer severe competition to the new forage seedlings. Pure grass seedlings can be mowed short without much injury to the seedlings. Legume seedlings are injured severely by close mowing for weed control. Mowing for weed control should be done when daytime temperatures are cool. Herbicides also may be applied as outlined in Circular W-253, "Weed Control in Field Crops."

Alfalfa planted in early spring without a companion crop and with herbicides used for weed control quite often makes enough growth for one cutting of forage in the fall. Harvest new seedings before August 20 to allow adequate regrowth for storage of food reserves in the roots. Spring planted perennial forage crops may be moderately grazed in late fall of the seeding year.

FORAGES FOR PROBLEM SOILS

Perennial forages are the most tolerant crops to salty or wet soil conditions. The tolerance of a particular crop to salty or wet soil conditions determines the ability to produce satisfactory yields. Generally, grasses are more tolerant than legumes. The performance of forage crops growing on problem soils will vary depending upon the variety selected, variety adaptation to the area, soil salinity level and the soil wetness.

There is no safe limit of soil salinity for many salt-sensitive or moderately salt-tolerant forage species. Forage yield decreases even at low levels of salinity. Table 43 provides an estimate of the salt tolerance for a number of different forage species. Within each tolerance grouping species are listed in decreasing order of salt tolerance. A particular species may vary in its ranking due to differences between varieties and strains. Ranking of an individual forage within each tolerance grouping is based on a yield reduction of approximately 50 percent. Yield of forages will be greater at lower salinity levels.

Table 43 **ESTIMATED TOLERANCE OF FORAGE CROPS TO SALTS BASED ON ELECTRICAL CONDUCTIVITY (EC) READINGS.**

DECREASING SALT-TOLERANCE →

Very High Tolerance	High Tolerance	Moderate Tolerance	Slight Tolerance
None (try high tolerance forages)	Tall wheatgrass	Sweet clover	Alfalfa (Seedling)
	Slender wheatgrass	Sudangrass	White Dutch clover
	Russian wildrye	Millet	Alsike clover
	Western wheatgrass	Sorghum	Red clover
	Birdsfoot trefoil	Alfalfa (Established)	
		Crested wheatgrass	
		Smooth bromegrass	
		Intermediate wheatgrass	
		Canada wildrye	
		Garrison creeping foxtail	
		Reed canarygrass	

Forages differ in their tolerance to early spring flooding (Table 44). Flooding tolerance is greater when temperatures are low. When temperatures are cool, as in early spring, plants remain dormant longer and oxygen requirements are lower than when growth begins. Most plants are easily killed when flooded in mid-summer. However, reed canarygrass and Garrison creeping foxtail can tolerate a water saturated soil or limited flooding in mid-summer. Grasses are usually more tolerant to flooding than legumes.

Table 44 **ESTIMATED FLOODING TOLERANCE OF ESTABLISHED FORAGE SPECIES IN EARLY SPRING.**

Species	Flooding Tolerance - Days -
Legumes:	
Sainfoin	5
Sweet clover	10
Alfalfa	15
Red clover	15
Birdsfoot trefoil	20
Grasses:	
Crested wheatgrass	10
Orchardgrass	10
Switchgrass	14
Intermediate wheatgrass	21
Russian wildrye	21
Smooth bromegrass	24
Garrison creeping foxtail	35 1/
Slender wheatgrass	49
Reed canarygrass	49
Tall wheatgrass	49
Western wheatgrass	49

1/ Estimated based on tolerance of meadow foxtail.

Forage varieties or seed mixtures to be planted on problem soil areas should be selected based on the level of soil salinity and the days or weeks of early spring flooding. Suggested seed mixtures are listed in Table 45 for various soil salinity and spring flooding conditions.

PLANTING PRACTICES

Forage establishment is usually the most critical phase in managing saline soils. This is because salt concentrations often build up in the surface inch or so of soil due to an upward movement of saline soil water. Evaporation occurs at the surface, leaving salts behind. The germinating seed is then exposed to salt concentrations much higher than encountered by roots during later growth states.

Low soil moisture is a severe handicap in securing adequate stands of forages. High concentrations of salts at the soil surface in combination with low soil moisture intensifies the moisture shortage. Therefore, the time of seeding must depend on the degree of salinity and the possibility of flooding. Available alternatives include:

Low salinity, little or no flooding
- Early spring planting
- Early fall planting
- Dormant-season planting

Moderate to high salinity - periodic flooding
- Early fall planting
- Dormant-season planting

Canadian studies indicate that germination, emergence and stand establishment are the most successful under moist soil conditions. Also, seedbed preparation is not as important as good soil moisture. If conditions permit a well-prepared seedbed is also desirable. Fall planting has resulted in better stands than spring planting. If early fall rains do not occur, a dormant-season planting (just prior to freeze-up) will place the seed in the soil, ready to germinate early the following spring when soil moisture is usually high.

FERTILIZER USE

- Make trial applications of commercial fertilizers.
- No chemicals or commercial soil conditioners will correct saline soil conditions.

Table 45 **SUGGESTED FORAGE SEED MIXTURES FOR PROBLEM SOIL AREAS.**

LITTLE OR NO SPRING FLOODING	
Slight to Moderate Salinity	Lbs Seed/acre
1. Smooth bromegrass + slender wheatgrass + alfalfa	4 + 4 + 4
2. Crested wheatgrass + slender wheatgrass + alfalfa	4 + 4 + 4
3. Smooth bromegrass, intermediate wheatgrass + alfalfa	4 + 4 + 4
Moderate to High Salinity	
1. Tall, slender and western wheatgrass + sweet clover	5 + 4 + 5 + 2
FLOODED 2 TO 5 WEEKS	
Slight to Moderate Salinity	
1. Reed canarygrass + bromegrass	4 + 6
2. Reed canarygrass + bromegrass + slender wheatgrass	2 + 6 + 3
3. Garrison creeping foxtail	5
4. Garrison creeping foxtail + slender wheatgrass	3 + 5
Moderate to High Salinity	
1. Russian wildrye	10
2. Russian wildrye + slender wheatgrass	8 + 4
FLOODED 5 TO 7 WEEKS	
Slight to Moderate Salinity	
1. Reed canarygrass	5
2. Reed canarygrass + slender wheatgrass	3 + 5
High to Very High Salinity	
1. Tall wheatgrass	15
2. Tall wheatgrass + slender wheatgrass	8 + 4
3. Tall wheatgrass + slender wheatgrass + western wheatgrass	6 + 4 + 5

ANNUAL FORAGE CROPS

Annual forages are most often used as emergency crops for hay, grazing or silage. The exceptions being corn and forage sorghums used for silage and sudangrass which are usually incorporated into planned livestock forage and grazing programs. Perennial forages will produce as much forage as such cereal crops as oats or barley and the cost of production will generally be lower.

Oats is an excellent annual insurance crop which can be used for hay, pasture or silage if perennial forages fail due to early-season drouth, especially if seeded on summerfallow. If the crop is not required for forage during average or better years it can be harvested for grain.

Studies at Fargo, North Dakota have shown that highest dry matter production is obtained when oats is harvested at the dough stage of growth, however protein production per acre was highest at the milk stage of seed development. Nitrate poisoning from oat hay or pasture may be a problem, especially during periods of drouth.

Oats may be useful as an early summer pasture during drouth years or it may be used as temporary pasture while perennial grasses and legumes are being established. Grazing may begin at the 5-6 leaf stage of growth and no later than the boot stage of growth. If left ungrazed longer, the crop will get ahead of the animals unless grazed at a high intensity. Carrying capacity of oats seeded on summerfallow for pasture is estimated to be approximately 1 cow/acre for 60 days in western North Dakota; 1.5 cows/acre in central areas; and 2.0 cows/acre in eastern North Dakota.

Recommendations are provided for various emergency pasture crops in Table 46 and emergency hay and silage crops in Table 47.

NOTES

Table 46. EMERGENCY PASTURE CROPS FOR NORTH DAKOTA

Crop	Varieties	Rate of Seeding Per Acre	Time of Seeding	When to Pasture	Remarks
Winter Rye	Any common variety	5 to 6 pecks	Fall, early spring or summer	6 inches high	Fall or early spring seeding will provide spring grazing. Summer seeding will provide fall grazing. May cause some flavor in milk. Take cows off 2 hours before milking
Oats	Any variety	2 bu.	Early spring	6-8 inches high	For early summer grazing. Wheat and other cash crop cereals can be grazed in an emergency
Sudan Grass	Piper (a low prussic acid variety)	20 to 30 lbs. close drilled 5 to 8 lbs. in rows for dry areas	Late May to July	Cattle: 18 to 24 in. high Sheep: 12 to 15 in. high	Piper has the lowest prussic acid content. There is little danger of poisoning except from regrowth after severe drouth or after frost in the fall. Keep stock off such new regrowth until it reaches a height of 18 inches. Other varieties can be used for hay or silage.
Rape and Oats	Dwarf Essex rape Any early variety of oats	6 to 8 lbs. rape & 5 pecks of oats, mixed and close drilled	Early spring	6-8 inches high	Provide summer and fall grazing up to and after frost. A very good hog and sheep pasture. May cause off flavor in milk. Take cows off 2 hours before milking.
Millet	Siberian, German or other hay millet	15 to 25 lbs. close drilled	Late May or early June	6 inches high	A better emergency hay crop than for pasture
Corn	Any adapted variety	7 to 10 lbs. in 42 inch rows	Late May or early June	In fall	Although corn is generally considered a fodder or grain crop it can provide a lot of pasture in an emergency.

Table 47. EMERGENCY HAY AND SILAGE CROPS FOR NORTH DAKOTA

Crop	Varieties	Rate of Seeding Per Acre	Time of Seeding	When to Harvest	Remarks
Corn	Early enough to make good ears.	7 to 10 lbs. in 42 inch rows	May 10-25 or later	Well dented or glazed	Corn makes excellent silage which is a good replacement for hay.
Sudangrass	Piper (a low prussic acid variety). Sweet Sudan. Hybrids	20 to 30 lbs.close drilled. 5 to 8 lbs. in rows for silage	Late May to July 1	Silage - dough stage Hay - heading, first crop before heading	Sudangrass makes better silag than hay. Two hay crops are sometimes possible from early seeding and early first cutting.
Sorghum	Rancher (low prussic acid) or other Black amber type - Leoti Red, Fremont. Hybrids	5-8 lbs. in rows	Late May to July 1	Heavy dough or after frost	Best as silage but can be use as a bundle feed.
Foxtail Millet	Siberian - German - Hungarian.	15-25 lbs.	Late May to early July	As soon as headed	Best used for hay although quality is only fair.
Oats	Any late-maturing variety	2 bu.	Early spring	Hay - late milk to early dough	Makes better hay than other cereal grains also good silag
Soybeans	Late-maturing varieties.	2 bu. close drilled or 1 bu. with 8 lbs. sudangrass	Late May to June 15	Leaves just starting to yellow	A good protein hay. Hay some what hard to cure. Plant onl in areas where soybeans are adapted.
Oats and peas	Midseason oats and Canadian field peas	40 lbs. oats 35 lbs. peas	May	Oats in milk or early soft dough	A good silage crop about equa to corn especially for dairy.

PASTURE MANAGEMENT

The key to maintaining productive stands of grass for livestock use is proper grazing management. Forage production can be highly variable from year to year due to the amount and distribution of precipitation and intensity of past grazing use. The number of livestock grazing a pasture should be based on the potential forage production during an average year and the needs of the grass plant.

Proper use of pastures is important if the grass stand is to be maintained in a healthy, vigorous growing condition. For NATIVE pastures, grazed from the date of grazing readiness (May 15 in southern North Dakota to May 25 in northern North Dakota) in the spring through the fall period, a minimum of 45 percent of the current seasons production by weight of the major forage grasses should be left standing at the close of the grazing season. Pastures grazed to obtain this degree of use will have a patchy appearance - some areas over-grazed, some areas under-grazed, and a number of grass seed heads should be showing. Late fall and winter grazed NATIVE pastures do not require as much carry-over of standing forage. Full use, 60 to 80 percent of the current seasons production may be utilized without apparent injury to the grass stand. This is because the grass plant has stored up food reserves in its roots and crown during the growing season. A carry-over of standing grass is desirable to provide winter protection and trap snow to help build up soil moisture reserves for use the following year.

SEEDED TAME GRASS pastures will produce higher forage yields than native pastures. Since production is higher and because old grass carry-over does not have to be as great, more forage is available to the grazing animal. A utilization of 70 percent of the current seasons production should be the goal to maintain healthy stands of grass. A 2 to 3 inch stubble height on crested wheatgrass and Russian wildrye pastures will provide approximately 30 percent forage carry-over. If Russian wildrye is used only in the fall, very little carry-over is required to maintain healthy, vigorous growing plants. Smooth bromegrass requires a 3 to 4 inch stubble to obtain adequate regrowth during the grazing season. Seeded pastures should have about 4 to 6 inches of leaf growth before grazing begins in the spring.

Following several years of grazing, livestock numbers or acres available for grazing should be adjusted to provide proper grass carry-over at the close of the grazing season. In dry years carry-over will be short and total production may not equal average total production for the area. Several management practices can be applied on farms and ranches to obtain proper use of the grassland resource.

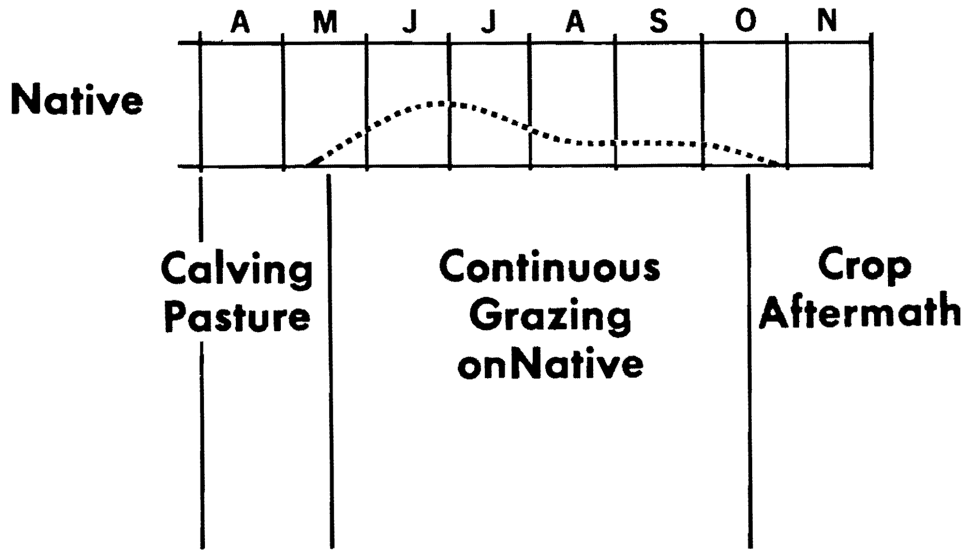
SELECTION OF GRAZING SYSTEM

SEASON-LONG USE OF NATIVE PASTURE

The grazing system used on farms and ranches is usually based on the acreage of native grassland available, kind of grasses available for grazing, topography of the area, number of pastures or pasture units, operators herd management objectives, and the ease of implementing the system.

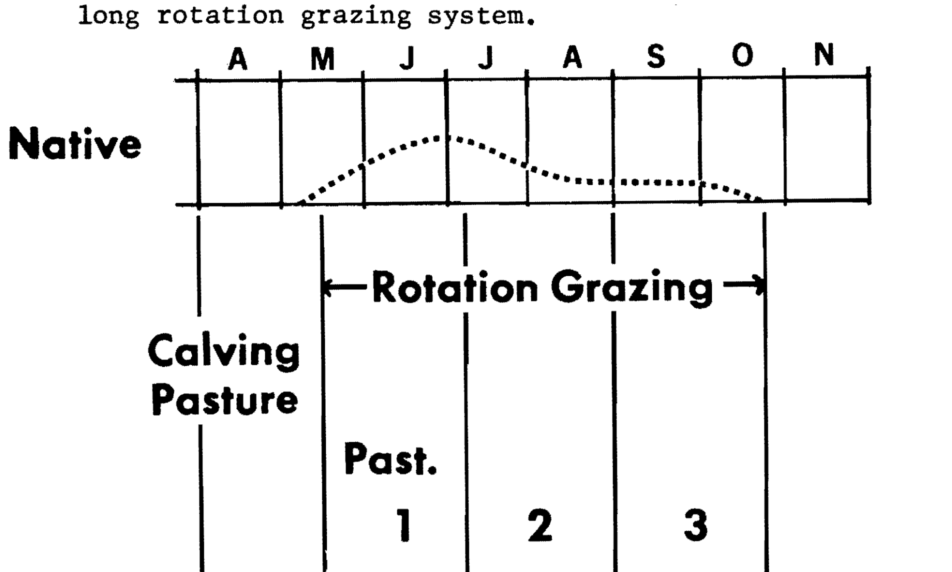
If adequate native grassland is available for season-long use, pastures may be grazed in a continuous or rotation system of grazing. CONTINUOUS GRAZING (Fig.20) is allowing the livestock to graze a particular pasture from the date of grazing readiness in the spring until the close of the grazing season. North Dakota grazing studies indicate that continouous grazing on native pastures at the proper stocking rate will maintain grasses in a vigorous growing condition.

Fig. 20 - Relative productivity of native pasture by months and a season long continuous grazing system.



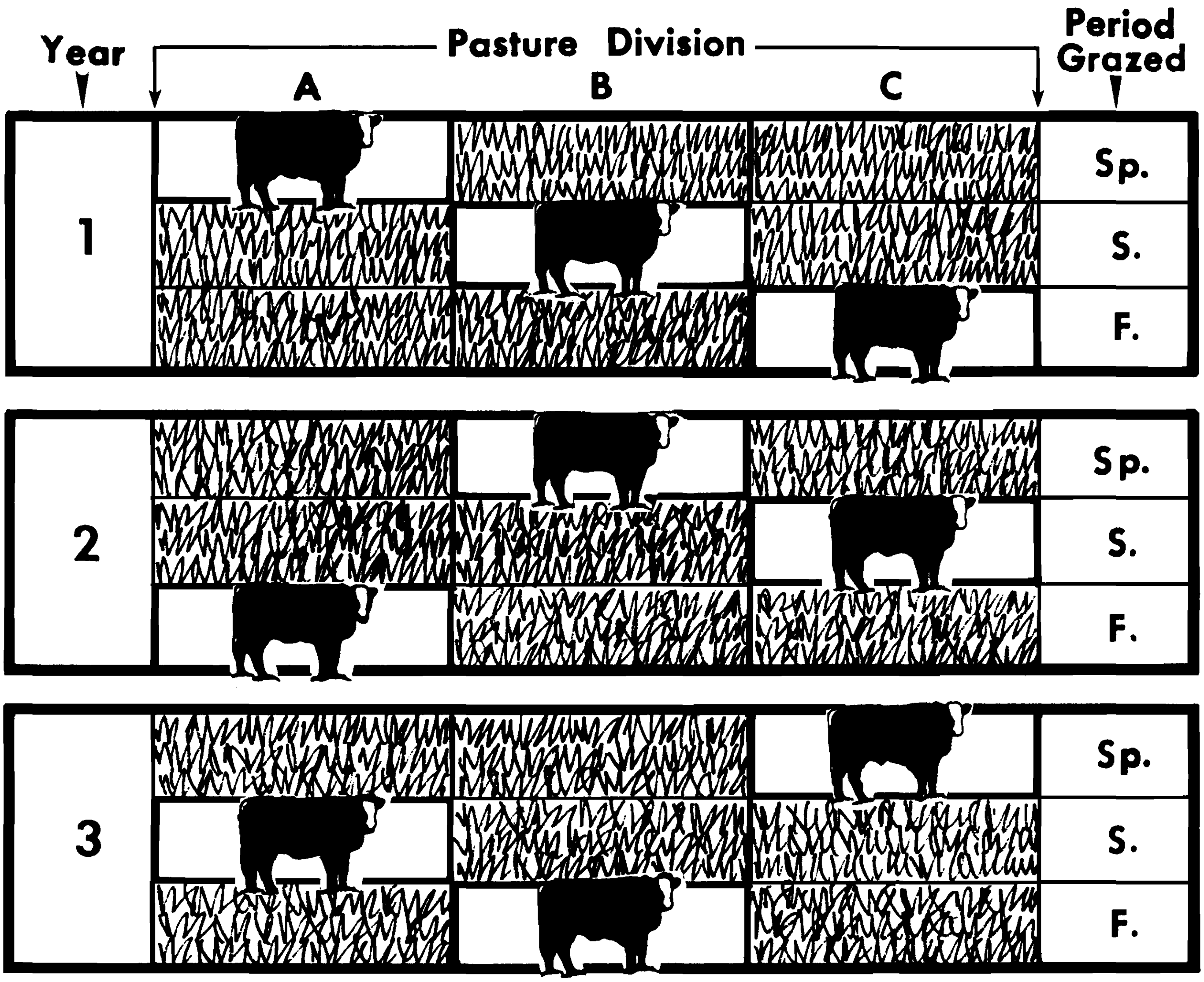
ROTATION grazing (Fig. 21) requires two or more pasture units. Grazing is permitted on each unit for a portion of the grazing season. If the season of pasture use in the rotation system is changed yearly or every two years, you have a DEFERRED-ROTATION grazing system (Fig. 22). The deferred-rotation grazing system provides seasonal grazing rest for portions of the pasture acreage during the critical spring growth season over a period of several years. In addition, grasses in low condition or health are permitted to grow to maturity before being grazed, providing an opportunity for the grass plant to build stored food reserves and regain health and vigor.

Fig. 21-Relative productivity of native pasture by months and a season long rotation grazing system.



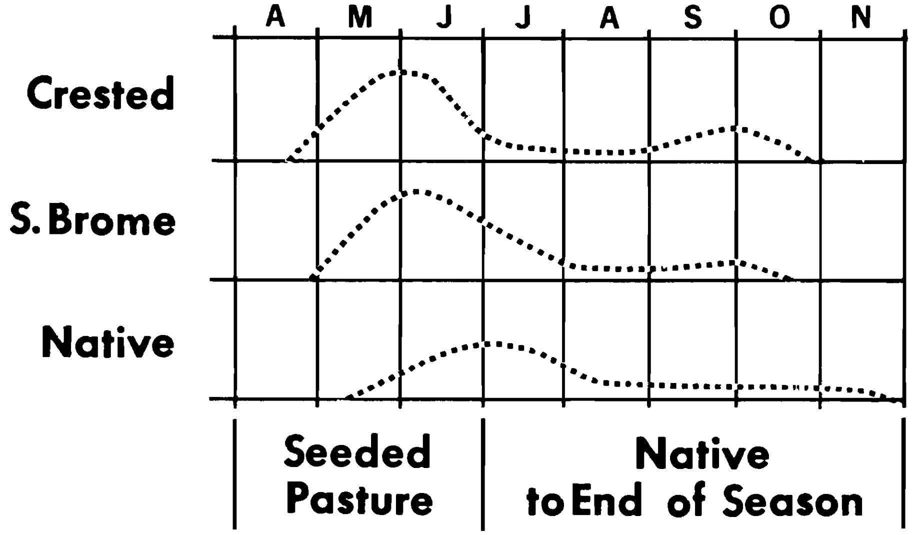
When using the deferred-rotation system of grazing it is necessary to graze each pasture unit quite close before a change is made to the next unit. A suggested grazing schedule might be May 15 to June 30, July 1 to August 15 and August 16 to the end of the grazing season. The spring turn-out date should be adjusted depending on the date of grazing readiness.

Fig. 22 - Schematic of a native 3-pasture deferred-rotation grazing system.



There are many grazing situations in North Dakota where the acreage of native grassland available is limited based on the number of cow units being grazed. If productivity of native grasslands is to be maintained, seeded cool-season tame grasses must be incorporated into the grazing system. If the use of native pasture is delayed for 30 to 45 days in the spring, you have a DEFFERED (delayed) system of grazing native grassland (Fig.23). Crested wheatgrass and

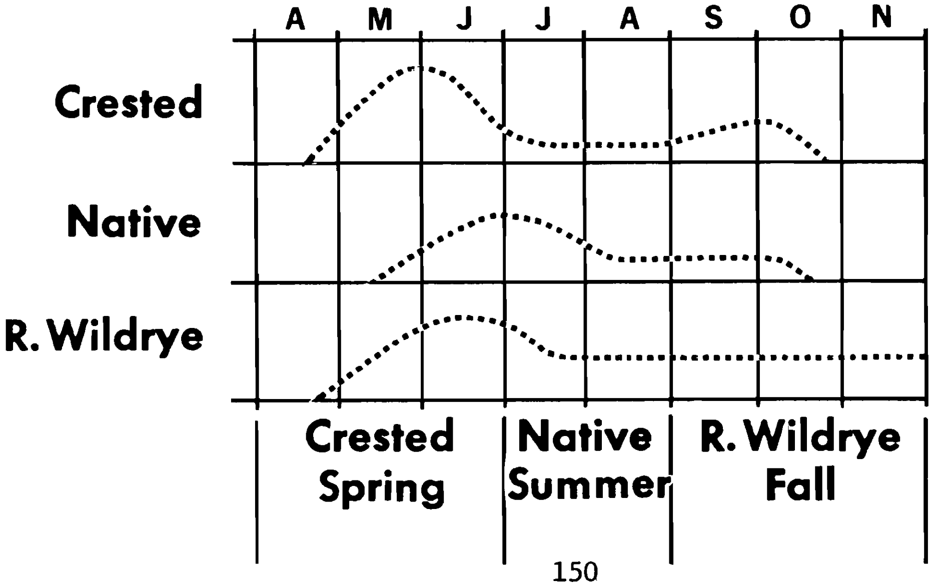
Fig.23 - Relative productivity of native and seeded cool-season grass pastures by months and a deferred system of grazing native grassland.



smooth bromegrass are the two most widely used grasses for spring pasture. The addition of alfalfa to the seed mixture will increase forage production and provide the needed nitrogen for the grass. Grass-alfalfa mixtures will be more productive than grass seeded alone, especially if nitrogen fertilizer is not applied. Tame grass seedings, not fertilized, will be the most productive the first 2 to 3 years after establishment.

When the acreage of native grassland is very limited for grazing, Russian wildrye can be incorporated into the grazing system for fall use (Fig.24). The spring and summer forage production of Russian wildrye can be saved and will provide nutritious fall grazing. When grazed in this manner, all available forage can be grazed without injury to the Russian wildrye stand.

Fig.24 -Relative productivity of native and seeded cool-season grass pastures by months and a deferred summer system of grazing native grassland.



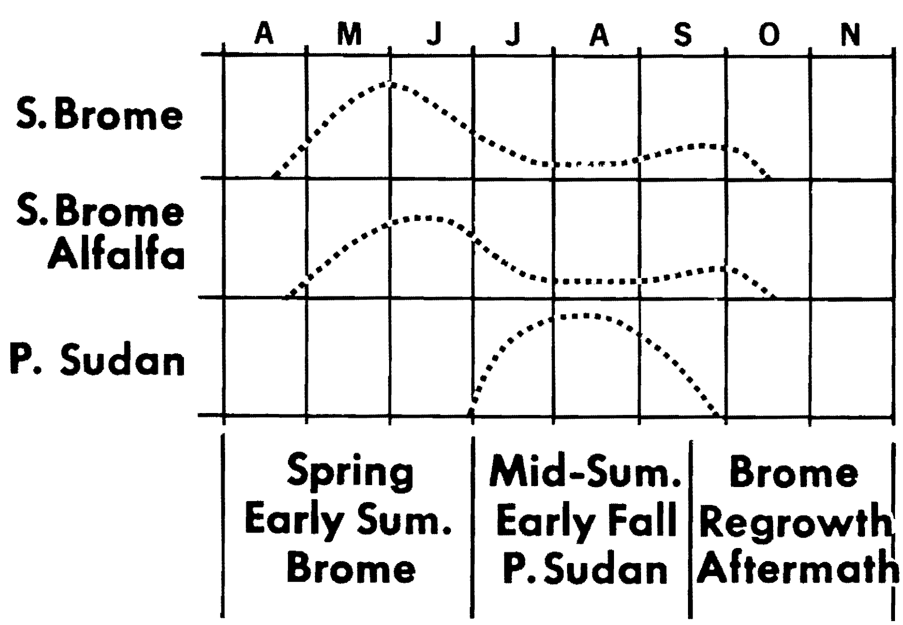
SEASON-LONG GRAZING OF SEEDED PASTURES

A number of livestock operations in North Dakota must depend entirely on the use of seeded pastures for season-long grazing. To provide nutritious forage throughout the grazing season, two or three grasses with different growth seasons or nutrient retaining characteristics may be required.

Seeded cool-season pastures such as crested wheatgrass and smooth bromegrass or mixtures containing alfalfa produce a large portion of their total season production during the first 50 days of the grazing season. Following the initial burst of growth in the spring, production declines due to the growth characteristics of the grass and because soil moisture often limits production during the months of July and August. If rainfall is adequate in mid-summer regrowth forage production will remain relatively high. Forage production of cool-season grasses is generally not dependable during the month of August. Several methods of providing season-long grazing on seeded pastures should be considered -

- Provide more acres of pasture than required for spring grazing - harvest the first crop on a portion of the acreage early for hay, and graze the regrowth.
- Use Piper sudangrass or sudangrass hybrids which are warm-season annuals for late summer and early fall grazing (Fig. 25)
- Use Russian wildrye for a fall pasture (Fig. 24)
- Utilize crop aftermath growth.
- Allow cattle to feed on the hay harvested early from excess early season pasture acres.
- Practice rotation grazing in areas of the state or on soils where soil moisture potentials favor regrowth.

Fig. 25 Relative productivity of cool- and warm-season grasses by months and a season-long grazing schedule.

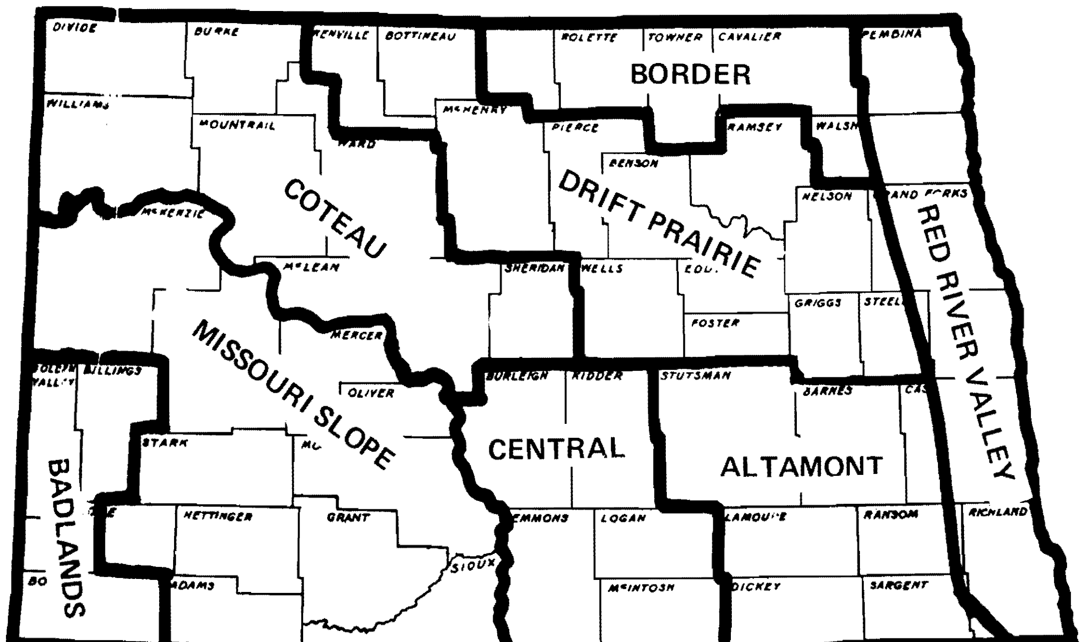


Russian wildrye may be incorporated into a seeded pasture grazing system (Fig.24) to provide grazing from early September until snowfall prevents further grazing. This grass has nutrient retaining qualities which permits the saving of early season growth for fall grazing. It can be grazed early in the growing season if needed, however, crested wheatgrass and smooth bromegrass alone or in combination with alfalfa will usually produce more forage for early season grazing.

Heavy use of the fall regrowth of cool-season grasses grazed intensively in the spring and early summer should be avoided or used only moderately to permit storage of food reserves. If grazed too heavily in the fall, spring growth may be slow and total production will be less. Utilize aftermath growth on small grain fields first, then graze regrowth on spring pastures after fall growth ceases.

The acreage of pasture required per animal unit will depend on the grazing system used, level or intensity of management applied and the pasture location within the state. An animal unit is considered to be 1,000 pounds of live animal weight or equivalent to a cow and calf. The estimated acres of native and seeded pasture required per animal unit per month (animal unit month - A.U.M.) are listed in figure 26 for various areas in North Dakota.

Fig. 26 - Estimated acres of native and seeded pasture required per animal unit month by areas.



	Estimated Acres/A.U.M.	
	Native	Tame Grass
Badlands	2.0 - 3.5	0.7 - 1.0
Missouri slope	1.4 - 2.2	0.6 - 0.9
Coteau and Central	1.3 - 2.0	.45 - 0.7
Drift prairie and border	1.2 - 1.6	.35 - 0.5
Altamont and Red River Valley	1.0 - 1.5	.25 - 0.35

The estimated acreage of native grassland required per animal unit month when grazed under a continuous grazing system is 2.0 to 3.5 acres for the Badlands area, 1.4 to 2.2 acres in the Missouri slope area; 1.3 to 2.0 acres in the Coteau and Central area; 1.2 to 1.6 acres in the Drift prairie and border areas and 1.0 to 1.5 acres in the Altamont and Red River Valley areas of North Dakota. Native grassland grazed under a rotation, deferred-rotation or a deferred system of grazing may require less acres per animal unit month of grazing. Cattlemen should estimate the degree of forage utilization each year on native grasslands. Stocking rates should be adjusted to obtain proper forage utilization based on the average of several years grazing use.

Cool-season seeded pastures will have the highest carrying capacity during the spring and early summer when adequate moisture is available for growth. The estimated acres of seeded pasture required per animal unit month under an intensive grazing system or when grazed intensively during the peak production period is .7 to 1.0 acres in the Badlands area, .6 to .9 acres in the Missouri slope area; .45 to .7 in the Coteau and central areas, .35 to .5 in the Drift prairie and border areas and .25 to .35 in the Altamont and Red River Valley areas of North Dakota. A larger acreage will be required if the grass stand is not fertilized.

FERTILIZATION

The land resource is limited; additional acres of grazing land are not readily available for expansion of the livestock industry. Therefore, the application of commercial fertilizer, especially nitrogen, to native and seeded tame grass pastures and hayland is a management tool livestock producers may use to expand their operations on acreage presently owned.

The response of grassland to fertilizer application will vary depending on the kind of grasses and/or types of grassland, soil, and available soil moisture. In general, seeded tame grass pasture and hayland should be fertilized first, then, native grassland with a high forage production potential.

Fertilized grasslands may create management problems. Weed problems may increase with fertilization, requiring timely weed control to realize the greatest increase in forage production. Cool-season grasses begin growth early in the growing season when soil moisture is usually more plentiful. Fertilizer may cause a shift in species composition on native grassland from a desirable mixture of both cool and warm-season grasses to a higher percentage of cool-season grasses. This will require more intensive grazing management in the spring to utilize the increased forage production while in a palatable growth stage.

Grassland fertilization has a number of advantages. The livestock producer must be prepared to incorporate the advantages into the livestock operation, otherwise, the value of the fertilization program will be lost. Advantages include: (1) greater forage production, (2) higher quality forage, (3) greater livestock carrying capacity, (4) longer green feed period (5) better distribution of grazing, (6) greater water use efficiency and, (7) improved plant vigor and productivity of abused grasslands.

PESTICIDES AND THE LAW

In 1972, production of pesticides including insecticides, fungicides, herbicides, rodenticides, bactericides, plant growth regulators, etc. totaled slightly over 1.158 billion pounds. Some 925 million pounds are used domestically each year, with about 34,000 separate pesticide products currently registered with the Environmental Protection Agency.

FEDERAL REGULATION

The U. S. Environmental Protection Agency (EPA) is responsible for administering the two basic Federal laws regulating the marketing and use of pesticides in the United States. These laws are the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and the Pesticide Amendment to the Federal Food, Drug, and Cosmetic Act. Their primary purpose is to allow the use of pesticides to help improve food and fiber production and control human disease carriers while protecting the general public and the environment from pesticide hazards.

THE FIFRA AS AMENDED

The regulation of pesticides is accomplished primarily through the registration of individual pesticide products. Under the original FIFRA, which was enacted in 1947, registration was required only of those pesticide products marketed in interstate commerce. The approved directions and precautions on the labels were not enforceable and thus amounted only to recommendations.

On October 21, 1972, the FIFRA was overhauled and expanded substantially through adoption of the amendments known as the Federal Environmental Pesticide Control Act of 1972.

Major provisions of the amended Act include:

--All pesticide products, those shipped intrastate as well as interstate, must be registered with EPA beginning in October 1974.

--The use of any registered pesticide in a manner inconsistent with labeling instructions is prohibited and is subject to civil and criminal penalties described below.

--Pesticides must be classified for "general" or "restricted" use by October 1976. Restricted pesticides may be used only by, or under the supervision of, certified applicators or under other conditions required by EPA.

--Federal standards for certification of restricted pesticide applicators will be set forth by EPA. The States must submit their certification programs based on these standards by 1975, and these plans are to be approved by EPA within one year of submission.

--Farmers and other private applicators can be fined up to $1,000 and/or 30 days in prison for a knowing violation of the law.

--Any registrant, commercial applicator or distributor who knowingly violates the law is liable to a $5,000 civil or $25,000 criminal fine or one year in prison or both.

-- EPA can issue a "stop sale, use, and removal" order and seize pesticides if they violate the law.

--Plants manufacturing pesticides moving in interstate commerce must now apply to be registered with EPA. Those plants which manufacture pesticides moving only in intrastate commerce have until October 1974 to submit their applications for registration. Information on pesticide manufacture must be submitted upon registration and annually thereafter.

--Federal assistance to the States to enforce and administer provisions of the law is authorized.

--EPA is required to develop procedures and regulations for storage or disposal of pesticide containers.

--EPA may issue experimental use permits, conduct research on pesticides and alternatives, and monitor pesticide use and presence in the environment.

PRODUCT REGISTRATION

Under the FIFRA, EPA grants registration only after a manufacturer has provided scientific evidence that a pesticide product, when used as directed, will (1) effectively control the pest(s) listed on the label, (2) not injure humans, non-target plants and animals, or damage the environment and (3) not result in illegal residues in or on food or feed.

REGULATION OF RESIDUES

Closely related to the amended FIFRA is the Pesticide Amendment to the Federal Food, Drug, and Cosmetic Act. To protect human and animal health, the Act gives EPA the responsibility for establishing a tolerance or allowable limit for any detectable pesticide residues that might remain in or on a harvested food or feed crop. There is always a substantial margin of safety between the tolerance level and the actual level which would be expected to cause adverse health effects.

The Act gives responsibility for the enforcement of tolerances to the Food and Drug Administration (FDA). FDA tests samples of food to determine if any residues exceeding the tolerance levels remain on the treated commodity. Livestock and poultry products are similarly tested by the U. S. Department of Agriculture (USDA) under other laws. Any residue in excess of the established tolerance is considered illegal.

The Federal Government cooperates with State health officials in a testing program for those commodities intended for intrastate shipment and also samples and examines food shipments entering the U. S. from abroad. If a food shipment contains residues in excess of established tolerances, the grower or shipper is notified so he can take the necessary action to avoid shipment of such food. Food or feed containing excessive residue is subject to seizure and destruction by the FDA or USDA.

CANCELLATION AND SUSPENSION

Scientific data developed subsequent to registration may call into question earlier evidence of safety. If substantial question arises as to the safety of a product or group of products, the Administrator of the EPA has the authority, under the FIFRA, to cancel or suspend previous product registrations to protect the public interest.

Private and public individuals or organizations may petition the Administrator for cancellation and/or suspension actions.

Cancellation--The Administrator may cancel Federal registration of a pesticide product on the basis of actual or potential hazard to people, animals, or the environment. The manufacturer of the affected product has 30 days after cancellation in which to challenge such action. If a firm files an appeal from cancellation with EPA, the law permits the manufacturer to continue marketing the particular product until all administrative procedures have been completed and a final order has been issued on the appeal.

Suspension--The EPA Administrator may suspend Federal registration of a pesticide product if he finds that its continued use for a particular purpose constitutes an imminent hazard to public health. He must simultaneously issue a notice of his intention to cancel the registration or change the classification of the pesticide. Under the new law, the manufacturer has five days after receipt of the notification in which to request an expedited hearing on the question of whether an imminent hazard exists. The manufacturer may continue to market his product pending the outcome of this hearing.

Whenever the Administrator feels that an emergency exists, he may bypass the expedited hearing and issue a suspension notice before notifying the manufacturer. If the Administrator issues a suspension order under emergency circumstances or as the result of an expedited hearing, the manufacturer receiving the notice may appeal the government's action, but he must immediately halt all domestic distribution and sale of the product in question while his appeal is being resolved under administrative procedures.

In the case of suspension, the EPA may issue a "stop sale, use and removal" order and/or request the manufacturer to voluntarily recall the product from the wholesalers, retailers, and even users to avoid further danger to the public.

SIGNIFICANT EPA CONTROL ACTIONS

Within the last few years EPA has taken significant control actions against a number of pesticides. In 1972 EPA cancelled and suspended pesticides labeled for control of predatory animals and issued a final cancellation order for all remaining registered uses of DDT in the U. S. with the exception of public health and quarantine uses. The Agency has also issued cancellation notices for all mercury-based pesticides along with suspension notices for specific mercury-based products.

Currently, EPA is involved in public hearings convened in response to the Agency's issuance of cancellation notices for uses of the insecticides Mirex, aldrin and dieldrin. Hearings are scheduled as well on the cancellation of uses of the herbicide 2,4,5-T and the mercury pesticides.

POLICY

EPA has become increasingly involved in the regulation of pesticide products to insure safer and more efficient pest control. In reaching its regulatory decisions, the Agency carefully weighs both benefits and risks involved in the use of pest control chemicals.

Benefits may include production of abundant high quality food and fiber; the protection of human health both here and abroad from malaria and other diseases; and the preservation of valuable forest and park land from insect destruction.

Risks or hazards may involve the buildup of persistent pesticide residues in the food chain and consequent damage to fish, birds, and other wildlife; the elimination of beneficial insects; widespread contamination of the environment; and immediate or future hazard to human health.

These are just some of the factors that must be considered in arriving at regulatory decisions that further the total public interest. Under EPA policy, all parties to a controversy over pesticides--environmentalist and manufacturer, farmer and wildlife conservationist, scientist and consumer--are given the opportunity to present their views to the Agency before a final decision is reached in accordance with the applicable laws of the land.

PRECAUTIONS IN PESTICIDE USAGE AND DISPOSAL

1. Always read the label before using sprays or dusts. Note warnings and cautions each time before opening the container.
2. Keep sprays and dusts out of reach of children, pets, and irresponsible people. Sprays and dusts should be stored outside of the home, away from food and feed, and under lock and key.
3. Always store sprays and dusts in original containers and keep them tightly closed. Never keep them in anything but the original container.
4. Never smoke or eat while spraying or dusting
5. Avoid inhaling sprays or dusts. When directed on the label, wear protective clothing and masks.
6. Do not spill sprays or dusts on the skin or clothing. If they are spilled, remove contaminated clothing immediately and wash thoroughly.
7. Wash hands and face and change to clean clothing after spraying or dusting. Also wash clothing each day before reuse.
8. Cover food and water containers when treating around livestock or pet areas. Do not contaminate fish ponds.
9. Use separate equipment for applying hormone-type herbicides in order to avoid accidental injury to susceptible plants.
10. Always dispose of empty containers so that they create no hazard to humans, animals, or valuable plants.
11. Observe label directions and cautions to keep residues on edible portions of plants within the limits permitted by law.
12. If symptoms of illness occur during or shortly after spraying or dusting, call a physician or get the patient to a hospital immediately.

I. SAFETY PRECAUTIONS AND FIRST AID

(a) Precautions when using toxic phosphates

Use natural rubber gloves to prevent absorption through the skin. Remove and wash contaminated absorbent clothing.

Avoid breathing any wettable powder, dust, or contacting an emulsion. If this is unavoidable, use a respirator specifically made for phosphates. Information on respirators can be obtained by writing to the Department of Entomology, North Dakota State University, Fargo, North Dakota 58102.

(b) Phosphate- and carbamate-poisoning symptoms and antidotes

Many organic phosphate insecticides (TEPP, parathion, methyl parathion, tetraethyl dithiopyrophosphate, EPN, demeton, azinphosmethyl, mevinphos, phorate and disulfoton) are hazardous to man during mixing operations and application. Contact with recently treated plants or surfaces may also be hazardous. Certain organic phosphates have been found which are considerably less toxic; malathion, coumaphos, and ronnel are much less toxic and diazinon, trichlorfon, and dioxathion are of intermediate toxicity.

All of the organic phosphates discussed, including the least toxic, produce similar symptoms in human beings. All require the same antidote. The symptoms may be produced by absorption through the skin, inhalation, or swallowing. Signs of poisoning include blurred vision (pinpoint pupils), abdominal cramps, tightness of the chest, digestive upset, sweating and excessive salivation, restlessness, giddiness, headache, and twitching of the facial and eye muscles. If any of these symptoms occur:

1. Call a physician immediately.
2. Remove contaminated clothing and wash skin thoroughly with soap and water.
3. If a chemical has been swallowed and the patient is conscious, generally you should induce vomiting.
4. Keep patient quiet and warm.
5. Physician may administer atropine and/or 2-PAM as an antidote.

If you have had these symptoms from organic phosphorous compounds, do not handle the compounds again until your physician determines by a blood analysis that your condition is satisfactory. Persons who often use these compounds should have analyses of the blood made at regular intervals.

(c) Chlorinated-hydrocarbon first aid

For chlorinated hydrocarbons (such as aldrin, BHC, chlordane, dieldrin, DDT, endrin, heptachlor, lindane, methoxychlor, toxaphene, endosulfan):

1. If chemical has been swallowed, call physician immediately. Generally, if the patient is conscious, induce vomiting with warm, salty water. Continue until vomit fluid is clear.
2. If chemical has been spilled on the skin or clothing, remove clothing and wash skin thoroughly with soap and water. Do not use kerosene, gasoline, or other solvents.
3. Keep patient quiet and warm.
4. Physician may administer sedatives such as phenobarbital or other barbiturates to keep patient calm or to control convulsions.

II. DISPOSAL OF PESTICIDES AND HANDLING TO MINIMIZE EXCESSES

(a) Handling and disposing of concentrates

Usable concentrates for which you no longer have a need, should be kept in the original container and stored until a proper disposal method is developed.

Unusable concentrates are those which have deteriorated, are contaminated by another material, or cannot be accurately identified, perhaps because they have lost their label. Some supplier might accept these concentrates, but be sure to tell the supplier why you think the concentrate is unusable. If the supplier is unable to accept such concentrates, store them until a disposal method is developed.

NOTE: The EPA has finalized a regulation specifying a procedure in which the agency accepts for disposal those pesticides which it suspends and cancels as serious health hazards. This applies only to pesticides suspended and cancelled after October 21, 1972. The EPA will not accept any product until the owner has first made "every reasonable attempt" to return the material to someone capable of safely reprocessing it.

All concentrates should be stored in the original container if possible. The storage area should be dry to minimize rusting of metal containers or damage to paper containers. You should mark the date of receipt of each concentrate on the container. It's age may be important for future disposal.

If the original container develops a leak, transfer the concentrate to another labelled container. Under special circumstances you may be able to get a replacement label from the original supplier.

Don't ever mix and store two or more different concentrates for disposal. Disposal techniques may differ for different pesticides. Don't burn concentrates unless the registered label provides instructions for such; toxic smoke or gases may be emitted and the ash may be toxic.

(b) Handling diluted materials to minimize excesses

The two key steps to minimizing excess diluted pesticides are:

1. Plan ahead--don't mix more than you need, and,
2. Use it up according to the directions on the label.

Stability of diluted materials - We are not aware of any significant stability problems related to diluted insecticidal dusts or oil base sprays, if the label directions are followed. Oils must be free of water, however, or insecticidal breakdown may occur. The basic manufacturers of water base materials have supplied the following information.

1. Water base sprays which may be held over a weekend without significant loss of active ingredient include:

Clorinated hydrocarbons (Chlordane, heptachlor, aldrin dieldrin, etc.)	Ronnel Dursban

2. Water base sprays which may be held for 24 hours (overnight) without significant loss of active ingredient include:

Diazinon	Malathion***

*** Malathion retains its activity for more than 24 hours but its emulsion system breaks down and it is difficult to reemulsify.

3. Water base sprays which must be used the same day they are mixed:

DDVP (Vapona)	Dibrom
Dylox	

(c) Disposing of excess diluted materials

Dispose of excess spray material that has been held longer than the recommended period. The best method of disposal is to apply the material according to the label, even though there may be no active ingredient in the spray. An alternate is to spray it out onto a soil surface where it will be exposed to weathering and biodegrading action. Spray rather than pour out the material to leave any active material on or near the soil surface; pouring saturates the soil and carries some of the active material below the soil surface where it is not subject to weathering.

(d) Disposing of rinses

There will be occasions where you need to rinse "empty"containers or sprayers. Use either oil or water for rinsing, as appropriate for the type formulation you're working with. Oil rinses should be sprayed out in accordance with the label directions for the pesticide being rinsed out. Do not spray oil rinses onto desirable plants or damage will result. Water rinses also should be sprayed out according to the label.

(e) Disposing of containers

All containers that cannot be returned or sold should be handled as follows:

1. Rinse and dispose of the rinse as described above.
2. Wrap all small containers in newspaper or similar material.
3. Take to municipal or authorized private sanitary land fill or have them picked up by local trash collection agency.

Two recommendations that are now considered unacceptable are:

1. Containers should not be burned unless the registered label provides such directions. Burning in most incinerators does not completely break down all pesticides. Toxic gases, vapors, or particles are released into the atmosphere. The distribution of these "by-products" cannot be controlled.
2. Containers should not be buried on your own property. Burying containers on your own property will result in accumulations of concentrated pesticides in one area. Such accumulations are not

easily broken down by natural forces and they present a potential hazard during floods and other natural catastrophies. Burying on your own property should be done only if there's no other disposal method available and if your property is large enough to permit burying containers in many areas rather than in a concentrated area.

(f) Conclusion

Following the above recommendations should minimize the possibility of contaminating the environment with pesticides through disposal. The recommendations are based on practicality and information and facilities currently available. They are subject to change as more information on the subject becomes available. If you learn of other practical recommendations that further minimize this possible contamination hazard, bring them to the attention of NDSU Pest Control Specialists.

POISON CONTROL CENTERS

North Dakota

Fargo

North Dakota State University
Pharmacology Department
Fargo, North Dakota
701-237-3115 or 237-7876

St. Luke's Hospital
North 5 and Mills Avenue
Fargo, North Dakota
701-235-3161

Grand Forks

Deaconess Hospital
212 South 4th Street
Grand Forks, North Dakota
701-775-4241

Jamestown

Jamestown Hospital
419 5th Street
Jamestown, North Dakota
701-252-1050

POISINDEX

(24 hour instant retrieval on more than 50,000 poisonous compounds including pesticides)

Rocky Mountain Poison Control Center
West 8th Avenue & Cherokee
Denver, Colorado
Ph. No. 1-303-893-7771

TOXICITY OF INSECTICIDES

All insecticides are classified as poisons, although there are considerable variations in the degree of toxicity to warm blooded animals. Toxicity refers to the degree to which a specific insecticide is poisonous to animals. TOXICITY is classified as acute (severe) or chronic (long term) and it varies with the species, age, sex and method of administration to animals, nutritional state and the type of insecticidal formulation used.

Poisoning with insecticides may occur through the mouth and nose (oral) or through skin contact (dermal). It usually requires less insecticide to kill when administered through the mouth, although the greatest potential occupational hazard in the use of insecticides is more closely associated with skin contamination.

The tests used to determine the toxicity of insecticides involve laboratory animals. Toxicity is expressed as LD_{50} which means the lethal dosage required to kill 50 per cent of the test animal population. The amount of material needed to produce a lethal dose is expressed as milligrams of toxicant per kilogram of live animal weight (mg./kg.). The following list of LD_{50} values is based on the technical material (usually close to 100% concentrate) and not on the various formulations registered for public use.

CLASSIFICATION OF ACUTE ORAL TOXICITY FOR DIFFERENT CHEMICALS AND LETHAL DOSAGE FOR 150 POUND MAN.

CLASS	LD_{50}, mg/kg	LETHAL DOSE FOR 150 POUND MAN
Highly toxic	50 & below	few drops to 1 teaspoon
Moderately toxic	above 50-500	1 teaspoon to 1 ounce
Toxic	above 500-5,000	1 ounce to 1 pint or 1 pound
Non-toxic	above 5,000	1 pint to over 1 quart

Insecticides	LD_{50} in mg./kg. Oral* Males	Oral* Females	Dermal* Males	Dermal* Females
Abate	1000-3000	----	1024-1782	----
Aldicarb (Temik)	1	----	5	----
Aldrin	39	60	98	98
Aramite	3900	3900	----	----
Azinphosmethyl (Guthion)	13	11	220	220
Azodrin	21	----	354	----
Benzene hexachloride (BHC)	1250	----	----	----
Binapacryl (Morocide)	63	58	810	720
Bux	87	----	400	----

* Oral toxicity data are usually taken on white rats and dermal toxicity on rabbits.

Insecticides	LD50 in mg./kg.			
	Oral*		Dermal*	
	Males	Females	Males	Females
Carbaryl (Sevin)	850	500	>4000	>4000
Carbofuran (Furadan)	11	----	10,200	----
Carbophenothion (Trithion)	30	10	54	27
Chlorbenside (Mitox)	>10,000	----	----	----
Chlordane	335	430	840	690
Chlorfenvinphos (Compound 4072)	15	13	31	30
Chlorobenzilate	1040	1220	----	5000
Coumaphos (Co-ral)	41 (56-230)	16	860-1000	----
Crotoxyphos (Ciodrin)	125	----	385	----
Crufomate (Ruelene)	635	460	----	----
Dasanit	10	2	30	3
DDT	113	118	----	2510
Demeton (Systox)	6	3	14	8
Diazinon	108	76	900	455
Dichlorovos (DDVP, Vapona)	80	56	107	75
Dicofol (Kelthane)	1100	1000	1230	1000
Dicrotophos (Bidrin)	22	----	225	----
Dieldrin	46	46	90	60
Dimetilan	50	----	600-700	----
Dimethoate (Cygon, De-Fend)	215	----	400	610
Dioxathion (Delnav)	43	23	235	63
Disulfoton (Di-Syston)	7	2	15	6
Dursban	163	135	2000	2000
Dyfonate	8	----	147	----
Endosulfan (Thiodan)	43	18	130	74
Endrin	18	8	18	15
EPN	36	8	230	25
Ethion	65	27	245	62
Ethylene dibromide	146	117	300	----
Ethylene dichloride	770	----	3890	----
Famphur (Warbex)	35-62	----	1460-5093	----
Fenthion (Baytex)	190	225	330	330
Gardona (Rabon)	4000-5000	----	>5000	----
Heptachlor	100	162	195	250
Imidan (Prolate)	147-299	----	>3160	----
Kepone	125	125	>2000	>2000
Lead Arsenate	----	1050	----	>2400
Lethane 384	90	----	250-500	----
Lindane	88	91	1000	900
Malathion	1375	1000	>4444	>4444
Mesurol	130-135	----	>200	----
Metaldehyde	1000	----	----	----
Methomyl (Lannate)	17-24	----	>1000	----
Methoxychlor	5000	5000	----	>6000
Methyl parathion	14	24	67	67
Mevinphos (Phosdrin)	6	4	5	4
Mirex	740	600	>2000	>2000

* Oral toxicity data are usually taken on white rats and dermal toxicity on rabbits.
means greater than.

Insecticides	LD50 in mg./kg.			
	Oral*		Dermal*	
	Males	Females	Males	Females
Mocap	61	----	26	----
Monitor	21	19	118	----
Naled (Dibrom)	250	----	800	----
Nemacide	270	----	----	----
Nicotine sulfate	----	83	----	285
Omite	2500	----	----	----
Orthene	945	866	> 2000	----
Ovex (Ovotran)	2050	----	----	----
Oxydemetonmethyl (Meta Systox-R)	65	75	250	----
Oxythioquinox (Morestan)	1800	1100	> 2000	> 2000
Paradichlorobenzene	> 1000	1000	----	----
Parathion	13	4	21	7
Paris Green	----	100	----	> 2400
Phorate (Thimet)	2	1	6	3
Phosphamidon (Dimecron)	24	24	143	107
Plictran	540	----	> 2000	----
Propoxur (Baygon)	95	104	> 1000	----
Pyrethrum	1870	820	2060	----
Ronnel (Korlan, Trolene)	1250	2630	----	> 5000
Rotenone	50-75	----	940	----
Strobane	200	----	> 5000	----
Supracide	25-48	----	375	----
TEPP	1	----	2	----
Tetradifon (Tedion)	> 14,700	----	> 10,000	----
Thanite	1600	----	> 6000	----
Toxaphene	90	80	1075	780
Trichlorfon (Dipterex, Dylox, Neguvon)	630 (450-500)	560	5000	> 2000
Zectran	15-63	----	7500	----

* Oral toxicity data are usually taken on white rats and dermal toxicity on rabbits. means greater than.

INSECT SURVEY METHODS

INTRODUCTION

The purpose of this section is to provide information on how to evaluate insect infestations. By following certain procedures in making estimates of insect numbers, you should be able to arrive at some conclusion as to whether insecticidal control is necessary.

In making your observations, it is extremely important that you identify the insect. To determine insect populations in a given area, you must carefully observe insect numbers and try to arrive at an average number per square foot, yard, etc. In some instances you will have to examine individual plants or maybe several plants to determine the population. The sampling method or the observation made will vary with the specific insect pest and crop.

Once you have arrived at an average infestation index for a given area, you must carefully consider such factors as stage of crop development, value of the crop, plant diseases present, degree of insect damage and chance of pests moving into other crops, presence of predators and parasites before you make a decision as to the need for insecticidal control.

Always keep in mind that even though certain population indexes are given in this outline, you must use good common judgment in advising control. These indexes are given primarily as populations that may be considered serious under certain conditions and there are always exceptions.

APHIDS

There are several different species of aphids that appear each season. Some are relatively unimportant and for the most part are kept in check by predators and parasites. Others occur in unusually high numbers for a short period, but they do little or no damage. There are a few that must be watched very closely, otherwise serious damage may occur.

Aphids are usually most troublesome during periods of cool, wet weather. Late seeded crops are likely to be most severely infested.

FIELD CROPS

The greenbug, English grain aphid, corn leaf aphid, and pea aphid are the principal species. The greenbug is definitely the most injurious, however, it seldom becomes economic in North Dakota. The English grain aphid starts building up on the leaves and later in the season, this species moves into the heads of grain. The corn leaf aphid may build up very quickly, however, the infestations are seldom economically important except possibly in extremely late seeded crops. The pea aphid infests sweet clover and alfalfa, and it seldom requires insecticidal control even though infestations may be extremely high during certain periods.

SAMPLING METHOD

In surveying for aphids, make several counts throughout the field. Too frequently farmers become alarmed after checking a few plants along the margins where populations are high. Counts should be at least fifty paces apart and observations should be made well into the center of the field. Start your counts from at least two sides of the field.

A rating for the infestation is given as follows:

Non-economic - - - - - - - -	1 to 10 aphids per linear foot
Light - - - - - - - - - - -	50 to 100 aphids per linear foot
Threatening - - - - - - - -	100 to 200 aphids per linear foot
Severe - - - - - - - - - - -	200 to 300 aphids per linear foot
Very severe - - - - - - - -	Above 300 aphids per linear foot

Insecticidal control would be advised whenever the greenbug infestation approaches the light to threatening category. For English grain aphids and corn leaf aphids, also pea aphids, the infestation should approach the threatening to severe category before insecticidal control is recommended.

When the English grain aphids move into the heads of grain, you should examine several hundred heads of grain throughout the field. If the average infestation per head is 40 to 50 aphids, control would probably be advised especially if the crop is late and population of predators and parasites are low.

POTATOES

The green peach aphid is important from the standpoint of virus transmission in certified potatoes. Most certified growers set up a prevention spray program. One or more aphids per plant usually suggests immediate spray programs. Aphid infestations in commercial potato fields are not as important, however, there is the danger of migration to certified fields if control is not carried out.

ARMYWORMS

Watch for armyworm infestations during wet seasons. Early infestations will usually be restricted to grassy areas and in lodged grain.

The larvae are dark green in color and up to two inches long. There is a white stripe on each side of the body and one down the middle of the back. When small, the larvae are usually curled up and on the ground. They feed during the late afternoon, night, and early morning. Injury consists of leaf stripping and head clipping.

In surveying for armyworms, check the field margins and lodged areas first. If they are present, then move into the standing grain. Whenever larval counts reach three to four per linear foot or six to eight per square foot in the field, insecticidal control would be recommended. There are exceptions, however, if the crop is nearly mature and there is no evidence of head clipping, control would not be advised, or if the larvae are all about two inches long, insecticidal control would not be advised as most of these larvae are through feeding and they will pupate very shortly.

Ten to twenty counts at 50 pace intervals will provide a good estimate of the infestation.

CRICKETS

Black field crickets usually occur late in the season. Flax seems to be the principal crop injured. Populations approaching 25 to 30 per square yard are considered economically important and insecticidal control advised. Whenever crickets invade homes, advise control immediately.

CUTWORMS

There are several species that infest crops. Many feed above ground, others feed below the soil surface.

The need for control is based primarily upon crop injury inasmuch as there is no easy method of determining economic infestations.

One method of surveying for cutworms is to pile several piles of straw, hay, etc. in the area where cutworms are suspected. After a few days, lift the piles and check for the larvae. If several cutworms are found under each pile, the infestation would be considered threatening and control would be advisable. This sampling method does not work for the species that feed underground. About the only method of checking on these would be to dig along the row and count the number of larvae per linear foot in the row. One or more cutworms per linear foot would be considered serious.

GRASSHOPPERS

Two types of surveys are made. One is a marginal count; the other is a field count. In both cases sufficient areas should be examined to obtain a good average infestation.

Grasshopper populations are determined on a square yard basis. However, for the unexperienced person, it is much easier to count the grasshoppers that leave a square foot. When using the square foot method, make 18 consecutive counts as you walk into the field. Add the total number of grasshoppers observed from the 18 square foot areas and divide by 2. This will give you the number of grasshoppers per square yard.

After you have arrived at an infestation index, use the following tables to classify the degree of infestation.

NYMPHAL

Number per square yard

	Margin	Field
Non-economic	10-17	7-11
Light	25-35	15-23
Threatening	50-75	30-45
Severe	100-150	60-90
Very severe	200 and above	120 and above

ADULTS

Number per square yard

	Margin	Field
Non-economic	5-10	0-2
Light	11-20	3-7
Threatening	21-40	8-14
Severe	41-80	15-28
Very severe	over 80	over 28

Insecticide control advised when infestation approaches threatening category.

EUROPEAN CORN BORER

In checking for European corn borer infestations, walk into a field about 25 paces and check 25 consecutive plants in a row. Repeat this operation at intervals of 25 paces, until you have examined plants in at least four locations. Check each plant for small shot-holes (fresh feeding) in the leaves. These holes are caused by the borer as it moves into the stalk. Multiply the number of infested plants by 4 to obtain the percentage of plants infested. Whenever 50 per cent or more of the plants show fresh leaf feeding, insecticidal control is advised, provided the borers are not already in the stalk. You can check on the location of the borers by cutting a few plants. Corn plants become susceptible to borer attack when they reach 30 inches in extended height.

LYGUS BUGS

Alfalfa grown for seed should be treated for lygus bugs only when the population justifies it and alfalfa field is capable of producing a second crop. Counts should be taken with a standard net at about 10 stops over a field. At least two counts should be made at every stop. Average all counts to determine the average population. Alfalfa in the early bloom stage is treated when the count reaches one lygus bug per net sweep.

BARLEY THRIPS

Look for adult thrips within the terminal leaf sheath of barley when plant is in the boot stage and before it heads. The adult thrips have small slender bodies and are dark brown to black in color.

Control of barley thrips is advised when the adult population averages two or more per stem, when the heads are just beginning to emerge and before the crop is fully headed. In order to obtain an accurate count, check several stems throughout the field. If numerous nymphs are present at the time the survey is made, it is probably too late to advise control.

SUGARBEET WEBWORM

The larvae are yellowish or greenish to nearly black in color; slender, 1 to ¼ inches long, with a black stripe down the middle of the back.

This pest attacks a number of crops and is especially injurious to sugar beets. In cereal grain fields, the larvae usually feed upon weeds. Webworm larvae skeletonize and devour the leaves. Often times, they spin a web, drawing the leaves together. They are also characterized by their active movement. It is not uncommon to see large numbers move out of a field into other areas. Occasionally, they will move into farmyards and crawl up a building.

Insecticidal control is suggested whenever populations approach 8 to 10 larvae per square foot in sugar beets. Heavy infestations may occur in crops such as soybeans, flax, etc., but control measures are not advised unless 10-15 larvae per square foot are present, or visible injury to plants is noticed. When infestations occur in these crops, and the feeding is restricted primarily to weeds, insecticidal control should be avoided unless their presence is a threat to adjacent crops which might suffer greatly from a migration of the pest.

SWEET CLOVER WEEVIL

This small gray snout-beetle may severely damage seedling sweet clover plants. A characteristic of his injury is half-moon notches cut in the leaves by the adult weevils as they feed. When 50 percent of the foliage in new seedlings has been eaten, control measures are recommended.

WIREWORMS

The adult "click beetle" is dark in color and about 1/2 inch in length. Larvae are yellow to red-brown in color and vary in size up to 3/4 inch in length. They remain and feed in the soil for several years, depending upon species and feeding conditions.

Wireworm sampling should be done before the crop is planted. There is no easy way to determine the severity of infestation without taking soil samples. Infestations vary from year to year, depending upon the season. There also may be considerable variation within a field and between fields. Sometimes the past history of a field is a pretty good indicator, especially if wireworms have been a problem in previous years.

The soil sampling technique for determining wireworm infestations involves the taking of approximately 20 well spaced samples from each 40 acres of land. Each sample should be approximately 1 square foot of soil taken down to a depth of 6 to 8 inches.

A simple way is to use a tongs-type post hole digger. These vary in size and you will have to determine the fractional part of a square foot per hole. Dump samples on a piece of canvas and go over soil by hand counting the number of wireworms per square foot.

If you find:

0 to 5 wireworms in 20 samples, the field is safe for all crops, including potatoes.

5 to 8 wireworms in 20 samples, the field is safe for all crops, except potatoes.

9 to 15 wireworms in 20 samples, the field is safe for small grains only, not including corn.

20 or more wireworms in 20 samples, damage is likely to occur to all crops. Such fields should be treated with an insecticide, seeded to legumes or summer fallowed.

STORED GRAIN INSECTS

The principal pests of stored grain are the "bran bugs." These insects feed primarily on broken kernels, chaff, etc. Their presence in grain is objectionable inasmuch as they can cause damage.

The granary weevil is not found very frequently in North Dakota stored grain.

Several other pests infest grain such as Indian meal moth, grain mites, etc.

Once the grain has become infested, control is difficult. The fumigants will kill most insects, however, during most of the storage period the temperatures are too low to effectively use fumigants. At low temperatures (below 60 degrees) most fumigants will not move downward into the grain very far.

The following are important considerations to remember in advising fumigation or treating for stored grain insects.

1. Are the pests "bran bugs" mites or the larvae of moths such as the Indian meal moth?

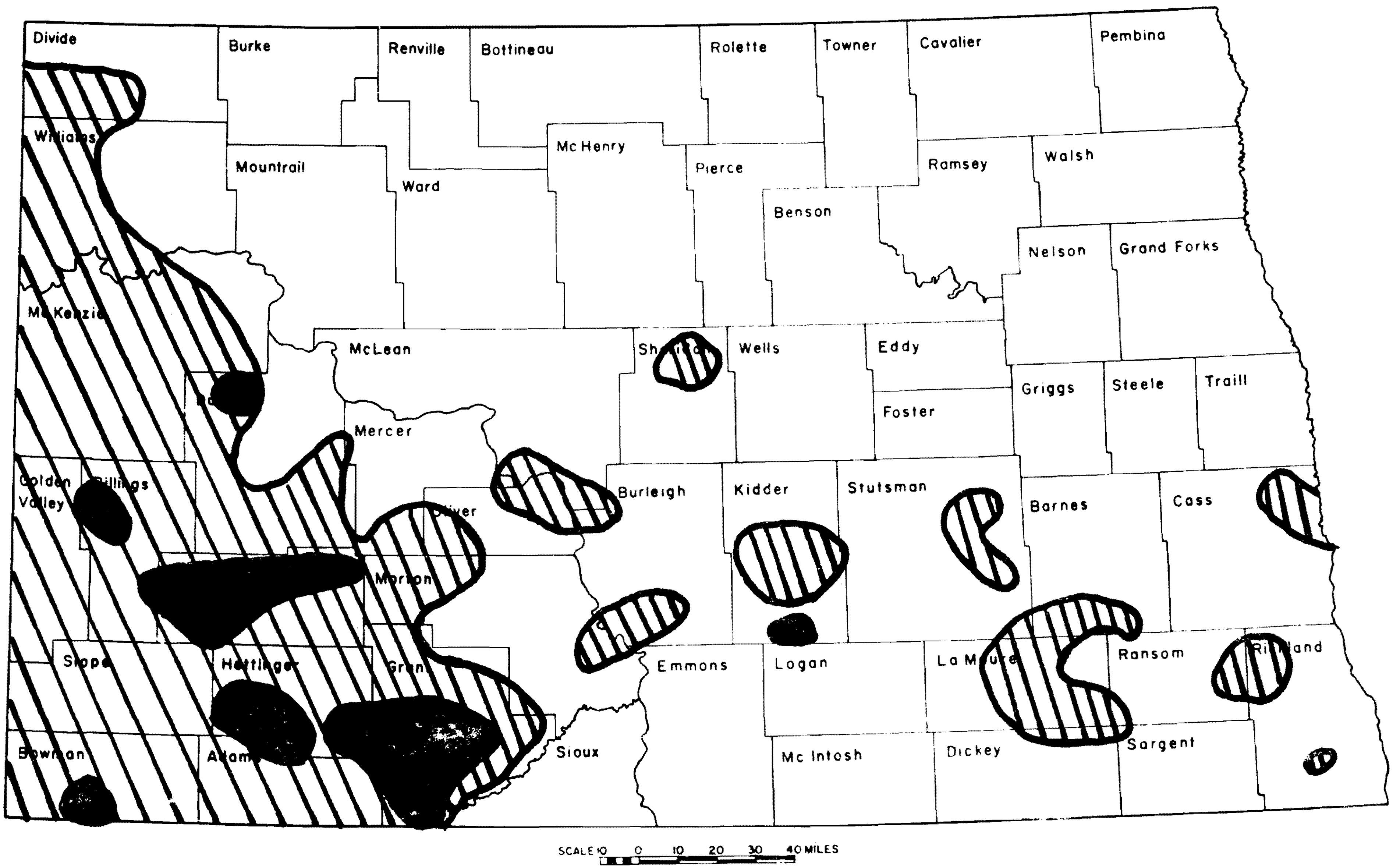
2. Is the infestation general throughout the grain mass? Often times in checking grain storages, you will find most of the insects concentrated near the surface.

3. Is the grain in good storable condition? If the grain is green or contains high moisture content, there isn't much use in controlling insects because the grain will go out of condition regardless of whether insects are present, and most certainly it will be reinfested.

If the infestation is found throughout the grain mass, the only alternative is to fumigate. However, if most of the insects are located near the surface, the surface treatment will usually suffice, or the top few inches of grain can be removed and treated or fumigated and then placed back in storage.

NOTES

ADULT GRASSHOPPER SURVEY
Fall 1974
North Dakota



Non-economic to light	0 to 3 per sq. yd.
Light to threatening	3 to 7 per sq. yd.
Threatening to severe	8 or more per sq. yd.

Prepared by: North Dakota Department of Agriculture in Cooperation with the USDA Animal and Plant Health Inspection Service

FACTORS INFLUENCING INSECT CONTROL

The following information is a compilation of some of the common reasons why inadequate or less than desired insect control may occur when conditions "appear" to have been ideal for achieving maximum control. Some of the problems encountered are such that they sometimes can be prevented by the Ag. Chemical Dealer. Others can be avoided by the farmer, whereas in some cases there are unavoidable problems such as a sudden change in weather conditions that may alter the effectiveness of an insecticidal compound.

The intent of the following information is to help serve as an aid in minimizing some of the common errors made in insect control efforts.

I. The Insecticide

1) Storage Conditions: The temperature and humidity conditions under which an insecticide is stored is a major consideration to assure that compounds held over for use (or sale) another season will remain effective. Certain insecticide formulations, for example, have a shorter shelf life than others. Dry insecticide formulations (dusts, granules, wettable powders) tend to degrade in storage more rapidly than insecticides formulated as emulsions. This is more of a problem with organophosphate insecticides than chlorinated hydrocarbon insecticides. However, under adequate storage conditions, dry insecticide formulations will normally hold up for at least 3 years.

Another problem with dry formulations is that if they're stored under conditions of high humidity, they will tend to become lumpy or "cakey". If this occurs, many times the dry insecticide is ruined and will have to be discarded. Often when attempts are made to use lumpy, dry formulations, plugging of application equipment occurs resulting in uneven application which will ultimately result in deficient insect control.

Low temperatures can also be a major factor in reducing the effectiveness of stored insecticides. This is especially true of emulsions. When such insecticides are subjected to freezing temperatures a condition often occurs called "breaking of an emulsion". This simply means that the emulsifying agent or surfactant has broken down and is no longer effective. When attempts are made to mix such an emulsion insecticide with water the materials will not mix or emulsify. Again, as with the dry materials, uneven or inadequate spray application often occurs resulting in poor insect control.

A good test to determine if stored emulsion insecticides are still usable is to mix a small sample of the insecticide with a quantity of water in a glass jar. If the mixture separates after standing a few minutes and will not form a milky emulsion that remains, the insecticide probably is no good and should be discarded. Occasionally such insecticides can be "rejuvenated" by sending them back to the formulator or manufacturer for addition of an emulsifying agent. However, this is normally not done unless large quantities of emulsion insecticides are involved.

Insecticide storage areas should be low in humidity and should have a temperature of 50-60° F. Storage temperatures near or below freezing will not only cause breaking of an emulsion but may also cause crystalizing of certain types of emulsifiable insecticides.

High storage temperatures tend to hasten degradation of insecticides especially chemicals having a high degree of volatility.

2) The Formulation: Insecticides used for the control of agricultural insects are usually available as liquid concentrates (emulsions), dusts, wettable powders, granules or pelleted baits. The proper selection of the insecticide formulation for the particular insect to be controlled is often a very important consideration in assuring maximum control without possible harmful affects (phytotoxicity) to the crops being treated. While there is no general rule of thumb to follow in selecting a particular formulation for a particular species of crop insect, some examples of formulations used for certain types of insects might be helpful.

a) Granular Insecticides: The granular formulation of insecticides is frequently used for the control of soil insects such as root maggots, wireworms, white grubs, corn rootworms and others. While there are several advantages in using granules, the most important is that granules tend to degrade more slowly in soil than do most emulsifiable insecticides. This is particularly desirable for soil insect control where chemical residual is often necessary to provide adequate control of insects protected by soil particles or soil insects that may have an extended period of hatching. An additional factor is that granular insecticides have less tendency to adhere to organic soil particles which will tend to minimize the effectiveness of certain other insecticide formulations.

A final advantage in using granular insecticides for the control of soil insects is that granules will allow proper placement in the soil through the use of equipment such as band applicators. Proper placement is desirable not only to maximize control in the soil zone where a particular soil insect is likely to be most prevalent, but also to minimize seed or seedling phytotoxicity.

b) Emulsion Insecticides: The emulsion or liquid formulated insecticides have a multiplicity of uses for a number of crop insect problems. Although emulsion insecticides are frequently applied as foliar sprays to crops, this is not always the most desirable selection inasmuch as certain factors can hinder the effectiveness of emulsion spray applications. For example, dense vegetative growth in certain crops requiring insect control in late season will often have a heavy canopy cover. Such a vegetative cover will often prevent spray droplets from penetrating to the inner crop foliage thus reducing control.

Very low or high temperatures may alter the effectiveness of emulsion insecticides. Malathion, for example, has been found to provide very poor insect control at temperatures of 60° F. or lower. Extremely high temperatures, on the other hand, will cause certain highly volatile insecticides, such as parathion, to vaporize rapidly and degrade too quickly thus providing a very short period of control or virtually no control at all.

c) Wettable Powders: One distinct advantage in using a wettable powder for crop spraying is that the applicator can avoid the possibility of foliar "burn" or injury that sometimes occurs as a result of applying emulsifiable insecticides that contain petroleum solvents. However, uneven chemical application (resulting in erratic control) can occur with wettable powders if they are not kept in adequate suspension. Therefore, in order to avoid "settling out" of wettable powders there must be adequate tank mixing as well as agitation prior to and during the spray operation.

d) Dusts: Dust formulations are seldom used in treating crops due to the problems of drift, handling and application. However, for some types of insect problems such as certain potato insects, dusts will perform very well. On hosts such as potato, dusts will become well distributed on the undersides of plant parts as well as the upper surfaces.

e) Baits: Pelleted baits are particularly effective against "foraging" insects that feed on or near the surface of the soil. In North Dakota pelleted apple pomace baits containing Sevin or Lannate insecticide have been found to be especially effective in controlling cutworms and crickets. Pelleted baits act as an attractant to insects of this type; thus baits appear to have somewhat of an advantage over the conventional spray method for cutworms, crickets and similar foraging insects.

3) Selection of an Insecticide: Failures in insect control can sometimes be attributed to the fact that the wrong insecticide was used for the insect to be controlled. Since various types or groups of insecticides are selective in their modes of action and entry, proper selection of an insecticide is extremely important.

a) Classification by Mode of Entry: Insecticides have been classified, according to the manner in which they are administered to insects and their mode of entry into the body, into the following four groups:

Stomach: application to the food and entry through the midgut, e.g. arsenicals and fluorine compounds.
Contact: application to the body surface and entry through the cuticle and trachea, e.g. pyrethrins, rotenone, nicotine.
Fumigant: application as a vapor and entry through the trachea, e.g. carbon tetrachloride, methyl bromide.
Residual: application to surfaces and subsequent uptake through the cuticle, especially of the tarsi (feet), e.g. DDT, chlordane.

This is not a completely true classification, since any given insecticide will be found to partake of a measure of several of the types of toxicity. Chlordane, for example, is capable of showing all four types of toxicity: lindane and DDT three out of the four. These insecticides will be found to arrange themselves in different orders of toxicity, depending on which category is considered.

Stomach: lindane > DDT > chlordane
Contact: DDT > lindane > chlordane
Fumigant: chlordane > lindane > DDT

The organophosphate insecticides as a group include compounds that may fall into one or all four of the mode of entry categories and therefore, a strict classification of the organophosphorous compounds is not possible.

Inasmuch as the modes of action and entry differ for each insecticidal compound, it is not possible for farmers and custom applicators to be aware of the characteristics of all available insecticides. However, the proper procedure is to first determine what type of insect you're dealing with and then select the insecticide (or insecticides) that are known to control that particular insect. A knowledge of the inherent capabilities of each insecticide is helpful but not necessary in selecting an insecticide since information on the pests an insecticide will control is either given on the pesticide container or can be obtained from county agents, ag. chemical dealers or university pest control personnel.

II. The Application

Space does not permit a completely comprehensive discussion of all the factors to consider in the application of an insecticide since application techniques vary considerably depending upon the formulation, insects to be controlled, crops to be treated, weather conditions, etc. However, a few guidelines can be given that should be helpful. In some cases these guidelines are all too frequently not observed.

1) Coverage: For virtually all types of insect control, coverage or adequate dispersion of the insecticide is essential. Factors that will often hinder coverage are lack of water in spray applications, improper calibration, heavy foliar cover, "waxy" cuticle of plants, settling out of wettable powders and wind velocity.

Frequently the problem of application is to make deposits on horizontal surfaces, either to contact resting insects or to leave a residual deposit for them to contact or eat. For modern application this becomes a problem of leaving a continuous film of the minimum thickness possible, for with the potency of present day insecticides there is seldom the problem of there not being enough poison. The main source of inefficiency in application is the existence of gaps, between the deposited droplets or particles, of sufficient size that the victim will escape.

When droplets of aqueous sprays are deposited on plant surfaces, their diameter increases up to 3 times; oil droplets spread up to 10-15 times their original diameter. However, this spread factor is lower the larger the droplet size. The number of droplets falling on a unit area decreases from about 10,000 per square inch when their unit diameter is 50 microns (25.4 microns = .001 inch) down to only 40 when their diameter is 300 microns. Since the area of leaf surface presented vertically in an acre of vegetation is many acres, the coverage per unit of leaf surface will be considerably less.

Considering the previously mentioned factors, selection of the proper nozzle size to provide proper sized droplets is extremely important to insure maximum insect control. Optimum droplet size for ground spraying should be 80 microns down to 30 microns. Sprays applied from aircraft (falling from 5 to 25 ft. with turbulence) require a larger droplet size to prevent drift, namely 70-100 microns.

With repeated usage spray tips tend to clog or wear, thereby providing improper, often costly, insecticide application. It is therefore most important to clean equipment and spray tips regularly and to check flow rates to be sure the spray flow is in accordance with what it should be for the nozzle tip size you are using.

2) Amount of Water: For certain types of insect control it is absolutely imperative that a maximum amount of water be used in order to provide maximum coverage and control. A good example is cutworm control where 15-20 gallons of water is recommended per acre using ground spray equipment. Frequently a failure to achieve good cutworm control can be traced back to the fact that not enough water was applied per acre. This is one of the reasons why failures will occur with aerial applications for cutworm control since most aerial applications will not exceed 5-7 gallons of water per acre.

3) pH of Water: In recent years another consideration in the application of insecticides is the pH of the water to be used for spraying. This is particularly important when organophosphate insecticides are to be used such as Dylox, Guthion, parathion and others. Experience in the Red River Valley area of North Dakota indicates that water with a pH of 8.0 - 8.2 or higher will cause rather rapid degradation of organophosphate insecticides which, of course, results in reducing the duration of time that pH affected insecticides will provide control.

Various buffering agents are now available for use in altering the pH of water in order to prevent rapid insecticidal degradation. In situations where insecticides appear to be breaking down at a faster rate than they should be, it might be advisable to run a pH analysis on the water and use a buffering agent if the test indicates such a compound is needed.

III. The Insects

Insects have great adaptability and have adjusted to many ecological conditions and situations throughout the world. The fact that certain insects can survive the heat of summer and the freezing temperatures of winter in the northern states attests to their ability to adapt to changing environmental conditions.

Certain factors will affect the abundance of certain insect species from year to year. However, it should be understood that not a single species of insect has ever been eradicated due to adverse climatic conditions or the efforts of man. All we can ever hope to do is suppress injurious insects. So in effect, although we talk about insect control, what we're really striving for is insect suppression in order to provide crop protection and attempt to maximize yields. The following information includes some of the major factors to consider in insect control.

1) Insect Identification: Correct identification is the first important step in pest control. It provides a key to information on the

life cycle, behavior and ecology of the insects, and to other important data in the development of control measures. Unfortunately, correct identification is often not observed and insufficient control becomes the end result.

One of the all too common mistakes made is that a grower assumes that if there are a large number of insects present in his field they must be causing damage. Many times this is not the case at all because insect pollinators, predators, weed feeders etc. often make up a large part of the insect population occurring in fields. If there are visible signs of damage in a field (such as leaf chewing, yellowing, etc.) then certainly this should serve as a clue that injurious insects are present and specimens should be collected for identification by qualified insect identification personnel. However, it is a mistake to immediately assume that a high population of insects present in a field means that the field must be immediately sprayed.

2) Insect Life Cycle and Habits: A basic knowledge of the life cycles and habits of common crop insects is extremely useful. All insects have a "weak link" in their life cycle or feeding habits which makes them more susceptible to insect control at certain times or stages than others. One of the key factors in successful insect control is knowing when to time an insecticidal application to coincide with the stage of insect development of feeding which is most susceptible. Common failures in insect control efforts sometimes occur as a result of making insecticide applications prior to or after a stage of insect susceptibility or a time of day or season when insects are protected from insecticidal application. Some examples will be helpful in explaining the importance of the concept, "timing of application".

a) Cutworms: A common habit that is characteristic of virtually all species of cutworms is their tendency to feed on plants during the evening hours and rest in the upper 2-3 inches of soil during the daytime. Since the cutworms are well protected by the upper layer of soil during the daylite hours, insecticidal applications for cutworm control should be made in the early evening when the cutworms begin to emerge and commence feeding. This will assure that the insecticide is at maximum strength when the cutworms are most vulnerable to control. This is very important when using short residual insecticides that only remain effective for a day or two.

Another important point about cutworms is that they are, for the most part, early season infestors of crops. Therefore, it is important to be aware of this fact and detect them in fields as soon as they appear rather than waiting until they have caused considerable damage. After cutworms have been allowed to feed for a time and develop into later larval growth stages, they are more difficult to control.

b) Wireworms: Another insect that infests crops early in the season is the wireworm. During the spring and early summer, wireworms move to the upper 3-4 inches of soil to feed on newly planted seeds or seedlings. Later when soil moisture becomes depleted the wireworms move deeper into the soil for the remainder of the season.

Thus in order to effectively control wireworms, a suitable seed treatment must be used or a preplant or planting time insecticide treatment. If wireworm damage is discovered once the crop is up and growing it is too late to initiate control measures. Soil sampling prior to planting is helpful in determining the need for wireworm control.

3) Insect Population Level: In recent years there has been considerable emphasis placed on determining the need for an insecticide application before it is made. A common phrase used in this connection is economic threshold. Very simply stated this means, is there a high enough insect infestation level to warrant the cost of an insecticide application. In order to make this determination it is often helpful to seek the help of someone who has training in evaluating insect infestations. Such a person should be able to determine whether or not the insect population is at a high or low level and whether or not the infestation can be expected to increase to more damaging proportions. The next step is to estimate how much can be spent profitably to reduce the damage and what would be the most efficient approach to the problem.

Certain situations will occur where the insect infestation level is moderate, located around field margins but expected to increase and move into fields. In such an instance, it would be desirable to control the infestation early in the interest of avoiding greater cost at a later date.

IV. The Soil and Weather Conditions

The presence of pesticidal residue in our environment has created problems that were unknown to us before the introduction of synthetic chemicals for pest control. Therefore, the behavior and fate of insecticides in soils and their translocation into either crops or water is of special significance.

SOILS: Soils are being contaminated either through "fallout" after crop spraying for insect control or through direct soil treatment with insecticides. The persistence or breakdown of insecticidal chemicals in soils depends on the following factors:

1) The Insecticide: Large differences exist in the different groups of insecticides. The chlorinated hydrocarbon group such as DDT, aldrin, dieldrin, and heptachlor are more persistent than those of the organophosphorous group such as parathion, malathion, Guthion, etc. Likewise differences exist within each group of chemicals whose half life in soil may range from days to several months.

2) Soil Type: Insecticides persist longer in soils of high organic matter than in those of low organic matter content. In a muck soil (organic matter approximately 50%) insecticidal residues are bound to the soil particles to such an extent that the same amount of toxicant is less effective in a muck soil as compared to a sandy one. Insecticides are absorbed into crops most readily from sandy soils and least readily from muck soils.

3) Soil Moisture: The persistence of aldrin is affected by soil moisture. Water apparently causes a displacement of aldrin from the soil

particles. Once this is accomplished, a major part of the insecticide is lost by volatilization. Aldrin is lost from water surfaces, but this loss does not seem to be affected by water evaporation as such.

The persistence of DDT is not affected by the amount of water evaporated from soil. Moisture enhances the release of volatile insecticides from soil particles and also influences the breakdown of other insecticides by way of hydrolysis. In addition, attacks of microorganisms on insecticidal chemicals require certain moisture conditions. While one of the main reasons for the loss of aldrin or heptachlor residues from soil was found to be volatilization of the chemical, parathion is detoxified and disappears through hydrolysis or reduction to its amino for form.

4) Soil Temperature: Soil temperatures have a remarkable effect on the rate of loss of an insecticide. They influence both the loss through volatilization as well as the breakdown of the insecticide by biological and chemical factors.

5) Cover Crops: Cover crops, such as alfalfa, in insecticide treated fields increase the persistence of volatile pesticides in soils. Two to three times more insecticidal residues were recovered from alfalfa-covered plots than from fallowed ones. Volatilization appears to be the main factor in the loss of insecticidal residues.

6) Wind or Air Movement: Longer persistence of pesticides in the soil can be expected where volatilization is reduced by restricting the wind or air movement at the soil-air interface with a dense cover crop.

7) Soil Cultivation: Cultivating the soil increases the disappearance of insecticidal residues from soils. Under field conditions, daily discing of a loam treated soil with aldrin or DDT has resulted in a reduction of 38 per cent of the aldrin residues and 25 per cent of the DDT residues during a 3 month period.

8) Application: The greatest loss can be expected when the insecticide is applied to the soil surface and not immediately incorporated. Conversely soil applications where the pesticides are incorporated to a depth (4 to 5 inches) will persist longer.

9) Formulation: The greatest persistence of residues is likely to occur with granules with the emulsion application (spray) less persistent.

10) Soil Microorganisms: Microorganisms in soil attack various insecticides. In dry soils, both aldrin and parathion persist longer than in wet soils. Due to microbiological activities, aldrin is oxidized to dieldrin. In soils containing a low number of microorganisms or in dry soils the amount of dieldrin formed from aldrin is small. Heptachlor persists slightly longer than aldrin but the amount of heptachlorepoxide formed is smaller than that of dieldrin. The effects of moisture and microorganisms on the persistence and metabolism of parathion is most persistent in soils with a high moisture content. Parathion is not lost through volatilization, as in the case with some insecticides of the chlorinated hydrocarbon group. Degradation of parathion is either by hydrolysis or by reduction to its amino form, depending on populations of soil microorganisms.

V. Systemic vs. Non-Systemic Insecticides

For certain types of insect problems it is desirable to use an insecticide that will translocate or move in the vascular tissue of the plant and essentially cause the plant to be toxic to insects. Such an insecticide is called a systemic. Systemics have an advantage over non-systemics in that once they are absorbed into the plant they are not as apt to break down as the non-systemics which are subject to weathering on the surface of the plant. Also, the systemics can provide a more complete means of plant protection since most types of systemics move out to all foliar plant parts.

Although systemics can be applied in liquid form, they are more frequently applied in granular form at planting time. As the crop germinates and begins to grow, the systemic insecticide is taken up by the roots and translocated to the stems and leaves.

Some of the common systemic insecticides used include Thimet, DiSyston, Temik, Cygon and Furadan. Common insects controlled are sucking insects such as aphids as well as certain soil insects such as rootworms, root maggots, wireworms etc.

Not all systemic insecticides translocate in the same plant areas. Therefore, it is extremely important to use the correct systemic insecticide for the crop to be treated (i.e. the systemic must be registered for certain crops). Also, be sure the systemic insecticide you select is registered for the control of the particular insect problem you have.

NOTES

1975 Crop Insecticide Recommendations

The insecticide recommendations listed conform to current federal and state laws and regulations relating to chemical pesticides at the time of printing. However, since pesticide recommendations are frequently subject to change, it is extremely important that you keep in contact with the NDSU Entomology Department for up-to-date information on possible changes in insecticide registration.

The Entomology staff at North Dakota State University believe that the recommendations given are essentially accurate. However, since we do not exercise control over their use and the manner or conditions under which they are used, we assume no responsibility for personal injury, property damage, or other types of loss resulting from the handling or use of the insecticides listed.

FIELD CROP INSECTS

PEST	INSECTICIDE	DOSAGE (Actual Toxicant)	REMARKS
APHIDS	Parathion EC	4-8 ozs. per acre	Aerial application only. Do not use within 15 days of harvest.
Greenbug	Methyl-parathion EC	4-8 ozs. per acre	Same as above.
Corn leaf English Grain	Malathion EC	1 lb. per acre	Do not apply within 7 days of harvest on wheat, oats, rye and barley. Do not apply below 60^{o} F.
	Di-Syston	6-8 ozs. per acre	Aerial application only. Do not apply within 30 days of harvest. Use lower rate on plants up to tillering and higher rate after tillering.
	NOTE: Infestations likely to appear in late seeded barley, especially during cool, wet weather. Watch for buildup of predators and parasites of aphids in fields. Control usually not advised until infestation approaches 300 aphids or more per linear foot of crop row.		
ARMYWORMS	Toxaphene EC	2 lbs. per acre	Do not feed treated straw to dairy animals or animals being finished for slaughter. No restriction on the use of the grain.
	Dylox SP, EC	1 lb. per acre	Do not apply within 21 days of harvest.
	Malathion	1½ lbs. per acre	Do not harvest for 7 days.

PEST	INSECTICIDE	DOSAGE (Actual Toxicant)	REMARKS
ARMYWORMS (continued)	Thiodan	½ lb. per acre	Do not apply after heads begin to form. Do not feed treated forage to dairy animals or animals being finished for slaughter. Follow the label on operator safety for prolonged usage.
	NOTE: Treat when larvae first appear. Most infestations are likely to appear in lodged grain, especially barley. Infestations may also appear in rye, oats, wheat and grassy roadsides or field margins.		
CORN ROOTWORM	Furadan G	3/4-1 lb. per acre	Apply at planting time or as a post plant treatment by banding over the row and cultivating into the soil or by side dressing on one or both sides of the row. Not more than one application per season.
	Thimet G	1 lb. per acre	Apply to furrow evenly at planting time or if not used at planting time, apply granules at the time of cultivation in a band at base of plants and cover with soil.
	Dasanit G	1 lb. per acre	Apply to furrow at planting time or apply granules at time of cultivation in a band at base of the plants and cover with soil.
	Dyfonate G	1 lb. per acre	Application at planting: Incorporate into the top ½ to 1 inch of soil by making application ahead of press wheel or by dragging a short length of chain behind the press wheels. Application at cultivation: Cover the treated band with 2-3 inches of soil by making application immediately ahead of disc hillers or cultivation equipment. Do not apply within 45 days of harvest.
	Prophos (Mocap, Jolt)	1 lb. per acre	Do not apply in contact with seed!

PEST	INSECTICIDE	DOSAGE (Actual Toxicant)	REMARKS
CORN ROOTWORM (continued)	NOTE: The insecticides recommended for larval control are suggested for application in the granular form only and are to be applied with a granular applicator. Apply in 4 to 7 inch bands over the rows (not with the seed) at planting time and incorporate the insecticide into the upper 1/2 inch of soil. Carefully calibrate equipment to give correct dosages.		
WIREWORMS (Corn only)	Thimet G	1 lb. per acre	Place granules in a 7 inch band over the row directly behind the planter shoe in front of the press wheel. Do not place Thimet in direct contact with seed.
	Furadan G	2-3 lbs. per acre	Apply in a 7 inch band or in the furrow at planting.
CRICKETS	Toxaphene EC	1½ to 2 lbs. per acre	Restrictions same as for armyworms.
CUTWORMS	Endosulfan EC (Thiodan)	½ lb. per acre	Do not apply after heads form. Do not feed straw or forage to dairy animals or animals being finished for slaughter.
	Toxaphene EC, D	2 lbs. per acre	Restrictions same as for armyworms.
	Dylox SP, EC	1 lb. per acre	Three applications may be made per season but not within 21 days of harvest.
	Sevin 5% bait (corn)	1 lb. per acre	No limitations on forage.
	NOTE: Residue problems following insecticidal application to crops infested with cutworms are not considered serious inasmuch as application is usually made early in the spring shortly after the crop is planted. Apply sufficient water (15 to 20 gallons per acre) to get uniform coverage on the surface of the soil.		
EUROPEAN CORN BORER	Carbaryl (Sevin)	1½ lbs. per acre (Use 10 gals. water)	No time limitations.
	Carbaryl (Sevin) 10% granules	1½ lbs. per acre	No time limitations.

PEST	INSECTICIDE	DOSAGE (Actual Toxicant)	REMARKS
EUROPEAN CORN BORER (continued)	Diazinon G	1 to 2 lbs. per acre	Corn may be picked immediately following last application. Do not feed forage to livestock within 10 days following last application.
	Furadan G	1 lb. per acre	Do not make more than 2 foliar applications per season.
	Furadan G	2-3 lbs. per acre	Apply in a 7 inch band or in the furrow at planting.
	Thimet G	8 ozs. per 1000 ft. of row	Apply granules into whorl of plant prior to tassel emergence with air or ground equipment. Do not apply within 30 days of grazing or cutting for forage.
	Bacillus Thuringiensis	Liquid 2-4 qts. per acre Dust-2.5%-15 to 20 lbs. per acre WP 25% - ½ lb. per acre	No restrictions on grain or ensiling of treated crops. Treat corn when 50 per cent or more of the plants show larval feeding in the whorl.
GRASS-HOPPERS	Toxaphene EC	1½ to 2 lbs. per acre	Do not feed treated straw to dairy animals or animals being finished for slaughter. No restriction on the use of the grain.
	Malathion (ULV 95% Concentrate)	8 fl. ozs. per acre	Commercial aerial applicators only. Do not harvest for 7 days.
	Malathion EC	1 to 1½ lbs. per acre	Wait 7 days before harvest on grain. No time limitation on grazing or straw for dairy or slaughter animals.
	Sevin S (corn)	2 lbs. per acre	No limitations on forage.
	Sevimol 4 (corn)	1½ lbs. per acre	Same as above.
GRASSHOPPERS (Winter wheat field border treatment)	Thimet	1 lb. per acre (based on 7" spacings)	Apply at planting time in seed furrow with granular applicator or grass seeder attachment. Do not graze treated wheat.

PEST	INSECTICIDE	DOSAGE (Actual Toxicant)	REMARKS
HESSIAN FLY	No chemical control recommended. Early infested fields may be reseeded. Early swathing recommended in heavily infested fields.		
WHEAT MIDGE	No effective control measure known.		
WHEAT STEM MAGGOT	No chemical control recommended. In most years a very small percentage of the stems will be infested. Heads of infested plants usually turn white and they can be easily pulled out. Crop rotation and destruction of volunteer grain and infested straw is helpful.		
WHEAT STEM SAWFLY	No chemical control recommended. Early fall tillage (shallow), crop rotation, early swathing or planting will help reduce crop losses. Two sawfly resistant varieties of hard red spring wheat are recommended for planting in sawfly areas. They include Fortuna and a new release named Tioga.		
BARLEY THRIPS	Parathion EC	4 to 6 ozs. per acre	Aerial application only. Treat at least 15 days before harvest. Treat when thrips population averages 3-4 adults per plant at the time the crop begins to head out.

SEED TREATMENT
(Wireworms)

Insecticide	Wheat	Barley	Rye	Oats	Corn	Soybeans	Method of Treatment
Dry	(Ounces actual ingredient per bushel)						
*Aldrin	½-3/4 oz.	½-3/4 oz.	½-3/4 oz.	½-3/4 oz.	½-3/4 oz.	½-3/4 oz.	Drill box
*Dieldrin	½-3/4 oz.	½-3/4 oz.	½-3/4 oz.	½-3/4 oz.	½-3/4 oz.	½-3/4 oz.	Drill box
Heptachlor	½-3/4 oz.	½-3/4 oz.	½-3/4 oz.	½-3/4 oz.	½-3/4 oz.	½-3/4 oz.	Drill box
Lindane	½ oz.	½ oz.	½ oz.	½ oz.	½ oz.	½ oz.	Drill box

NOTE: For maximum benefits, the insecticide must be mixed thoroughly with the seed.

Liquids

*Aldrin L	Follow directions for use on label.	Liquid or Mist type
*Heptachlor L	Follow directions for use on label.	Liquid or Mist type

NOTE: The registrations for Aldrin and Dieldrin seed treatments has been cancelled by EPA. This means that existing supplies can be sold and used in the state but these compounds can no longer be manufactured or shipped in interstate commerce.

Combinations

Lindane + Fungicide D	Follow directions for use on label.	Drill box
Heptachlor + Fungicide L	Follow directions for use on label - Do not use on corn or soybeans.	Liquid or Mist type treater
Aldrin + Fungicide L	Follow directions for use on label - For use on beans, peas and soybeans	

NOTE: Do not use any of the above mentioned insecticides on sugarbeet seed - Check with Sugarbeet Representatives before treating beet seed. Lindane is the only insecticide approved for use on sunflower seed.

Caution: Do not use treated seed for feed or food purposes. Prevent the contamination of commercial grain by thoroughly cleaning bins, grain augers and trucks that have been used to store, handle and/or home treat seed.

FORAGE CROP INSECTS

NOTE: When spraying legume fields, apply insecticides between 7:00 p.m. and 7:00 a.m. to protect the local bee population. Never spray fields in bloom.

PEST	INSECTICIDE	DOSAGE (Actual Toxicant)	REMARKS
ALFALFA WEEVIL (larvae)	Early cutting if possible. Regrowth should be carefully observed for signs of damage or retardation of growth before applying a spray. Where early cutting of the first crop is not possible or when damage to regrowth occurs use one of the following insecticides:		
	Methyl parathion EC	8 ozs. per acre	Aerial applications only. Do not apply within 15 days of harvest.
	Ethyl parathion EC	6 ozs. per acre	Restrictions same as for methyl parathion.
	Guthion EC	12 ozs. per acre	Aerial application only. Do not apply within 21 days of harvest. Only one application per cutting.
	Diazinon EC	1 lb. per acre	Do not graze livestock within 2 days after application. Do not cut for hay within 10 days after application.

PEST	INSECTICIDE	DOSAGE (Actual Toxicant)	REMARKS
ALFALFA WEEVIL (larvae) (continued)	Furadan 4F	½-1 lb. per acre	Do not cut or graze for 14 days at ½ lb. rate and 28 days at 1 lb. rate.
	Supracide EC	½-1 lb. per acre	Do not apply within 10 days of harvest or feeding to livestock.
	Imidan	1 lb. per acre	Do not graze or cut within 7 days of application - do not apply over once per cutting.
	Methoxychlor	1½ lbs. per acre	Do not apply within 7 days of harvest.
	Carbaryl (Sevin)	1½ lbs. per acre	No waiting period.
	NOTE: Combinations of diazinon + methoxychlor and malathion + methoxychlor are also registered for use.		
PEA APHID, SWEET CLOVER APHID, LEAFHOPPER	Cygon	4 ozs. per acre	Do not apply more than once per season or within 28 days of harvest.
	Diazinon EC	½ lb. per acre	May be grazed or fed green immediately. Do not cut for hay within 7 days after application.
	Furadan 4F (Pea Aphid)	½-1 lb. per acre	Do not cut or graze within 14 days at 1 lb. rate or 28 days at 2 lb. rate. Use 10 gals. finished spray per acre with ground equipment, 2 gals. per acre with aircraft.
	Guthion EC	8 oz. per acre	Aerial application only. Do not harvest within 16 days.
	Malathion EC, D	1 lb. per acre	No time limitation on forage or grazing.
	Naled (Dibrom)	1 lb. per acre	Do not cut hay within 4 days after application.
	Parathion EC	½ lb. per acre	Aerial application only. Wait 15 days before cutting or grazing.

PEST	INSECTICIDE	DOSAGE (Actual Toxicant)	REMARKS
CATERPILLARS LOOPERS AND WORMS FEEDING ON LEAVES	Carbaryl (Sevin) SP	1½ lbs. per acre	No time limitations.
	Parathion EC	4-8 ozs. per acre	Wait 15 days before cutting or grazing.
	Dylox SP, EC	8 ozs. per acre	Three applications may be made per cutting with last application up to the day of cutting.
CUTWORMS	Carbaryl (Sevin) SP	1½ to 2 lbs. per acre	No time limitations.
	Parathion (Ethyl or Methyl)	8 ozs. per acre	Aerial application only. Do not apply within 15 days of harvest.
	Dylox	1 lb. per acre	Three applications may be made per cutting with last application up to the day of cutting.
CRICKETS	Carbaryl (Sevin) SP	1½ to 2 lbs. per acre	No time limitations.
	Sevin 5% bait	1 lb. per acre	No time limitations.
	Toxaphene EC	1½ to 2 lbs. per acre	Do not feed forage to dairy animals or animals being finished for slaughter.
GRASS-HOPPERS	Toxaphene EC	1½ to 2 lbs. per acre	Do not feed treated forage to dairy animals or animals being finished for slaughter.
	Carbaryl (Sevin) Sprayable	1½ lbs. per acre	No time limitation for grazing or cutting. Avoid treating fields where honey bees are working.
	Sevimol 4	1½ lbs. per acre	No time limitation for grazing or cutting. Avoid treating fields where honey bees are working.
	Guthion	½ lb. per acre	Do not harvest within 16 days.
	Malathion EC	1 to 1½ lbs. per acre	No time limitation on cutting or grazing.

PEST	INSECTICIDE	DOSAGE (Actual Toxicant)	REMARKS
GRASS-HOPPERS (continued)	Malathion (ULV)	8 to 10 ozs. per acre	Aerial application. Applied alone or dissolved in 1 pint diesel oil per acre.
LYGUS OR PLANT BUGS	Dylox SP	1 lb. per acre	Application may be made up to day of cutting.
	Guthion	½ lb. per acre	Do not harvest within 16 days.
	Methoxychlor EC, D	1 to 1½ lbs. per acre	Wait 7 days before cutting or grazing.
	Sevimol 4	1½ lbs. per acre	No time limitations.
	Sevin S	1½ lbs. per acre	No time limitations.
	Thiodan EC, WP (seed crop only)	1½ to 2 lbs. per acre	Do not feed treated forage to dairy or meat animals. Do not use on forage to be sold commercially or shipped interstate.
	Toxaphene EC, D	1 to 1½ lbs. per acre	Do not graze or feed treated forage to dairy cows or animals being finished for slaughter.
SWEET CLOVER WEEVIL	Toxaphene EC	2 lbs. per acre	Apply in early spring or after cutting before new growth is 4 inches tall. Do not feed treated forage to dairy animals or animals being finished for slaughter.
	Parathion (Ethyl or Methyl)	8 ozs. per acre	Do not harvest within 15 days. Aerial application only.
SPOTTED ALFALFA APHID	Demeton (Systox) EC	¼ lb. per acre	Aerial application only. Wait 21 days before cutting or grazing. Do not apply more than once per cutting.
	Di-Syston EC	1 lb. per acre	Apply as a stubble treatment only after cutting. Do not apply as a foliage treatment. Allow 28 days between treatments.
	Malathion EC	1 lb. per acre	No time limitation on grazing or cutting.

PEST	INSECTICIDE	DOSAGE (Actual Toxicant)	REMARKS
APOTTED ALFALFA APHID (Continued)	Parathion EC	½ lb. per acre	Apply by airplane only. Wait 15 days before cutting or grazing.

NOTE: When the crop is grown for seed or green manure and no part of the crop is fed to livestock or treated areas grazed, the waiting periods do not apply. Dairy cows or animals to be slaughtered within 6 weeks should not graze or be fed treated forage until after maximum waiting periods. Legumes should not be treated when in bloom since this will affect bees and pollination. Insecticides applied late in the evening or early morning are least harmful to bees.

RANGELAND-PASTURE-ROADSIDE-WASTELAND

PEST	INSECTICIDE	DOSAGE (Actual Toxicant)	REMARKS
GRASS-HOPPERS	Malathion EC	1 to 1½ lbs. per acre	No time limitation on grazing or cutting.
RANGELAND PASTURES	Carbaryl (Sevin) Sprayable	1 to 1½ lbs. per acre	No time limitation on grazing or cutting. Remove lactating dairy animals from area before spraying. Animals may be turned into pasture after spraying.
	Diazinon EC	3/4 to 1 lb. per acre	No time limitation on grazing. Do not cut for hay for 21 days if the spray is a water solution or for 30 days if the spray is an oil solution.
	Malathion LV 95% Tech.	8 ozs. per acre	Aerial application. Applied alone or dissolved in 1 pt. diesel oil per acre. Remove lactating dairy animals from area before spraying. Animals may be turned into pasture after spraying.

ROADSIDE AND IDLE LAND (Soil Bank)	All the above restrictions apply unless the treated areas are not utilized for grazing or used for hay.

PEST	INSECTICIDE	DOSAGE (Actual Toxicant)	REMARKS
		POTATO INSECTS	
APHIDS	Azodrin EC	½ to 1 lb. per acre	Do not apply within 7 days of harvest.
	Dimethoate (Cygon) EC	½ lb. per acre	No time limitation.
	Endosulfan (Thiodan)EC	½ to 1 lb. per acre	No time limitation.
	Endosulfan (Thiodan) D	0.8 to 1.2 lbs. per acre (20 to 30 lbs. 4% dust)	No time limitation.
	Meta-Systox-R	6 ozs. per acre	Do not apply within 7 days of harvest.
	Methomyl (Lannate)	0.9 lb. per acre	Do not apply within 14 days of harvest.
	Monitor	3/4 to 1 lb. per acre	Do not apply within 14 days of harvest.
	Phosphamidon EC (Dimecron)	1 lb. per acre	Wait 7 days before harvesting.
COLORADO POTATO BEETLE	Aldicarb (Temik)	2 to 3 lbs. per acre at planting	Apply granules with seed piece in planting furrow and cover with soil or drill granules in even bands 2 to 4 inches on each side of the row and 3 to 8 inches deep (usually 1 to 2 inches below seed piece).
	Carbaryl (Sevin) sprayable	1-1½ lbs. per acre	First generation beetles likely to occur in late June to early July. Treat as soon as larvae appear. No time limitation.
	Guthion EC	½ lb. per acre	Start applications when potatoes are about 6 inches in height and continue on a 10 day schedule during the season. At least 3 applications prior to bloom are necessary for optimum response on red varieties. Wait 7 days before harvesting.

PEST	INSECTICIDE	DOSAGE (Actual Toxicant)	REMARKS
COLORADO POTATO BEETLE (Continued)	Imidan WP	2 lbs. per acre	Do not apply within 7 days of harvest.
	Monitor	3/4 to 1 lb. per acre	Do not apply within 14 days of harvest.
	Phosphamidon EC (Dimecron)	1 lb. per acre	Wait 30 days before harvesting.
FLEA BEETLE POTATO LEAFHOPPER, SIX-SPOTTED LEAFHOPPER	Aldicarb (Temik)	3 lbs. per acre at planting	See planting instructions in Colorado Potato Beetle section.
	Azodrin	½ lb. per acre	Do not apply within 7 days of harvest.
	Carbaryl (Sevin) sprayable	1-1½ lbs. per acre	No time limitation.
	Dimethoate (Cygon) EC	½ lb. per acre	No time limitation.
	Endosulfan (Thiodan) EC, D	1 lb. per acre	No time limitation.
	Guthion EC	½ lb. per acre	Same as Colorado Potato Beetle.
	Imidan WP	2 lbs. per acre	Do not apply within 7 days of harvest.
CABBAGE LOOPER	Monitor	3/4 to 1 lb. per acre	Do not apply within 14 days of harvest.
	Phosphamidon EC (Dimecron)	1 lb. per acre	Wait 30 days before harvesting.
	NOTE: Watch for infestations and be prepared to treat when insects first appear.		
POTATO INSECT COMPLEX	Disulfoton (Di-Syston) G	3 lbs. per acre	Band application at planting. Do not apply Di-Syston within 75 days of harvest or Thimet within 90 days of harvest.
(Thimet registered for Colorado Potato Beetle control)	Phorate (Thimet) G	3 lbs. per acre	Band application at planting.

PESTS	INSECTICIDE	DOSAGE (Actual Toxicant)	REMARKS
WIREWORMS	Chlordane G	4 lbs. per acre	Broadcast prior to planting. Disk in.
	Phorate (Thimet) G	2 to 3 lbs. per acre	Band application at planting.
		SUGARBEET INSECTS	
SUGARBEET ROOT MAGGOT	Dasanit G	1 to 2 lbs. per acre (Use lower rate in light soil, higher rate in heavy soil).	Apply specified dosage in a 3 to 7 inch band in one of the following ways: 1) In front of the planter. Incorporate the granules lightly into the soil with shallow tilling equipment. Plant seed into the center of the treated band of soil. 2) Directly behind the planter shoe in front of the press wheel. Place the granules 1 inch or more above seed. Do not allow granules to come in direct contact with the seed.
	Diazinon G	1½ to 2 lbs. per acre	Apply in a 7 inch band above the seed, or apply as a furrow treatment after the seed is covered. Make application ahead of the press wheel. A second application may be made early post-emergence in a 7 inch band over the row. (See label directions.)
	Dyfonate G	1 to 1½ lbs. per acre	Apply specified dosage in a 7 inch band over sugar beet rows 22 or more inches apart. Apply at planting and lightly incorporate into the soil. Do not place Dyfonate granules in direct contact with the seed.
	Phorate (Thimet) G	1 lb. per acre	Apply at seeding time in furrow above seed. 7 inch band.

PEST	INSECTICIDE	DOSAGE (Actual Toxicant)	REMARKS
SUGARBEET ROOT MAGGOT (Continued)	Temik G	1½ to 2 lbs. per acre	Apply granules in a 7 inch band over seed row at planting time and immediately work well into the soil by incorporation or cultivation equipment. May be applied postemergence according to label recommendations.
SUGARBEET WEBWORM	Carbaryl (Sevin) WP	1½ lbs. per acre	Do not apply within 14 days of harvest.
	Sevimol 4	1½ lbs. per acre	Do not apply within 14 days of harvest.
	Dylox SP, EC	1 lb. per acre	Do not treat within 14 days of harvest. No restriction on feeding tops to livestock.
	Endosulfan (Thiodan) EC	1 lb. per acre	Do not feed treated tops to livestock.
	Parathion EC	4 to 8 ozs. per acre	Do not apply within 15 days of harvest. Aerial application only.
WIREWORMS	Diazinon G	2 to 4 lbs. per acre	Broadcast and worked in just prior to planting.
	Dyfonate	4 lbs. per acre	Broadcast and worked in just prior to planting.
CUTWORMS	Carbaryl (Sevin) WP	2 lbs. per acre	Do not apply within 14 days of harvest. Use 15-20 gals. water per acre.
	Sevimol 4	2 lbs. per acre	Do not apply within 14 days of harvest. Use 15-20 gals. water per acre.
	Dylox SP, EC	1 lb. per acre	Apply specified dosage per acre using sufficient water for complete coverage. Repeat as necessary. Do not apply within 14 days of harvest. No restriction on feeding tops to livestock.

PEST	INSECTICIDE	DOSAGE (Actual Toxicant)	REMARKS
CUTWORMS (Continued)	Sevin 5% Bait	1 to 2 lbs. acre	Broadcast applications may be made with either ground or aerial equipment. Treatments may be repeated as necessary but do not apply within 14 days of harvest.

SOYBEAN INSECTS

PEST	INSECTICIDE	DOSAGE (Actual Toxicant)	REMARKS
ARMYWORM	Carbaryl (Sevin)	1½ lbs. per acre	No time limitations.
	Dylox SP	1 lb. per acre	Do not pasture or use treated crop for feed, food or oil purposes.
	Toxaphene EC	1½ to 2 lbs. per acre	Do not apply within 21 days of harvest. Do not feed treated plants or ensilage made from treated plants to poultry, dairy animals, or animals being finished for slaughter.
CRICKETS OR CUTWORMS	Toxaphene EC	1½ to 2 lbs. acre	Restrictions same as for armyworm.
	Chlordane EC	1½ to 2 lbs. per acre	Do not graze or feed threshings to dairy cattle or animals being finished for slaughter.
	Dylox SP (Seed crop)	1 lb. per acre	Do not pasture or use treated crop for feed, food or oil purposes.
	Sevin 5% bait	1 lb. per acre	No time limitations.
GRASSHOPPERS	Carbaryl (Sevin)	1½ lbs. per acre	No time limitation.
	Guthion EC	½ lb. per acre	Aerial application only. Do not apply within 21 days of harvest.
	Malathion EC	1 to 1½ lbs. per acre	Wait 1 day before harvest for forage use.
	Toxaphene EC	1½ to 2 lbs. per acre	Restrictions same as for armyworms.

PEST	INSECTICIDE	DOSAGE (Actual Toxicant)	REMARKS
		FLAX INSECTS	
ARMYWORMS CRICKETS GRASS-HOPPERS	Chlordane EC	1½ to 2 lbs. per acre	Chlordane cannot be applied on flax after blossoms appear. Do not feed treated forage to dairy animals or animals being finished for slaughter. No restrictions on the use of the oil.
	Dylox SP, EC	1 lb. per acre	Do not apply within 21 days of harvest. Allow 3 days between treatment and use of treated straw as feed for dairy or meat animals.
		MUSTARD INSECTS	
WESTERN BLACK FLEA BEETLE	Carbaryl (Sevin)	1-1½ lbs. actual per acre	Do not use within 14 days of harvest.
DIAMOND-BACK MOTH	Malathion (dust)	3 lbs. actual per acre	Do not use within 7 days of harvest.
	Malathion (spray)	2½ lbs. actual per acre	Do not use within 7 days of harvest.
	NOTE: Sevin has limited effectiveness on Diamondback Moths.		
		SAFFLOWER INSECTS	

There have been few insect infestations on safflower to date. However, given proper climatic and field conditions, aphids, lygus bugs and grasshoppers may be a problem.

APHIDS LYGUS BUGS GRASS-HOPPERS	Malathion EC	1 to 1½ lbs. per acre	Multiple applications may be necessary in years of high density populations. Do not apply within 3 days of harvesting of seeds.
	Parathion EC	½ lb. per acre	Do not apply after flowering.
	Dylox SP, EC	1 lb. per acre	Do not apply after flowering stage.

PEST	INSECTICIDE	DOSAGE (Actual Toxicant)	REMARKS
		SUNFLOWER INSECTS	
SUNFLOWER MOTH	Endosulfan (Thiodan) EC, WP	1 lb. per acre	Make first application at onset of bloom and make two more applications at 4-7 day intervals. Do not make more than 3 applications. May be applied up to day of harvest. Do not feed treated forage to livestock.
	Methyl Parathion EC (aerial application only)	1 lb. per acre	Make no more than three applications at 5 day intervals. Do not apply within 30 days of harvest.

NOTE: As of this printing toxaphene is not permanently registered for application on sunflowers. Efforts are continuing to obtain EPA registration for the use of toxaphene in the control of certain sunflower insects.

STORED GRAIN INSECTS

METHODS OF CONTROL	CROP	MATERIALS TO USE
Residual bin sprays: Clean, sweep and spray all bins before harvest. NOTE: Do not add grain to a treated bin for at least 24 hours or until walls have dried thoroughly.	All bins	Methoxychlor: 1 qt. 25% emulsifiable concentrate or 3/4 lb. 50% wettable powder in 3 gals. of water or apply ready-mixed 2% methoxychlor solution. or Malathion: 1 pt. premium grade 57% emulsifiable concentrate in 2 to 5 gals. of water. or Pyrethrins plus synergist can be used as residual bin spray. Use 1 gal. to each 750 square feet of bin surface.
Surface treatment: Apply insecticide to surface after grain is binned.	Wheat Barley Oats Corn Rye	Malathion: 1 pint premium grade 57% emulsifiable concentrate in 2 to 5 gals. of water per 1,000 square feet of grain surface area.

METHODS OF CONTROL	CROP	MATERIALS TO USE
Surface treatment: (Continued)		or Pyrethrins plus synergist used without further dilution with water at approximately 1 gal. per 750 square feet of grain surface area.
Grain treatment:		
All the grain is treated when bin is being filled. Insecticides may be applied as a spray to the grain as it is being augered into bin.	Wheat Barley Oats Rye Corn	Malathion: 1 pint 57% premium grade emulsifiable concentrate in 2 to 5 gals. of water per 1,000 bushels of grain. or Pyrethrins plus synergist applied without further dilution at approximately 2 gals. per 1,000 bushels.

FUMIGANTS

A grain fumigant is a gas, a liquid, or a mixture of liquids which evaporates easily to form vapors toxic to insects. These vapors permeate the grain mass and kill insects by suffocation or by chemical action on their breathing system, preventing the assimilation of oxygen, or other vital functions. In order for a grain fumigant to kill insects, it is necessary that the vapor or gas has a high enough concentration for a sufficient period of time. No fumigant kills insects instantaneously, usually it requires several hours, even under ideal conditions for fumigating.

Some Important Steps For Successful Fumigation

1. Do not attempt fumigating grain unless the grain temperature is 60 degrees or higher. Apply fumigants on a calm day.
2. Before applying fumigants, level the surface of the grain and break up any "caking" on the surface.
3. Seal bins as tightly as possible. The gas fumigant should be retained in the grain and not allowed to "leak" out. Use building paper or other material to cover all holes and cracks.
4. All fumigants should be handled with extreme care as the fumes are toxic. Apply the fumigant from the outside of the bin whenever possible. Always have a second person nearby while fumigating.
5. Always use the recommended dosage.
6. Keep all persons and animals out of the building for at least 36 hours. Fumigated grain may be fed to livestock 3 or 4 days after treatment.
7. Never use fumigants when the outside air temperature is below 60 degrees. During the cold winter months it would be better to turn or move the grain.

FUMIGANT	RESIDUE TOLERANCE	DOSAGES FOR 1,000 BUSHELS[1/] WHEAT	SHELLED CORN OATS, BARLEY	SORGHUM
Chloropicrin 15%	exempt	1-1/2 gal.	2 gals.	3 gals.
Chloropicrin 100%[2/]	exempt	2-1/2 lbs.	3 lbs.	4-1/2 lbs.
80% Carbon tetrachloride 20% Carbon bisulfide	exempt	3 to 4 gals.	5 to 6 gals.	6 to 8 gals.
75% Ethylene dichloride 25% Carbon tetrachloride	exempt	3 to 6 gals.	6 to 8 gals.	8 to 10 gals.
80% Carbon tetrachloride 15% Carbon bisulfide 5% Sulfur dioxide	exempt	2 to 4 gals.	5 to 6 gals.	6 to 8 gals.
60% Carbon tetrachloride 35% Ethylene dibromide	50 PPM[3/]	2 to 4 gals.	5 to 6 gals.	6 to 8 gals.
100% Carbon tetrachloride	exempt	3 to 6 gals.	6 to 8 gals.	8 to 10 gals.
Methyl bromide 98% Compressed gas	50 PPM	Apply at rates of 2-1/2 to 3 lbs. per 1,000 cubic feet or 0.3 gallon per 1,000 bushels.		

1/ Lower dosages recommended where grain is stored in tight bins, where little escape of gas or vapor is likely to occur.

2/ Chloropicrin also available as aerosols.

3/ Tolerance is expressed in terms of inorganic bromide calculated as Br. Frequent fumigation with methyl bromide is not recommended.

PHOSTOXIN: This is a type of grain fumigant that is currently available in pellet or tablet form and has two distinct advantages. First, a grain bin can be fumigated for stored grain insects with less hazard to the operator than is the case with liquid fumigants. Second, phostoxin can be used to fumigate grain at temperatures down to 40° F. which is not true of liquid fumigants.

Phostoxin can be used to treat grain as it is being augered into a bin or after the grain is in the bin. The recommended dosage rates for the tablets are as follows:

1) As grain is being binned - 60 per 1,000 bushels.
2) Grain already in the bin - 180 per 1,000 bushels.

The recommended dosage rates for the pellets are as follows:

1) As grain is being binned - 120 per 1,000 bushels.
2) Grain already in the bin - 300 to 400 per 1,000 bushels.

Treating Grain in the Bin: For treating grain in the bin, a 5 to 7 foot piece of conduit should be used (longer conduits can be used) with a flapper on the end and a washer on the top as a handle. The conduits are inserted in the grain at approximate 5 foot centers and the pellets or tablets are put in as the conduit is pulled out.

Due to the upward moving of the convection currents through the center of the bins during cold weather all hot spots treated should be covered with a poly tarp to stop as much of that current as possible and keep the air from carrying the phosphine gas away.

The exposure under the tarp should be five to six days. Then the tarp should be removed to keep moisture from condensing under it and causing further problems.

NOTES

PLANT DISEASE

Disease losses are serious every year in North Dakota. They result from reduced yield, grade or marketability that occur at planting, growing, harvesting or storage. Losses of wheat and potatoes have been valued at $22 mill. and $5 mill., respectively. Other crops have comparable losses.

Plant disease loss can be reduced by observing several procedures:

1. Use only clean disease-free seed.
2. Know which diseases have plagued you in the past.
3. Rotate crops and use cultural practices that prevent buildup of disease; especially soil borne diseases.
4. Plant resistant varieties if available.
5. Use seed and foliar treatments to prevent disease.
6. Recognize disease early.
7. Obtain prompt assistance for identification.

A disease is a harmful process to the physiology or morphology of a plant. Non-infectious diseases are caused by nutrient deficiency, extreme or sudden hot or cold weather, excess or limited water, mechanical damage or genetic reaction. Infectious diseases result from microscopic organisms such as fungi, bacteria, viruses, or nematodes (eelworms) that invade the plant and rob it of food.

Most microorganisms are beneficial for natural decay. But, the harmful ones cause serious disease loss. The principal disease causing agents in North Dakota are fungi. Bacteria and viruses also cause many diseases. Nematodes have not been troublesome. Disease causing agents have no chlorophyll so they can not make their own food, consequently they are parasites on plants that do, such as wheat, oats, and beans.

Fungi are plants. They grow vegetatively and most produce seed (spores). Fungi grow into plants through pores or wounds or enter directly through the surface.

Bacteria are one-celled plants. They do not grow as fungi do, but each cell simply divides to produce two bacteria. Some bacteria can divide every 30 minutes. Bacteria enter through wounds and pores in a film of water that is continuous with the inside of the plant.

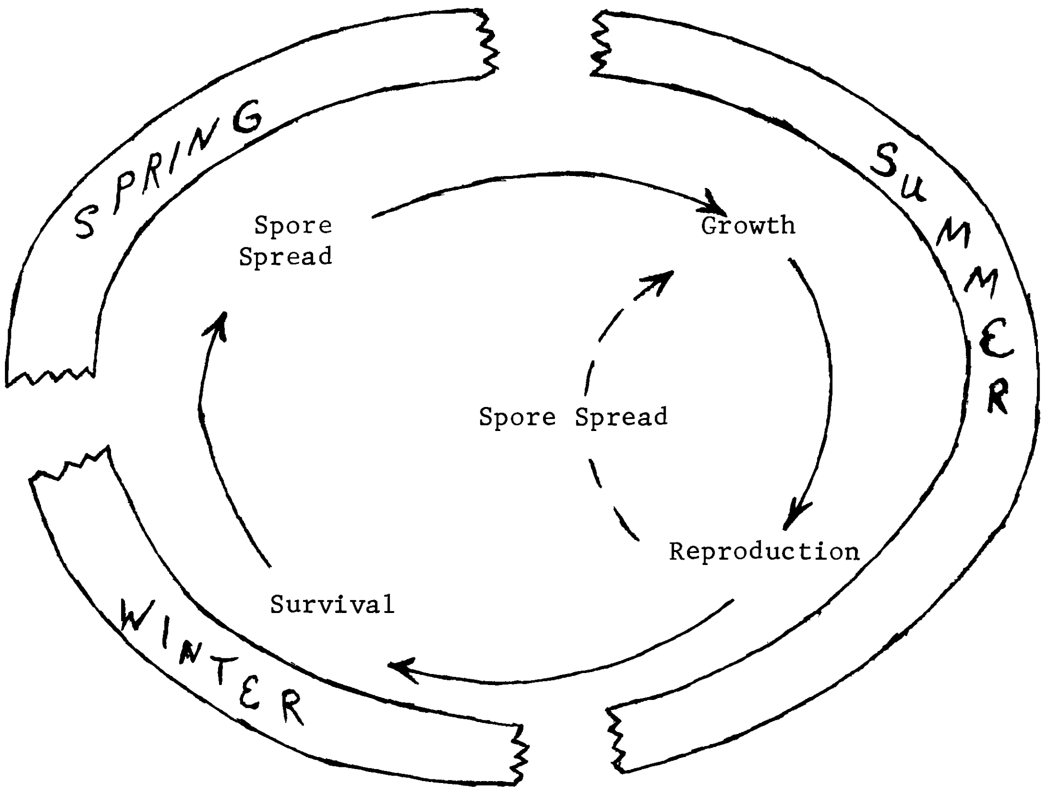
Viruses are viewed only with an electronmicroscope. They usually are introduced into a plant by feeding leafhoppers or aphids which carry the virus in their mouths.

Diseased plants show symptoms. These appear as cankers, rots, galls, curling, striping, spots, wilt, and stunt. Parts of the causal organism often show on the diseased plant such as ergot, rust, or smut.

Disease Development

Infectious disease results when susceptible plants are invaded by a disease causing organism. This process is directly influenced by weather. The relationship is usually complex, involving moisture, temperature, wind, and light. Infectious disease organisms such as rust or smut spores and bacteria are spread by wind and splashing rain. Water is required for fungal spores to germinate. Free water on the leaf aides penetration by bacteria or fungi. Free water comes from dew, rain or fog. Strong winds and high temperatures dry plant leaf surfaces thus preventing germination and penetration. Cloudy, foggy weather with moderate temperatures favors many leaf diseases. Root rot develops most readily when dry periods alternate with occasional rain.

Most disease causing organisms follow a growth cycle similar to wheat, potatoes, or other crop plant. The cycle is drawn schematically below.



THE OBJECT OF DISEASE CONTROL IS TO USE A MECHANISM TO INTERFERE WITH THE CYCLE.

Spread of fungi, bacteria, and viruses is by wind, water insects, animals, and birds.

Growth begins in fungi by germination of the spores (seeds). The fungus penetrates the plant, becomes established as a parasite and infection results. Growth of viruses and bacteria occur inside the plant.

Reproduction in fungi occurs after infection. More spores of the fungus develop in the affected plant, often in specialized chambers. Bacteria multiply by each cell dividing. Viruses multiply by using the plant processes to manufacturer more virus particles. With many disease organisms the cycle in summer is repeated every 10 days to several weeks. Others have only one cycle per year.

Survival of disease causing agents from one crop year to another occurs by various means. Some fungi survive in soil in a specialized form called sclerotia; others survive in seed or plant residue; and some such as rusts survive in milder climates to the south. Bacteria live in plant residue or seed. Viruses survive in perennial weeds or plant parts such as potato tubers.

Disease Control

Disease results when a pathogen (disease causing fungus, bacteria, or virus) in a favorable environment of moisture, temperature, and light comes in contact with a susceptible plant.

Disease control exists when the life cycle of the pathogen is halted, the environment becomes unfavorable for the organism to grow, or the host is not available for the pathogen to infect.

Disease control can be categorized into several areas. These are:

1. Avoid the disease organism --- Select a planting site or field not contaminated by the disease causing organism, use varieties that resist the disease, bury infested crop residue, rotate crops, and plant early. The surest and easiest way to control disease is to grow resistant varieties. Crop rotation allows time for infected residue to decompose, and for parasitic fungi and bacteria to die. Correct harvesting procedures and good methods of storage help to avoid rots and decay.

2. Exclude the disease organism --- Certified planting stock and seed is inspected for disease and when the amount of disease exceeds tolerance limits the field of seed is not certified. This prevents spread of certain diseases from field to field and through quarantine laws, country to country or state to state.

3. Eradicate the disease causing organism; or its vector --- Remove diseased plants from fields or screen diseased plant parts or parts of the disease causing organism from seed. Soil fumigation eliminates organisms that cause and spread disease. Insecticides are used to stop an invasion of vectors (aphids, leafhoppers) that carry viruses.

4. Protect the crop plant from disease --- Chemical protection of foliage, flowers, or seed is commonly used in North Dakota. Fungicides kill disease organisms on seed such as smut or blight, and provide some protection from fungi in soil that cause seedling decay and blight. Leaves and stems are sprayed to prevent infection by fungi and bacteria thereby stopping mold, leaf spots, and blights.

Direct costs of a fungicide program often help decide if the protection should be given.

Seed treatment is the best known way to prevent certain fungus diseases. Different fungicides may be used for different purposes. Select the fungicide correctly for the job to be done.

Powder, liquid, and slurry fungicides are available. Some are a combination of fungicide and insecticides (to control wireworms). Apply seed dressings with a mist applicator, drill box, or slurry treater.

It is necessary that seed germinate quickly and the sprout emerge rapidly. Slow or delayed growth allows fungi to invade and cause disease. Poorly filled, low test weight, frosted or weathered seed is benefited by seed treatment through protection from soil borne fungi. Inclement weather and cool, moist soil prevent rapid growth of seedlings, and favor growth of certain disease organisms. Seed treatment stops these organisms from causing decay, rot, and blight.

Covered smut and bunt of cereals, dry rot of potatoes, bacterial blight of dry beans, and phoma blight of sugarbeets are all controlled with seed treatment. The fungicide or bactericide kills the spores that cause the disease. Loose smut of wheat and barley is controlled with Vitavax only.

If non-weathered, high test weight seed is planted in a good seed bed of mellow soil and no inclement weather persists after planting until the sprout emerges, seed treatment will give little help for stand or yield increase. But it still may be necessary to control smuts.

Oilseed crops except flax are usually not treated. The flax diseases rust, pasmo, and Rhizoctonia blight are seed carried and should be controlled with a seed dressing.

Legumes and grass seed can be treated to prevent seed rot and blight. Treat forage legume seed well in advance of planting and inoculate at the time of planting. It is not advisable to inoculate dry beans treated with Streptomycin to control blight.

Chemical Precautions

1. Read the label.
2. All seed dressings are poisonous.
3. Label all containers.
4. Dispose of excess treated grain in landfill.
5. Wear masks, goggles, and gloves.
6. Treat in ventilated place.
7. Wash thoroughly your hands and skin.
8. Be accurate. Overdoses injure seed.

Diseases of Cereals and Grasses

Rust --- Stem and leaf rust attack wheat, oats, barley, rye, and grass. Many varieties are resistant to rust. However, oat leaf rust resistance is not very good. New races of rust appear periodically making the release of new varieties necessary.

Rust fungi have several spore stages. The red spore stage causes the damage in North Dakota. These spores are carried by wind from fields of wheat or barley south of here. Successive red spore stages occur every 10 to 14 days in the summer. Oat crown (leaf) rust overwinters on buckthorn in North Dakota.

Leaf rust can be controlled with sprays when susceptible varieties are grown (See Leaf Disease Section and Fungicide List).

"Green rust" --- When cereals ripen prematurely due to severe heat, drought or frost, stems, leaves, and heads show a green-black discoloration. This is mold or secondary leaf spot fungus spores. The plants appear as if rusted. Yields are not affected. But allergies occur among harvester operators due to the molds.

Root rots --- This is perennially very troublesome in North Dakota. Five to 15% yield losses occur each year. Frequently the disease goes by unobserved. It shows as a seedling blight or mature plant root and crown rot. The rot weakens the plants. Heads on diseased plants have fewer seeds and many of the seeds are shriveled. Some plants die prematurely. They show as bleached plants with crowns and roots rotted away.

The fungi, *Fusarium* and *Helminthosporium* that cause crown and root rot live in the soil. Spores grow on infected crop debris and are blown or washed to nearby plants. Infection occurs on young seedlings in spring. The disease continues in the crown during summer. With good plant growing conditions the effects of the disease may not show. Most fields in North Dakota are affected with diseased crop residue or fungus spores. Therefore, crop rotation with a resistant crop such as flax, potatoes, sugarbeets, corn, soybeans, sunflowers, or dry beans as well as fallow helps reduce the magnitude of disease. Shallow seeding, seed treatment, and a good seed bed aid emergence of the crop thereby reducing possibility of infection. Plowing infected trash or debris helps also.

There are some injuries confused with common root rot. Alkali, drought, 2,4-D, wireworms, and wheat stem maggot are frequently confused with root rot. Often when a plant is weakened by one of these factors it is invaded by root rot fungi which add to the yield loss.

Leaf diseases --- Several fungi cause leaf disease (See Circular PP A-533). If enough leaf area is killed, especially the flag leaf, vigor is lessened and seed set reduced. Grain is lower test weight and yield reduced.

Leaf disease causing fungi and bacteria live in infected debris and trash. The tiny, black fruiting bodies on straw and litter produce spores that are wind blown to leaves from early May to September. Infected leaves show spotting. Spots merge and the leaf dries. Diseased flag leaves (upper most leaf) prevent filling of grain. Severe infections cause reduced yields by 10 to 30%.

Chemical control is possible and practical because resistant varieties are not available for all leaf diseases of each grain crop (See Circular PP-556 and Fungicide List).

The fungi survive in diseased residue, so use crop rotation with a non-cereal crop. Plowing down crop residue and fallow help reduce disease.

Smuts --- There are several kinds of smuts. Covered smut of barley, loose smut of barley and wheat, bunt of wheat, black loose smut of oats, and covered smut of oats. Many grasses are infected with smut.

Smuts and bunt are controlled with fungicides (See Fungicide List). Smut resistant varieties also are available. Use the State Seed Department embryo test for loose smut of barley.

Flax and Sunflower

Flax rust --- This was a serious disease in 1973, because of the situation in which it placed growers. Only Linott, Foster, and Raja flax varieties survived the new rust race change. In 1974, rust did not develop severely (See Research Section).

Flax growers in 1975 can use several methods to reduce rust losses.

1. Plant available rust resistant lines.
2. Plant early for your area.
3. Use clean seed.
4. Avoid 1973 or 1974 flax land.
5. Treat seed and make sure you buy variety pure seed.

Flax and sunflower rusts are different than cereal rusts because they complete their entire cycle on one crop. The black spores overwinter in the field and cause infections in spring. Crop rotation is therefore necessary when a crop has been rusted unless resistant varieties are available. The possibility of a rust race change is great when extensive acreages are planted to susceptible varieties.

Sunflower diseases --- Rust, downy mildew, Sclerotinia stalk rot, and Verticillium wilt are persistent diseases of sunflower (See Circular PP-570). The confectionery new variety, Sundak, is resistant to rust. Oilseed varieties have moderate rust resistance.

Downy mildew and Verticillium wilt resistance have been located and incorporated into new hybrid varieties. A phase of downy mildew called basal stem gall shows as enlarged basal stems. The plants wilt. The swollen basal stem rots and the plants lodge. This occurs on land that drains poorly, especially when rains fall about 3 to 4 weeks after emergence. The infection is thought to arise from downy mildew contaminated seed (See Research Report).

Sclerotinia stalk rot is potentially a very serious disease for growers. It is a disease that will build up in soil when sunflower is planted successively or in close rotation with dry field beans. Sunflower is principally attacked through the root or basal stem. Beans are only attacked in this manner when young (See Bean Disease Section).

Bleaching of lower parts of stems is an initial symptom on sunflower. The plants ripen prematurely and blacken. Such plants pull easily and the stalks shred. When split open black-gray, hard, rat-dung shaped sclerotia are found. At harvest these fall and are scattered and mixed in the soil. They survive over winter. Control by rotating with cereal crops. Avoid dry beans. Control weeds.

Soybeans and Dry Edible Beans

Sclerotinia white mold --- This disease is caused by the same fungus causing stalk rot of sunflowers (See Circular PP-576). The fungus sclerotia overwinter to produce a mushroom in July which contains spores that infect dried leaves and flowers lodged in stems and foliage. The fungus grows into the plant, produces a white mold on stems, and rots the stem and pods. Sclerotia form inside stems and on outside of diseased plant tissue. Many fields of Pinto beans have yields reduced by 30%. And some fields have been nearly lost to the disease.

Chemical control is possible on dry beans with Benomyl (See Fungicide List).

Rotations of 4 to 5 years are necessary between dry bean crops. Avoid sunflowers in the rotation.

Soybeans contract the disease when grown in fields heavily contaminated with sclerotia.

Bacterial blights --- Soybeans and dry beans (Navy or Pea and Pinto) are attacked by several bacterial blights. In 1974 blights caused damage among Navy beans in particular. This was due to seed entering the state that carried the blight bacteria. When the contaminated beans were planted the bacteria multiplied and spread causing a leaf blight. Common blight shows as a brown, sunken, irregular shaped area, often with a yellow zone around each spot. Halo blight shows as a large, yellow spot with a small, brown center.

Certified bean seed from a western state is usually free of bacteria. However Certified seed from other states may also be bacteria free, but because of more humid growing weather, there is a greater possibility of bean seed contamination.

Bean seed should be treated (See Fungicide List). Western states use a triple treat process of a fungicide, plus Streptomycin, plus an insecticide. Streptomycin helps reduce surface contamination. But some bacteria are inside the seed. So use only

Certified seed grown in an area where blight was minimal.

Soybeans contract bacterial blight, but are not injured as severely as dry beans.

Copper sprays can be used to control blight (See Fungicide List). Their usage is limited by weather conditions. With favorable weather for disease, blight is difficult to control. Rotate other crops with beans, because bacteria live in bean debris. Plow bean straw. Avoid cultivation when beans are wet.

Sugarbeets

Leaf spots --- Cercospora leaf spot is potentially troublesome. The disease shows when warm, humid and wet weather persists. A comparable disease Ramularia leaf spot shows in spring or when cooler, wet weather occurs.

Cercospora shows as a small spot, with a characteristic red border. Ramularia shows as a larger spot without the red border. Cercospora can develop rapidly in a favorable environment and cause death of leaves. Usually older leaves die first.

Resistant varieties have long been used to control Cercospora leaf spot. Recently however, some varieties are being used with inadequate resistance. This practice is unwise.

Fungicide spray programs are used to hold leaf spot in check. Several sprays are made each summer (See Fungicide List).

Potatoes

Diseases perennially threaten the potato crop each year in North Dakota. These diseases are discussed by J. E. Huguelet in the Potato Section.

Late blight --- Growers should clean up cull piles, where blight gets its start every year, but must rely on fungicides to combat the disease in summer (See Fungicide List).

Seed Piece Decay --- Several fungi and bacteria cause decay or rot of seed pieces. Some of the tubers are already diseased when cut, and the contamination of cut surfaces with fungi and bacteria from these diseased tubers is a major cause of seed rot.

Seed treated with a chemical (See Fungicide List) has a better chance of warding off decay than untreated seed pieces. Some diseases develop only when weather conditions prevent the natural healing process and vigorous growth.

Precautions:

1. Before planting, warm seed at 60-70° F for 1 1/2 - 2 weeks.
2. Plant cut seed immediately in warm, 50° F, moist soil.
3. If cut seed must be held, store in ventilated area for healing at 65° F with RH of 85%. Hold for one week, then lower temperature to 55° F.

FUNGICIDE RECOMMENDATIONS
Seed Treatment

Wheat-Oats-Barley-Rye-Flax

Chemical	Application	Dosage	Disease Control1/ Covered Smut	Loose Smut	Seedling Blights	Remarks
Phenylmercury acetate						
Mistomatic or	spray or	½ oz/bu	E	No	E	Chemical can be used but registrations have been cancelled.
Oxymatic	dust	2 oz/bu	E	No	E	
Terraclor						
Terra-coat 2LF, 24%	spray	2 oz/bu	F - G	No	E	Not registered on rye.
Terraclor + Terrazole						
Terra-coat L20-5	spray	2 oz/bu	G - E	No	E	Not registered on rye. Combined with Terrazole to control seedling blights.
Terra-coat SD20-5	dust	3 oz/bu	G - E	No	E	
Maneb, 50%						
Agsco DB Green, or			G - E	No	G - E	DG Green, Cover Up + Plus and Granol NM are combined with Lindane 18.75% for wireworms control.
Agsco DB Yellow, or			G - E	No	G - E	
Cover Up, or	dust	2 oz/bu	G - E	No	G - E	
Cover Up + Plus, or			G - E	No	G - E	
Granol NM, or			G - E	No	G - E	
Granox NM (+ HCB)			G - E	No	G - E	
Carboxin						
Vitavax, 75%	dust, spray or slurry	1 oz/bu	E	E	G	Controls all smuts. Use on barley and wheat only.
Carboxin + Thiram						
Vitavax 200, 17%: 17%	spray or slurry	2 oz/bu	E	E	E	Controls all smuts. Use on barley and wheat only; contain Thiram for blights and molds.
Zineb + Captan	dust, slurry	1 oz/bu	F - G	No	E	Not registered on rye.
Polyram, 53.5%	dust	2 oz/bu	F - G	No	G	Not registered on rye. Preferred use of 3 oz. on wheat.
Thiram, 75%						
Arasan 75%	dust	1 1/3 oz/bu	E	No	E	Not registered on oats. Overtreat with Vitavax to control smuts of wheat and barley.

Table continued . . .

Table Continued . . .

Wheat-Oats-Barley-Flax

Chemical	Application	Dosage	Disease Control 1/ Covered Smut	Loose Smut	Seedling Blights	Remarks
Maneb + zinc ion, 80%						
Dithane M-45	dust	1 1/3 oz/bu	G - E	No	G - E	
Manzate 200	dust	1 1/3 oz/bu	G - E	No	G - E	
Dithane M-22 (Special)	dust	1 1/4 oz/bu	G - E	No	G - E	
TCMTB, 30%						
Cover Up L	spray	3/4 oz/bu	G	No	G	Not registered on rye.
Thiogen	spray	3/4 oz/bu	G	No	G	

1/ F = Fair; G = Good; E = Excellent

Dry Field Beans and Soybeans

Chemical	Application	Dosage	Disease Control 1/ Bacterial Blights	Seedling Blights	Remarks
Captan					
Orthocide 75%	slurry	1 1/3 oz/cwt	No	G - E	
Captan 80%	slurry	1 1/3 oz/cwt	No	G - E	
Agrox - 3 Way	dust	3 oz/cwt	No	G - E	Contains insecticide for insects.
Captan + Thiram 43:43	slurry	2 ½ oz/cwt	No	E	
Thiram					
Arasan 75%	dust	1 1/3 oz/cwt	No	G - E	
Arasan 50%	dust	3 ½ oz/cwt	No	G - E	
Terraclor + Terrazole					
Terra-coat L20-5	spray	2 oz/cwt	No	G - E	Controls Rhizoctonia seedling diseases plus other seedling blights.
Terra-coat SD 20-5	dust	2 oz/cwt	No	G - E	
Maneb 50%	dust	4 oz/cwt	No	G - E	
Streptomycin					
Agri-Strep 21.2%	slurry	2 ½ oz/cwt	G - E	No	Controls surface contamination on dry beans.

(Triple Treat Process Uses a Fungicide + Insecticide + Streptomycin.)

1/ F = Fair; G = Good; E = Excellent

Potatoes

Chemical	Application	Dosage	Disease Control 1/ Dry Rot	Verticillium Wilt	Bacteria	Remarks
Captan 7 ½%	dust	1 lb/cwt	E	E	No	Treat poor quality seed, and seed held after cutting. Dust cut potatoes and plant as soon as possible. Use a drum-type treater or slurry. Avoid diseased tubers.
Zineb 8%	dust	1 lb/cwt	E	E	No	
Maneb 7 ½%	dust	1 lb/cwt	E	E	No	
Polyram 7 ½%	dust	1 lb/cwt	E	E	No	
Zinc ion + Maneb 8%	dust or slurry	1 lb/cwt	E	E	No	
Streptomycin 0.01%	dust	100 ppm	No	No	F - G	Combined with Zineb and Captan.
PCNB						
Terraclor 2 lb EC 24%	spray	5 gal/A	No	No	No	Controls Rhizoctonia at planting as a furrow treatment.

1/ F = Fair; G = Good; E = Excellent

Foliar Sprays

Wheat-Barley-Oats

Chemical	Application	Dosage	Disease Control 1/ Leaf Spots	Leaf Rust	Stem Rust	Remarks
Zinc ion + Maneb						Spray wheat when 10% of heads show; barley and oats when boot begins to swell. Second application 7-10 days later. Use 5 gal water with airplane. Zineb cannot be used on barley or oats.
Dithane M-45	spray	1 ½ lb/A	E	E	P	
Manzate 200	spray	1 ½ lb/A	E	E	P	
Kocide 101	spray	2-3 lb/A	G - E	G - E	P	
Zineb						
Parzate C	spray	1 ½ lb/A	G - E	G - E	P	
Dithane Z78	spray	1 ½ lb/A	G - E	G - E	P	

1/ P = Poor; F = Fair; G = Good; E = Excellent

Field Beans

Chemical	Application	Dosage	Disease Control1/ Rust	Bacterial Blight	White Mold	Remarks
Maneb + zinc ion						
Dithane M-22 (Special)	spray	1 ½ lb/A	E	P	P	See Circular PP-576 on Bean Diseases. Repeat sprays in 7 days for rust or blight. Use 2 sprays of Benomyl for mold at 2-week intervals. Begin at ½ bloom about July 20.
Maneb						
Dithane M-22	spray	1 ½ lb/A	E	P	P	
Manzate D	spray	1 ½ lb/A	E	P	P	
Zineb						
Parzate C	spray	1 ½ lb/A	E	P	P	
Dithane Z78	spray	1 ½ lb/A	E	P	P	
Copper						
Kocide 101	spray	2-3 lb/A	G - E	F	P - F	
Oxy Cop 8L	spray	1/3-3/4 gal/A	F - G	F	P - F	
Kocide 404	spray	2/3-1 ½ gal/A	F - G	F	P - F	
Benomyl 50W	spray	1 3/4 lb/A	P	No	G - E	

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Sugarbeets

Chemical	Application	Dosage	Disease Control1/ Leaf Spots	Remarks
TBZ				
Mertect 340 Flowable 42%	spray	5-10 oz/A	E	Alternate chemicals from one year to the next. Begin when disease is first observed in field or area. Higher rates used when disease is severe on susceptible varieties. Use 5-10 gal water airplane or 25-100 gal water ground equipment. Repeat TBZ, Benomyl, and Du-ter at 14-21 days. Repeat copper, maneb, Polyram at 7-10 days.
Du-ter 47 ½%	spray	4-10 oz/A	E	
Benomyl				
Benlate 50W	spray	6-8 oz/A	E	
Copper				
Oxy-Cop 8L	spray	½-3/4 gal/A	G - E	
Kocide 101	spray	2-4 lb/A	G - E	
Maneb + zinc ion				
Dithane M-45	spray	1 ½ lb/A	G - E	
Manzate 200	spray	1 ½ lb/A	G - E	
Dithane M-22 8%	dust	30 lb/A	G - E	
Maneb				
Dithane M-22	spray	1 ½ lb/A	G - E	
Manzate D 6%	dust	30 lb/A	G - E	
Polyram 80%	spray	1 ½-3 lb/A	G - E	

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Potatoes

Chemical	Application	Dosage	Disease Control 1/ Late Blight	Early Blight	Remarks
Captan					
Orthocide 50W	spray	3-4 lb/A	E	E	
Orthocide 7 ½%	dust	30 lb/A	E	E	
Copper					
Oxy Cop 8L	spray	½-3/4 gal/A	E	E	
Kocide 404	spray	1-1 ½ gal/A	E	E	
Kocide 101	spray	2-3 lb/A	E	E	Use late blight forecast as signal to begin spraying. Or if connected with over-flight disease detection use personal film information. Repeat at 7-10 day intervals when favorable weather persists.
Daconil					
Bravo 6F	spray	1-1 ½ pt/A	E	E	
Bravo W75	spray	1 ½ lb/A	E	E	
Difolatan					
4-Flowable	spray	1 ½-3 pt/A	E	E	
80-Wettable	spray	1 ½ lb/A	E	E	
Du-ter 47 ½%	spray	5-10 oz/A	E	E	
Maneb 80%					
Manzate D	spray	1 ½ lb/A	E	E	
Dithane M-22	spray	1 ½ lb/A	E	E	
Manzate D 6%	dust	30 lb/A	E	E	
Polyram	spray	1 ½ lb/A	E	E	
Zinc ion + Maneb					
Dithane M-45	spray	1 ½ lb/A	E	E	
Manzate 200	spray	1 ½ lb/A	E	E	

1/ P = Poor; F = Fair; G = Good; E = Excellent

1975
CHEMICAL WEED CONTROL GUIDE
for
FIELD CROPS AND PERENNIAL WEEDS

THE WEED CONTROL SUGGESTIONS are based on Federal label clearances and on information obtained from the North Dakota Agricultural Experiment Station and the Research Committee of the North Central Weed Control Conference.

CAUTION:
The weed control suggestions in this circular are based on the assumption that all herbicides mentioned in this guide will continue to have a registered label with the Environmental Protection Agency.

USE CHEMICALS ONLY AS RECOMMENDED ON THE LABEL.

APPLICATION RATES are broadcast rates and are based on active ingredient or acid equivalent rather than the amount of commercial product. Commercial formulations of the same herbicide may vary in their amount of active ingredient. For example, a pint of 4 pound acid equivalent per gallon 2,4-D contains ½ pound acid equivalent, a pint of 3.3 pound acid equivalent per gallon contains 2/5 pound, and a pint of 6 pound acid equivalent per gallon contains 3/4 pound. Three pounds of atrazine (AAtrex 80W) powder contains 2.4 pounds active ingredient, or 3 pounds active ingredient is 3 3/4 pounds of product ($3 \div 0.80 = 3.75$).

WEED COMPETITION reduces crop yields severely, unless weeds are removed when small. Good cultural practices are one of the many methods of controlling weeds. However, selective herbicides can be an effective supplement. Timely applications of selective chemicals at the recommended rate will control many annual weeds satisfactorily without damaging the crop in which the weeds are growing.

PERENNIAL WEEDS in crops such as field bindweed, leafy spurge, Canada thistle and perennial sowthistle also can be controlled. MCPA is as effective as 2,4-D on Canada thistle, but 2,4-D gives slightly better control of sowthistle. Use MCPA to suppress thistles in oats and flax. However, these crops do not tolerate rates of MCPA necessary to give adequate thistle control.

When controlling field bindweed and thistle in small grains except oats, apply the maximum rate of 2,4-D or MCPA the crop will tolerate: 3/4 pound per acre of 2,4-D or MCPA amine and 2/3 pound per acre of 2,4-D low volatile ester or MCPA ester. If such herbicides are planned for controlling hard-to-kill annuals or perennial weeds in crops, grow the more tolerant cereals--rye, wheat and barley.

CONSIDER BOTH the crop tolerance and kind of weeds present in determining the rate of herbicide to apply. A range of rates is given for most of the herbicides in this circular. Use the lowest recommended rate of postemergence herbicides under favorable growing conditions when weeds are small and actively growing. Under adverse conditions of drouth or prolonged cool weather, or for well established weeds, use the highest recommended rate, except for barban (Carbyne). (See Wild Oat Section for Discussion of barban use.)

IDEAL TEMPERATURES for applying most postemergence herbicides are between 65^o and 85^o F. Below 60^o, weeds are killed very slowly or not at all; above 85^o there is danger of herbicide injury to the crop. Avoid applying volatile herbicides such as 2,4-D ester, MCPA ester and dicamba (Banvel) during hot weather, especially near sensitive broadleaf crops, shelterbelts or farmsteads.

Some of the so-called high volatile esters of 2,4-D vaporize at temperatures as low as 70^o F and most vaporize readily at temperatures above 85^o F. The temperature at ground level always is several degrees warmer than that at chest height. Consequently, vaporization from the high volatile esters could occur at temperature readings as low as 60^o F. Vapor drift may be avoided by using the 2,4-D amines. However, spray drift (droplets) can occur even with non-volatile herbicides and cause injury to susceptible plants.

DO NOT SPRAY when there is danger of spray or vapor drift, or when the wind is blowing toward a neighboring crop or planting more susceptible than the crop being sprayed. The amines of 2,4-D and MCPA are not volatile and eliminate the danger of vapor injury.

PREEMERGENCE HERBICIDES: Soil type, weather conditions and the weeds to be controlled determine the rate of preemergence herbicides to apply. Generally heavy clay soils high in organic matter require higher rates of such herbicides than lighter soils or those lower in organic matter.

Good weed control with preemergence herbicides depends on many factors, including rainfall after application, soil moisture, soil temperature and soil type. For these reasons, preemergence chemicals applied on the soil surface sometimes fail to give satisfactory weed control. Herbicides which are incorporated into the soil surface usually depend less upon rainfall after application for effective weed control than unincorporated herbicides. If weeds are emerging through a preemergence herbicide treatment, the field may be rotary hoed without reducing the effect of the herbicide.

HERBICIDE COMBINATIONS: The effect of postemergence herbicides often is increased when applied to areas already treated with a preemergence or preplant herbicide. Combinations of certain postemergence herbicides or preemergence herbicides may give better weed control than from the use of the individual herbicide alone. However, loss of weed control or increased crop damage may sometimes result from the use of certain other herbicides in combination.

Use herbicide combinations with caution until experience or research has shown that the combination is effective and safe. See the discussion on individual crops for more specific information.

All agricultural pesticides which are tank mixed should be registered for use as a mixture by the Environmental Protection Agency. However, agricultural pesticides may be tank mixed if all pesticides in the mixture are registered by the Environmental Protection Agency on the crop being treated. Users must assume liability for any possible crop injury, inadequate weed control and illegal residues.

PERENNIAL WEEDS IN PASTURES: Picloram (Tordon 22K) has a state registration for the control of broadleaf perennial weeds such as leafy spurge, field bindweed, Canada thistle, and Russian knapweed on rangelands and permanent grass pastures. Rates of 1 to 2 pounds per acre give excellent control of these weeds and are economical for spot treatment. During a single growing season do not use more than 10 gallons of picloram for any 100-acre area and do not treat more than 20 acres of any 100-acre area. To suppress the growth of perennial broadleaf weeds in large areas, use 1/4 to 1/2 pound per acre and apply as a single broadcast spray during any one growing season. Retreatment at the same rate may be necessary the following year.

Picloram is a highly potent herbicide. Do not allow spray drift of picloram, as tiny amounts may cause damage to sensitive plants. Especially susceptible to picloram are soybeans, potatoes, safflower, sunflowers and sugar beets. Picloram is highly water soluble and moves in the soil; consequently, do not apply in areas with a high water table. Do not apply near shelterbelts or shrubs or trees. Do not treat or allow picloram spray drift to fall onto the inner banks or bottoms of irrigation and drainage ditches.

Do not graze picloram treated areas with dairy animals. Do not transfer beef cattle directly from areas treated in any one growing season onto broadleaved crop areas without allowing seven days on untreated grass pastures, as urine may contain enough picloram to cause crop injury.

WEED CONTROL IN FIELD CROPS

FLAX: MCPA at 1/4 pound per acre controls most broadleaf weeds in flax when it is 2 to 6 inches tall. Avoid spraying flax during the period between bud stage and when 90 per cent of the bolls have formed, as serious crop injury would likely occur. In addition, applying MCPA between full bloom and the stage when flax seeds are colored may reduce germination of the seed. Rates of MCPA amine higher than 1/4 pound per acre or MCPA ester should be used in flax only for the more resistant weeds.

Postemergence weed control in flax is most effective when the herbicide is applied as soon as most of the weeds have emerged. While an application of MCPA may reduce the yield of both seed and straw, weed competition generally is reduced sufficiently to compensate for any herbicide injury.

EPTC (Eptam) at 2 to 3 pounds per acre controls annual grass weeds, including wild oats, and some broadleaf weeds in flax. Incorporate EPTC immediately (within minutes) and thoroughly after application. Double disk twice in opposite directions or use any other method which will thoroughly mix the chemical with the top 3 inches of soil.

Flax tolerance to EPTC is marginal. EPTC is more injurious to flax on coarse textured, low organic matter soils, and in experiments at North Dakota State University has not caused flax injury on fine textured, high organic matter soils. A limited reduction in the flax stand from EPTC will not reduce yields since weed competition is decreased and there is an increased branching of the remaining plants.

Dalapon (Dowpon) will control green and yellow foxtail (pigeongrass) in young flax. Apply dalapon when the flax is over 2 inches tall and the weeds less than 2 inches for best results. Caution: Spraying must be completed prior to the early bud stage. Generally dalapon is applied in a mixture with MCPA amine to control both the susceptible grassy and broadleaf weeds with one application.

Flax is a poorer competitor with weeds than are small grains. Consequently, grow flax on relatively weed-free fields. Early after-harvest tillage of small grain stubble will prevent weed seed production, control perennial weeds and encourage annual weed seed germination prior to freeze-up.

Use flax in the rotation following corn, soybeans or other cultivated row crops. If good weed control practices were employed in the previous year's crop, flax would require only shallow tillage. One or more crops of wild oats frequently are destroyed by spring tillage before flax is sown. However, delayed planting sometimes reduces crop yields. Early maturing varieties should be planted with late seeding.

SMALL GRAINS-SPRING WHEAT (INCLUDING DURUM), BARLEY AND OATS: All small grains are sensitive to 2,4-D during the seedling stage but can be treated safely with MCPA from the time of emergence until the early boot stage. Wheat and barley, when treated from the fifth leaf to the early boot stage, are more tolerant than oats to 2,4-D applications. Oats is more resistant to MCPA than to 2,4-D, but injury to oats is possible with either chemical at any growth stage. Oats in the five-leaf stage of growth is especially susceptible to injury from 2,4-D. Use 2,4-D on oats only for such hard-to-kill weeds as Russian thistle, kochia, common ragweed and redroot pigweed. While some injury to the oats can be expected, the better control of these weeds with 2,4-D usually will compensate for any yield loss caused by the chemical. Do not treat small grains in the boot stage. Oat varieties vary in their tolerance to 2,4-D but there is little or no difference in such tolerance among the wheat and barley varieties.

Rates of 2,4-D or MCPA required to control most broalleaf weeds cannot be applied in small grain crops underseeded to sweetclover, alfalfa or other legumes without seriously injuring or killing the legumes.

Dicamba (Banvel) controls wild buckwheat, smartweed and certain other broadleaf weeds in wheat and oats. It can be applied alone or in a mixture with MCPA to increase control of wild mustard. Dicamba alone usually gives unsatisfactory control of wild mustard. Oats is more tolerant to dicamba than wheat. Both crops must be treated at the second through fourth leaf stage. Barley is more susceptible to injury from dicamba than wheat or oats.

Bromoxynil (Buctril, Brominal) controls wild buckwheat, fumitory and most annual broadleaf weeds in wheat and barley from the third leaf stage of the crop to early boot. Mixtures of bromoxynil plus MCPA ester (Bronate and Brominal Plus) are applied for better wild mustard control.

NOTE: Wild oat control in small grains is discussed in the wild oat section of this circular.

CORN: A combination of cultural practices and herbicide applications is necessary for weed control in corn.

Destroy early germinating weeds by cultivation before planting if conventional tillage is used for controlling weeds. Leave the space between the rows rough to reduce weed germination. Cultivate after the weed seeds have germinated or as soon as the weeds appear above the soil surface. Use a rotary hoe as soon as weeds appear.

Atrazine (AAtrex) applied preemergence at 2 to 4 pounds per acre gives good control of annual weeds without crop injury. Fine textured soils and those high in organic matter require a 4-pound per acre application. Atrazine residues injurious to susceptible crops may remain in certain soils longer than one growing season. Residues are more likely to persist with low soil temperatures or low moisture conditions.

Crops vary in their tolerance to atrazine. Corn and millet are tolerant. General ranking of other crops in order of least to most tolerant is: sugarbeets, sunflowers, oats, wheat, barley, soybeans and flax. Minimize residues by applying the lowest rate of chemical consistent with good weed control, using band instead of broadcast applications, and plowing the field prior to planting the next crop.

Propachlor (Ramrod) applied preemergence at 4 to 5 pounds per acre controls annual grasses and some broadleaf weeds, but is ineffective against wild mustard or perennial weeds. Propachlor often is used in mixtures with atrazine, cyanazine (Bladex) or linuron (Lorox) to enhance broadleaf weed control.

Alachlor (Lasso) is used preemergence at 2 1/2 pounds per acre for control of annual grasses and certain broadleaf weeds such as redroot pigweed, common lambsquarters and common ragweed. Propachlor in North Dakota State University experiments has given superior weed control to alachlor except when alachlor was incorporated.

Early postemergence weed control must be done at the proper time for satisfactory results. Atrazine effectively controls most annual weeds in corn and control of broadleaf weeds is excellent. Apply 1 to 2 pounds per acre of atrazine within three weeks of planting while the weeds are less than 1 1/2 inches tall. Adding 1 to 2 gallons per acre of crop (petroleum) oil with an emulsifier increases the effectiveness of the treatment. Substituting 1 to 1 1/2 quarts per acre of emulsifiable vegetable oil (Bio-Veg, a linseed oil) gives results similar to petroleum oil applied at 1 to 2 gallons per acre.

When corn is 3 to 8 inches tall, an overall broadcast application of 2,4-D amine at 1/4 to 1/2 pound per acre can be made to control broadleaf weeds. Use the 1/4 pound rate for susceptible weeds like wild mustard. The 1/2 pound rate is satisfactory for controlling the more resistant weeds, but corn may be injured. Do not use MCPA, as it is more injurious to corn than 2,4-D. When corn is over 8 inches tall, use drop nozzles to avoid getting the 2,4-D on the upper leaves and leaf whorl of the crop. This reduces the danger of 2,4-D injury.

Corn sprayed with 2,4-D may show signs of injury. Brittleness, followed by bending or breaking of the stalks, sometimes occurs. A severe stand loss may result when applications of 2,4-D are followed by a storm or careless cultivation.

Dicamba (Banvel) at 1/8 to 1/4 pound per acre, either alone or in a mixture with 2,4-D amine at 1/4 to 1/2 pound per acre, can be applied postemergence in corn. It gives better control of Canada thistle, smartweed and wild buckwheat than 2,4-D with less effect on the corn. Make dicamba applications until corn is 3 feet tall or until 15 days before tassel emergence, whichever comes first. Use drop nozzles after corn is 8 inches tall if applied with 2,4-D.

EPTC + R-25788 (Eradicane) is registered for use on field and silage corn. R-25788 increases the tolerance of corn to EPTC. Apply 4 pounds per acre in 10 to 50 gallons of water per acre using a properly calibrated, low-pressure sprayer having good agitation. The soil should be well worked and dry enough to permit immediate and thorough soil incorporation. This chemical controls a large number of annual broadleaf and grass weeds as well as giving some quackgrass control.

1,8-naphthalic anhydride (Protect) is a seed treatment product for field, silage and sweet corn that permits the use of EPTC at 4 pounds per acre. Use only 2 ounce package of Protect for each 1/2 bushel of corn to be treated. Protect must be thoroughly mixed with the seed so each kernel is completely coated. After treatment, the corn may be stored until planting time or transferred directly to the planter box. Just before the corn is planted, apply and incorporate EPTC according to its label.

Emergency control of broadleaf and grassy weeds in corn can be obtained with directed applications of ametryne (Evik) or linuron (Lorox). Apply ametryne at 2 to 2.5 pounds per acre or linuron at 0.6 to 1.5 pounds per acre as a directed spray to the weeds. Keep the chemicals off the leaves of corn. Application over the top of corn will cause severe injury and contact with the leaves will cause burning. Ametryne should not be applied before corn is 12 inches high and linuron before corn is 15 inches high. The weeds should not be more than 6 inches high.

SUGARBEETS: Herbicides may be used in sugarbeets to supplement conventional cultivation practices. Hand labor, mostly hoeing, is still needed but can be reduced by timely cultivations and herbicide applications. The uses of preplant, preemergence and early postemergence herbicides in sugarbeets are discussed in the table.

Late germinating weeds can become a problem in sugarbeets with early seeding or when good moisture conditions prevail well into the season. Trifluralin (Treflan) is cleared at 3/4 lb/A and EPTC (Eptam) is cleared at 3 lb/A for use on sugarbeets after thinning for annual grass and broadleaf control. The chemicals should be broadcast applied and incorporated immediately with cultivators or tillers adjusted to mix them thoroughly with soil in the row without damaging the sugarbeets. The crop should be clean cultivated before application since established weeds are not controlled. Exposed sugarbeet roots should be covered with soil prior to trifluralin application to reduce possibility of girdling.

EPTC sometimes will cause a sugarbeet stand reduction and temporary stunting, however, if enough sugarbeets remain to obtain an adequate plant population after thinning, no yield reduction will result. EPTC is less phytotoxic on fine textured, high organic matter soils so rates must be increased on these soils and decreased on coarse-textured, low organic matter soils. EPTC should be used with extreme caution on sugarbeets grown in sandy loam or lighter soils with low organic matter levels because it is difficult to predict a safe rate on such soils.

To avoid possible sugarbeet injury from desmedipham (Betanal-475) and phenmedipham (Betanal), several precautions should be observed. The sugarbeets should have at least four true leaves before treatment. Do not apply if the highest temperature on the day of application exceeds 85 F. Use no more than 1 pound per acre following EPTC or TCA. Start application late in the afternoon or early in the evening so cool temperatures follow application. Set the proper band width near the top of the sugarbeets so that the beets rather than the ground receive the proper rate. Calibrate the sprayer very carefully.

SOYBEANS: Preemergence herbicides in soybeans are easily banded to reduce costs whereas preplant herbicides must be incorporated, making band application difficult. Soybeans are poor competitors with weeds when cool soil temperatures slow germination and growth. They are good competitors in warm soils, however, because germination and growth are rapid. Management practices such as thorough seedbed preparation, adequate soil fertility, choice of a well-adapted variety, and use of good quality seed all contribute to a soybean crop that will compete with weeds. Soybean production requires good cultural practices. Prepare the seedbed immediately prior to planting the crop to kill germinating weeds. After planting but before the soybeans emerge, kill weeds by using a rotary hoe, spike-tooth harrow or weeder. However, do not cultivate by these means when the soybeans are just emerging. Once the soybeans have emerged and are standing erect (beyond the crook stage), the crop can be harrowed.

The rotary hoe is an effective and economical weed killer in soybeans. For best results use it when the ground is not trashy, lumpy or wet and when weeds are just emerging, and not more than 1/4 inch tall. A rotary hoe, light harrow or weeder can be used effectively in soybeans 3 to 8 inches tall to effectively kill weed seedlings with little damage to the crop. Cultivation is most effective when the soybeans are slightly wilted during the warm part of the day, because the crop is less susceptible to breakage and the weeds will wilt and die most quickly.

Trifluralin (Treflan) applied 3/4 to 1 pound per acre preplanting and thoroughly incorporated gives good control of annual grasses and broadleaf weeds except wild mustard. Proper incorporation is essential. Incorporate thoroughly in two directions 3 to 4 inches deep. Proper incorporation of trifluralin can be accomplished by double disking twice in opposite directions or by other methods which thoroughly mix the chemical with the top 3 inches of soil. Incorporate as soon as possible after application for best results. Incorporation may be delayed up to eight hours on cool, dry soils.

Dinitramine (Cobex) is a preplant herbicide that must be thoroughly and shallowly incorporated into the top 1 1/2 to 2 inches of soil. Apply at 1/3 to 2/3 pounds per acre depending on soil type. Incorporation should be completed within 24 hours of application. The herbicide effectively controls many annual grasses and broadleaf weeds as they germinate, but does not control cocklebur or sunflower. Wild mustard control is not adequate.

Alachlor (Lasso) at 2 1/2 pounds per acre gives good preemergence control of annual grasses and some broadleaf weeds, including redroot pigweed and common lambsquarters. It is ineffective against wild mustard. Soybeans have good tolerance to alachlor.

Chloramben (Amiben) at 2 to 3 pounds per acre is applied preemergence to control most grassy and broadleaf weeds, including wild mustard. At least one-half inch of rain is necessary within 10 days after application to activate the herbicide. If rain falls later than this, the degree of weed control will be reduced. Excessive rainfall on light soils may leach chloramben below the level of germinating weed seeds resulting in poor weed control and/or crop injury.

Linuron (Lorox) is a preemergence herbicide for controlling most annual broadleaf weeds and grasses. Rates of application are 1/2 to 2 1/2 pounds per acre. Weed control and crop injury with linuron are greatly influenced by soil texture and organic matter. Linuron works best on medium textured soils with less than four per cent organic matter. Crop injury occurs occasionally on sandy soils. It is important to use rates recommended on the label for various soil types.

Fluorodifen (Preforan) is used for broadleaf and grassy weed control, including wild mustard in most instances. It is applied preemergence at 4 1/2 pounds per acre. Fluorodifen appears to be more effective on light than heavy soils.

Metribuzin (Sencor) is a new preemergence herbicide for soybeans. It controls many kinds of broadleaf weeds, including wild mustard, and certain grass weeds. The rate is critical. Consult the label for the proper dosage based on soil type and per cent organic matter. Do not apply to sandy soils. Seed soybeans at least 1 1/2 inches below the soil surface to reduce possible soybean injury. Metribuzin may be used in a tank-mix combination with alachlor (Lasso) as a preemergence broadcast or band application to soybeans. Also it may be applied as a preplant, incorporated treatment with trifluralin (Treflan) or as a preemergence broadcast or band overlay application following a preplant incorporated treatment of trifluralin. Alachlor and trifluralin do not give adequate wild mustard control but good control is possible when used in combination with metribuzin. Also these combinations permit a lower rate of metribuzin to be used thus reducing the risk of soybean injury.

SUNFLOWERS: Weeds usually are a problem in sunflowers as the crop does not develop ground cover rapidly enough to prevent weeds from becoming established.

Since weeds generally emerge before the sunflowers, cultivating with a spiketooth or coil spring harrow about one week after sowing but prior to germination of the crop will kill many weeds. After sunflowers reach the four to six leaf stage, kill weeds in the row by using a weeder, coil spring or spike-tooth harrow or rotary hoe. Weeds between the rows are controlled by cultivation.

Trifluralin (Treflan) and EPTC (Eptam) are herbicides that are applied preplanting and incorporated into the soil. See the preceding soybean discussion concerning the incorporation of trifluralin. Apply trifluralin on sandy soil at 3/4 pound per acre and increase the rate to 1 pound per acre on clay soil. Apply EPTC at 3 pounds per acre and incorporate immediately (within minutes) and thoroughly. Proper incorporation of EPTC can be accomplished by double disking twice in opposite directions or by other methods which thoroughly mix the chemical with the top 3 inches of soil. Trifluralin and EPTC control grasses and some broadleaf weeds.

Chloramben (Amiben) at 2 to 3 pounds per acre is applied preemergence to control most grassy and broadleaf weeds, including wild mustard. At least 1/2 inch of rain is necessary within 10 days after application to activate the herbicide. If rain falls later than this, the degree of weed control will be reduced. Excessive rainfall on light soils may leach chloramben below the level of germinating weed seeds resulting in poor weed control and/or crop injury.

LEGUME ESTABLISHMENT: Seedling legumes usually are poor competitors with weeds. Good management practices in preceding crops are recommended such as clean cultivation of row crops and after harvest tillage to reduce the amount of weed seeds in the soil. Mowing seedling legumes (except sweetclover) when sown alone, or the stubble of companion crops, and mowing patches of perennial weeds also aid in weed control.

When alfalfa, sweetclover, alsike clover or birdsfoot trefoil are sown without a companion crop or a grass in a mixture, EPTC (Eptam) at 2 to 3 pounds per acre preplant incorporated effectively controls annual grass and broadleaf weeds except wild mustard.

SPECIAL WEED PROBLEMS

WILD OATS is difficult to control because the plants shatter their seeds before crops are harvested and because of seed dormancy which results in delayed germination. Wild oat seeds are abundant in infested soils. Wild oats is a cool season plant and seeds germinate in the spring and fall when favorable temperature and moisture conditions exist.

Apply barban (Carbyne) for postemergence control of wild oats when the majority of the weeds are in the 1 1/2 leaf stage, which generally occurs from four to nine days after emergence. Rates of 4 to 6 ounces per acre are applied to wheat, barley, flax, soybeans, sunflowers and mustard. Thick, vigorous stands of crop plants help suppress wild oats and enhance the degree of control obtained with barban. Crop competition is important for wild oat control; therefore, control may not be satisfactory in thin crop stands. In sugarbeets apply 12 to 16 ounces per acre of barban.

Barban must be applied before the fourteenth day after wheat, durum and barley emerge and before the fourth leaf stage of the crop to avoid injury and poor wild oat control. Treat flax before the twelfth leaf stage and soybeans before the first trifoliate leaf stage or no later than 14 days after crop emergence. There are no restrictions on winter wheat, sunflowers or sugarbeets. Do not mix barban with any other chemical.

To reduce possible injury to wheat and barley, apply barban when the daytime temperature will exceed 50 F. for 3 days following application. Barban is different from most herbicides since its action is greater at lower temperatures. Use the higher rate at temperatures above 85 F. and on low soil fertility or droughty conditions. Frost prior to barban application does not increase barban injury to wheat and barley if the wild oat leaves are not damaged by the frost and temperatures after application are greater than 50 F.

Leeds and Wells varieties of durum are more tolerant of barban than Botno, Ward and Rolette. Barban is still selective with the more susceptible varieties. When treating the less tolerant durum varieties, observe the precautions stated in the above paragraph very closely.

Preplant or preemergence incorporated applications of diallate (Avadex) at 1 1/2 pounds per acre controls wild oats in flax, corn, soybeans, potatoes and sugarbeets. Triallate (Far-go) is applied preemergence to wheat at 1 pound per acre and barley at 1 1/4 pounds per acre for wild oat control. Both herbicides are volatile and should be incorporated in the top 2 inches of soil by harrowing immediately after application to prevent losses by evaporation.

Wild oats in alfalfa seeded with barley as a companion crop can be controlled with diallate. Apply diallate at 1 1/4 pounds per acre in the spring as a preemergence soil incorporated treatment. Or make a fall preplant soil incorporation treatment within three weeks of soil freeze-up and plant the alfalfa and barley the following spring.

Diallate and triallate can be applied in the fall after October 15 until freeze-up. Granular formulations of both are available for use as fall applications.

See Circular A-351, "Chemical Control of Wild Oats in Field Crops" for additional information.

TILLAGE SUBSTITUTE

Paraquat, a non-selective contact herbicide, can be used as a substitute for a weed controlling tillage operation when wet fields or the desire to conserve seedbed moisture make tillage impractical. Paraquat may be applied before planting or after planting until just before crop emergence. Paraquat should be applied in 5 to 10 gallons per acre of water by air or in 20 to 60 gallons per acre of water by ground. Ortho X-77 surfactant should be added to the spray solution at 8 ounces per 100 gallons. Paraquat can be used on land intended for barley, wheat, corn, potatoes, sugarbeets and soybeans. Paraquat is corrosive to aluminum so aluminum spray equipment and aluminum aircraft structures exposed to paraquat should be rinsed thoroughly immediately after use. Paraquat is quite toxic. Avoid contact with the skin. Even small amounts could be fatal, if swallowed.

RELATIVE RESPONSE OF WEEDS TO HERBICIDES

	Barnyardgrass	Cocklebur	Field bindweed & P. thistles	Foxtails (Pigeongrass)	Kochia	Lambsquarters	Pigweed, redroot	Sunflower, volunteer	Wild buckwheat	Wild mustard	Wild oat
PREPLANT INCORPORATED											
Dinitramine (Cobex)	G	P	N	G	G	G	G	N	F	P	P-F
EPTC (Eptam)	G	P	N	G	F	G	G	N	F	P	G
Trifluralin (Treflan)	G	P	N	G	G	G	G	P	G	N	F
PREEMERGENCE											
Alachlor (Lasso)	G	N	N	G	F	F	G	N	F	P	P
Atrazine (AAtrex)	G	F	P	G	G	G	G	F	G	G	G
Chloramben (Amiben)	G	P	N	G	F	G	G	N	G	F	F
Cyanazine (Bladex)	F	F	N	G	F	G	F	F	G	G	P
Di- & Triallate (Avadex, Far-go)	N	N	N	N-F	N	N	N	N	N	N	G
Metribuzin (Sencor, Lexone)	G	F	N	G	G	F	G	N	F	P	P
Propachlor (Ramrod)	G	P	N	G	G	F	G	N	F	P	P
TCA	G	N	N	G	N	N	N	P	N	N	P
POSTEMERGENCE											
Atrazine + oil (AAtrex)	G	G	P	G	G	G	G	G	G	G	G
Barban (Carbyne)	N	N	N	N	N	N	N	N	P	N	G
Bromoxynil + MCPA (Brominal Plus, Bronate)	N	G	F	N	G	G	G	G	G	G	N
Dalapon (Dowpon)	G	N	N	G	N	N	N	N	N	N	F
Desmedipham (Betanal-475)	P	P	N	P	F	G	G	P	F	G	N
Dicamba (Banvel)	N	G	G	N	G	G	G	G	G	F	N
Dicamba + MCPA (Mondak)	N	G	G	N	G	G	G	G	G	G	N
Endothall (Herbicide 273)	N	P	N	N	P	P	F	P	G	F	N
MCPA	N	G	G	N	F	G	F	F-G	N	G	N
Phenmedipham (Betanal)	P	P	N	F	F	G	P	P	G	G	N
2,4-D	N	G	G	N	F	G	G	G	P	G	N

G = Good F = Fair P = Poor N = None

This table is a general comprative rating of the relative effectiveness of herbicides to certain weeds. Under very favorable weather conditions control might be better than indicated. Under unfavorable conditions, some herbicides rated good or fair might give erratic or unfavorable results.

CHEMICAL WEED CONTROL
For Field Crops

Crop	Herbicide	Act. Ingred. lb. per Acre	Weeds	When to Apply	Remarks
WHEAT, DURUM OR BARLEY	2,4-D amine 2,4-D L.V. ester	1/4 to 1/2	Broadleaf	Crops--5th leaf to boot	Do not apply later than boot stage. Barley more sensitive than wheat.
	MCPA amine MCPA ester	1/4 to 2/3	Broadleaf	Crops--emergence to early boot	Apply 1/2 lb/A or less from emergence to tiller stage.
	Bromoxynil plus MCPA ester	1/4 plus 1/4	Wild buckwheat and most broadleaf weeds	Crops--3rd leaf to boot stage	Apply when weeds are in early seedling stage for best results. Commercial mixtures (Brominal Plus & Bronate) are available.
	Paraquat	1/2	Emerged annual grasses and broadleaf weeds	Preplant or anytime prior to crop emergence	A non-selective, postemergence herbicide. No soil activity. Apply with X-77 surfactant. Good coverage is essential.
WHEAT OR DURUM	Dicamba (Banvel) plus MCPA amine	1/8 plus 1/4	Wild buckwheat and most broadleaf weeds	Crops--2nd through 4th leaf stage	Commercial mixture (Mondak) is available.
WINTER WHEAT OR RYE	2,4-D amine 2,4-D L.V. ester	1/4 to 1/2	Broadleaf	Crops--fully tillered to boot	Do not apply in the fall.
OATS	MCPA amine MCPA ester	1/4 to 1/2	Broadleaf	Oats--emergence to boot	Early jointing stage most sensitive. Possible injury to oats at any growth stage.
	Bromoxynil plus MCPA ester	1/4 plus 1/4	Wild buckwheat and most broadleaf weeds	Crops--3rd leaf to boot stage	Apply when weeds are in early seedling stage for best results. Commercial mixtures (Brominal Plus & Bronate) are available.
	Dicamba (Banvel) plus MCPA amine	1/8 plus 1/4	Wild buckwheat and most broadleaf weeds	Crops--2nd through 4th leaf stage	Commercial mixture (Mondak) is available.
SMALL GRAIN PRE-HARVEST	2,4-D L.V. ester or 2,4-D oil soluble amine	3/4 to 1 1/2	Broadleaf	Crops--dough stage to harvest	Use only when weeds may interfere with harvest operations. Do not feed straw to livestock.

Crop	Herbicide	Act. Ingred. lb. per Acre	Weeds	When to Apply	Remarks
FLAX	MCPA amine	1/4	Broadleaf	Flax--2 to 6 inches tall	Use higher rates or MCPA ester for hard-to-kill weeds.
	Dalapon (Dowpon)	3/4	Annual grasses except wild oats	Best results obtained when flax is over 2 inches and weeds are under 2 inches tall	Mix MCPA with dalapon to control broadleaf and annual grassy weeds. Under drouth conditions, grass control is poor and flax injury may occur.
	Bromoxynil plus MCPA ester	1/4 plus 1/4	Wild buckwheat and most broadleaf weeds	Flax--2 to 6 inches tall	Use for wild buckwheat control. Flax injury is possible.
	EPTC (Eptam)	2 to 3	Grasses and some broadleaf weeds	Preplant incorporated	Incorporation directions and rate discussed under flax narrative at beginning of Weed Control Guide. Flax safety is marginal. Weak on wild mustard.
CORN	Alachlor (Lasso)	2 1/2	Grasses and some broadleaf weeds	Preplant incorporated or preemergence	Ineffective against wild mustard. Usually less effective preemergence than propachlor (Ramrod) in North Dakota. Preplant incorporation gives more consistent weed control.
	Atrazine (AAtrex)	2 to 4	Broadleaf and grasses	Preplant incorporated or preemergence	Atrazine may remain in soil longer than one year and damage following crops other than corn or millet. Use higher rate on heavy soils and for quackgrass control.
	Cyanazine (Bladex)	2 to 3.2	Broadleaf and annual grasses	Preemergence	Soil residues unlikely the year after treatment. Weak on redroot pigweed. Use higher rate on heavy soils.
	Propachlor (Ramrod)	4 to 5	Grasses and some broadleaf weeds	Preemergence	Ineffective against wild mustard.
	Atrazine plus Alachlor	1 plus 2	Most grasses and broadleaf weeds	Preplant incorporated or preemergence	See soil residue comment under atrazine.
(cont. on next page)	Atrazine plus propachlor	1 plus 3 (tank mix)	Broadleaf and annual grasses	Preemergence	Commercial mixture is available (ratio 1 lb. atrazine to 2.3 lb. propachlor). See soil residue comment under atrazine.

Crop	Herbicide	Act. Ingred. lb. per Acre	Weeds	When to Apply	Remarks
CORN (cont.)	Atrazine plus Butylate (Sutan)	1 plus 3	Most grasses and broadleaf weeds	Preplant incorporated	Incorporate immediately (within minutes) and thoroughly in two directions 4 to 6 inches deep with tandem disk. See soil residue comments under atrazine.
	Cyanazine plus Alachlor	1 to 2 plus 2	Most grasses and broadleaf weeds	Preemergence	Use lower rate of Cyanazine on sandy soils.
	EPTC plus R-25788 (Eradicane)	4	Grasses and some broadleaf weeds. Weak on wild mustard.	Preplant incorporated.	See discussion under corn at beginning of Weed Control Guide for rates and incorporation directions. R-25788 and naphthalic anhydride protect corn from injury by EPTC. EPTC plus R-25788 is a commercial mixture.
	EPTC (Eptam) plus naphthalic anhydride (Protect)	4		EPTC preplant incorporated with naphthalic anhydride treated seed	
	Linuron plus propachlor	3/4 to 1 1/2 plus 1 1/2 to 3	Broadleaf and annual grasses	Preemergence	Use the higher rate on heavy soils. Soil residues unlikely the year after treatment.
	Atrazine (AAtrex) plus phytobland oil	1 to 2 plus a phytobland oil	Broadleaf and grasses	Early postemergence-weeds less than 1 1/2 inches tall	Use emulsifiable linseed or petroleum oils at volume recommended on label. See soil residue comment under atrazine.
	Cyprazine (Outfox)	3/4	Broadleaf and annual grasses	Early postemergence	Cyprazine residue remains in soil longer than one year and may damage following crops other than corn. Best results when weeds less than 2 inches high.
	2,4-D amine	1/4 to 1/2	Broadleaf weeds	Postemergence, corn--3 inches to tasseling	Use drop nozzle when corn is over 8 inches tall but before tasseling.
	Dicamba (Banvel)	1/8 to 1/4	Wild buckwheat, Canada thistle, P. sowthistle	Postemergence, before corn is 36 inches tall	See narrative under corn at beginning of the Weed Control Guide.
SOYBEANS (See later section for wild oat control) (cont.)	Chloramben (Amiben)	2 to 3	Annual grasses and broadleaf weeds	Preemergence	Wild oat control not adequate.

Crop	Herbicide	Act. Ingred. lb. per Acre	Weeds	When to Apply	Remarks
SOYBEANS (cont.)	Trifluralin (Treflan)	3/4 to 1	Grasses and some broadleaf weeds	Preplant incorporated	Incorporation directions discussed under soybean narrative at beginning of Weed Control Guide. No wild mustard control.
	Dinitramine (Cobex)	1/3 to 2/3	Grasses and some broadleaf weeds	Preplant, shallow incorporation	Incorporation directions discussed under soybean narrative at beginning of Weed Control Guide. Weak on wild mustard.
	Chloroxuron (Tenoran, Norex)	1	Wild mustard and some other broadleaf weeds, NOT GRASSES	When weeds are less than 2 inches tall and crop has first trifoliate leaf	Use as emergency wild mustard control measure. Must be applied with surfactant (Adjuvan T).
	Alachlor (Lasso)	2 1/2	Grasses and some broadleaf weeds	Preemergence	Wild mustard and wild oat control not adequate. Preplant incorporation gives more consistent weed control.
	Fluorodifen (Preforan)	4 1/2	Broadleaf and grasses	Preemergence	Wild oat control not adequate. Generally more effective on light soils.
	Metribuzin (Sencor, Lexone)	0.4 to 0.8	Broadleaf weeds including wild mustard and some grasses	Preemergence	Seed at least 1 1/2 inches below soil surface to reduce possible soybean injury. The rate is critical. See label for details.
	Trifluralin plus Metribuzin	3/4 to 1 plus 1/4	Broadleaf weeds including wild mustard and annual grasses	Preplant incorporated	Rate of metribuzin is critical. See label for details.
		3/4 to 1 plus 1/4 to 1/2		Trifluralin preplant incorporated, metribuzin preemergence	
	Alachlor plus Metribuzin	2 plus 1/4 to 1/2	Broadleaf weeds including wild mustard and annual grasses	Preemergence	Do not incorporate. Use lower rate of metribuzin on light soils.
	Dinoseb, amine salts	1 1/2 to 2 1/4	Wild mustard	Cracking stage	Use the higher rate below 75°F and the lower rate above 75°F.
(cont. on next page	Paraquat	1/2	Emerged annual grasses and broadleaf weeds	Preplant or anytime prior to crop emergence	A non-selective, postemergence herbicide. No soil activity. Apply with X-77 surfactant. Good coverage is essential.

Crop	Herbicide	Act. Ingred. lb. per Acre	Weeds	When to Apply	Remarks
SOYBEANS (cont.)	Paraquat	1/4	Desiccant	Prior to harvest	Make application when beans are fully developed and half of leaves have dropped and remaining leaves are turning yellow.
DRY, EDIBLE BEANS	Chloramben (Amiben)	2	Annual grasses and broadleaf weeds	Preemergence	Wild oat control not adequate.
	EPTC (Eptam)	3	Grasses and some broad-leaf weeds	Preplant incor-porated	Incorporation directions discussed under sunflower narrative at beginning of Weed Control Guide. Weak on wild mustard.
	Trifluralin (Treflan)	3/4 to 1	Grasses and some broad-leaf weeds	Preplant incor-porated	Incorporation directions discussed under soybean narrative at begin-ning of Weed Control Guide. No wild mustard control.
	Fluorodifen (Preforan)	4 1/2	Broadleaf and grasses	Preemergence	Wild oat control not adequate. Generally more effective on light soils.
	Dinoseb	3 to 4 1/2	Small broad-leaf weeds	Emergence, not beyond "crook" stage	Apply in 30 gallons of water per acre.
SUNFLOWERS (See later section for wild oat control)	EPTC (Eptam)	3	Grasses and some broad-leaf weeds	Preplant incor-porated	Incorporation directions discussed under sunflower narrative at beginning of Weed Control Guide. Weak on wild mustard.
	Trifluralin (Treflan)	1/2 to 1	Grasses and some broad-leaf weeds	Preplant incor-porated	Incorporation directions discussed under soybean narrative at begin-ning of Weed Control Guide. No wild mustard control.
	Chloramben (Amiben)	2 to 3	Annual grasses and broadleaf weeds	Preemergence	Wild oat control not adequate.
SUGARBEETS (See later section for wild oat control) (cont. on next page)	EPTC (Eptam)	2 to 3	Annual grasses and some broad-leaf weeds	Preplant incor-porated	Incorporation directions discussed under sunflower narrative at begin-ning of Weed Control Guide. Use higher rates on heavy, high organ-ic matter soils. Some stand reduction and temporary stunting may occur from the use of EPTC. Weak on wild mustard.
		4 to 4 1/2 (See narra-tive sec-tion for details.)		Fall incorporated after October 15 until freeze-up	

Crop	Herbicide	Act. Ingred. lb. per Acre	Weeds	When to Apply	Remarks
SUGARBEETS (cont.)	Cycloate (Ro-Neet)	3 to 4	Annual grasses and some broadleaf weeds	Preplant incorporated	Use lower rate only on light, sandy soils. Incorporate same as EPTC. Sugarbeets have better tolerance to cycloate than to EPTC. Following cycloate with a postemergence herbicide is suggested. Weak on wild mustard.
	TCA (various names)	6 to 8	Most annual grasses	Preemergence	Weak on wild oats. Do not use sugar beet tops for livestock feed.
	Pyrazon (Pyramin plus TCA)	3.8 plus 6 to 8	Annual grasses and most broadleaf weeds	Preemergence	Has not been effective on soils with more than 5% organic matter.
	Pyrazon plus Dalapon (Pyramin Plus)	3.8 plus 2.2	Most annual grasses and broadleaf weeds	Postemergence when broadleaf weeds are in the two-leaf stage or earlier, and the sugarbeets are in the two-leaf stage or later	Results on soils with more than 5% organic matter have been erratic
	Dalapon (Dowpon)	2 to 3	Most annual grasses	Apply from emergence to 6-leaf stage of sugarbeets. Use directed spray after beets have 6 leaves	Use high rate if grasses have over 2-4 leaves or if they are growing slowly due to dry conditions. May be applied more than once up to a maximum of 5.9 lb/A per year. Some yield reduction may occur from rates over 3 lb/A.
	Endothall (Herbicide 273)	3/4 to 1 1/2	Wild buckwheat smartweed marshelder	Sugarbeets should have 4-6 leaves. Do not apply later than 40 days after emergence	When temperatures are over 80°F., endothall may cause excessive injury, especially to very small sugarbeets. Endothall is ineffective at temperatures below 60°F.
	Phenmedipham (Betanal)	1 to 1.5	Most annual grasses and broadleaf weeds except redroot pigweed	Postemergence when broadleaf weeds are between cotyledon and four-leaf stage and the sugarbeets are in the four-leaf stage or later	To avoid sugarbeet injury, use no more than 1 lb/A following EPTC or TCA, do not apply if highest temperature during day is over 85°F. and apply late in afternoon or early in the evening.
(cont. on next page)	Desmedipham (Betanal-475)	1 to 1 1/4	Most annual grasses and broadleaf weeds including redroot pigweed		

Crop	Herbicide	Act. Ingred. lb. per Acre	Weeds	When to Apply	Remarks
SUGARBEETS (cont.)	Paraquat	1/2	Emerged annual grasses and broadleaf weeds	Preplant or anytime prior to crop emergence	A non-selective, postemergence herbicide. No soil activity. Apply with X-77 surfactant. Good coverage is essential.
POTATOES	Dalapon (Dowpon)	6	Quackgrass	Preplant in spring when grass is 4 to 6 inches tall	Plow after 4 days and potatoes may be planted immediately
	EPTC (Eptam)	3 to 6	Grasses and some broadleaf weeds	Preplant or directed spray at dragoff	Incorporation directions discussed under sunflower narrative at beginning of Weed Control Guide. Weak on wild mustard.
	Linuron (Lorox)	3/4 to 2	Most annual grasses and broadleaf weeds	Preemergence (just before crop emerges)	Apply to crop planted 2 inches deep, after dragoff or hilling. Do not plant to other crops within 4 months after treatment.
	Trifluralin (Treflan)	1/2 to 1	Grasses and broadleaf weeds	After planting, incorporated. Use up to or immediately following dragoff	Care should be taken that incorporation machinery does not damage seed pieces or elongating sprouts.
	Chlorbromuron (Maloran, Bromex)	2 to 4	Most annual grasses and broadleaf weeds	Preemergence, after planting or dragoff	Do not plant crops other than potatoes, corn or soybeans within 6 months after application. Generally does not perform satisfactorily on heavy, organic soils.
	Paraquat	1	Most annual grasses and broadleaf weeds	Preemergence--when weeds are up but before crop emerges	Do not apply later than ground cracking. Paraquat kills only emerged weeds.
POTATO VINE KILLING	Endothall (Des-i-Cate)	3/4 to 1	Desiccant	10 to 14 days prior to harvest	Use higher rate during cool, cloudy weather and on heavy vine growth.
	Dinoseb	1 1/4 to 2 1/2	Desiccant	10 to 20 days prior to harvest	See label for details. Rate depends on temperature, spray volume, potato variety and vigor of the vines.
	Paraquat	1/4 to 1/2	Desiccant	More than 3 days prior to harvest	Do not use when the potatoes are to be stored or used for seed.

Crop	Herbicide	Act. Ingred. lb. per Acre	Weeds	When to Apply	Remarks
GRASS Seedling	2,4-D	1/2 to 3/4	Broadleaf	After 3-leaf stage of grasses	Use rate for established grasses after tillering.
Established (See later section for control of specific perennial weeds)	2,4-D	3/4 to 2 lb/A	Annual and perennial broadleaf weeds	Weeds--emergence to bud stage, preferably when young and actively growing	Do not graze dairy cows for 7 days after application. Do not apply after boot stage on grasses for seed production. Use 1 lb/A on annuals and gumweed and 2 lb/A on sages and other perennials.
LEGUMES Alfalfa and clover with nurse crop	MCPA	1/8 to 1/4	Broadleaf	Legumes 2-3 inches tall and nurse crop 4-16 inches tall	Canopy of crop or weeds reduces injury. NOTE: POSSIBLE INJURY TO SWEETCLOVER AND ALFALFA.
	Dinoseb	1.1 to 1.5	Small broadleaf weeds	Grain--3 to 6 inches tall and weeds small	Apply in 30 gallons of water per acre. Partial burning of grain leaves is not ordinarily harmful.
Alfalfa or trefoil alone. Established or seedling stage	2,4-DB	1/2 to 1	Broadleaf	Weeds and legumes less than 3 inches tall, nurse crop 1-6 inches tall	Sweetclover killed by 2,4-DB. Wild mustard control generally not adequate. 2,4-DB must be applied 30 days before hay harvest or grazing. See narrative at beginning of Weed Control Guide for herbicides in legume establishment.
Alfalfa only	Simazine (Princep)	0.8 to 1.6	Grasses and broadleaf weeds including wild oats and mustard	After last cutting but before freeze-up	Do not use on sands or loamy sands or where soil pH is above 7.5. Use low rate on sandy loam. Apply to pure stands of alfalfa established at least 12 months.

Weed	Herbicide	Rate per Acre	Crop	When to Apply	Remarks
WILD OATS Selective control in crops	Triallate (Far-go)	1 1/4 lb liquid 1 1/4-1 1/2 lb granules	Barley	Fall--after October 15 and until freeze-up	Incorporate immediately by cultivation. Keep spring tillage to minimum. Use lower rate of granules on wheat
(cont. on next page)	(cont. on next page)	1 lb liquid 1 1/4-1/2 lb granules	Wheat and durum		

Weed	Herbicide	Rate per Acre	Crop	When to Apply	Remarks
WILD OATS Selective control in crops (cont.)	Triallate (Far-go) (cont.)	1 1/4 lb	Barley, peas and lentils	Spring--immediately after planting	Apply on smooth soil surface and incorporate immediately in top 2 inches by cultivation. Wheat must be below the incorporated zone.
		1 lb	Wheat and durum		
	Diallate (Avadex)	1 1/2 to 2 lb	Flax, sugarbeets, soybeans and potatoes	Preplanting	Incorporate immediately by cultivation.
		1 1/2 lb	Corn and lentils	Preplanting or preemergence	Incorporate immediately by cultivation.
		1 1/4 lb	Peas		
		1 1/2 to 2 lb liquid	Flax and sugarbeets	Fall--after October 15 and until freeze-up	Incorporate immediately by cultivation. Keep spring tillage to minimum
		1 1/2 to 2 lb granules	Sugarbeets		
	Barban (Carbyne)	4 to 6 oz	Wheat, winter wheat, durum, barley, flax, peas, mustard, sunflowers and lentils	Wild oats-1 1/2 leaf stage. Crops: Small grain before 4th leaf stage; flax before 12th leaf stage; peas before 6th leaf stage; mustard before true 3rd leaf stage; winter wheat, sugarbeets and sunflowers-no restrictions	Usually applied 4 to 9 days after wild oats emerge. Must be applied before the 14th day after wheat, durum, barley and lentils emergence and before the 4th leaf stage to avoid serious crop injury and poor wild oat control. Do not mix barban with any other chemicals. See Narrative for effects of temperature, low soil fertility and droughty conditions on barban activity.
		12 to 16 oz	Sugarbeets		
		4 to 6 oz	Soybeans	Before the first trifoliate leaf stage or no later than 14 days after crop emerges	Do not feed treated soybean forage or pods to livestock.
FUMITORY	Triallate (Far-go)	1 1/4 lb	Barley	Immediately after planting	Use only if wild oats also is a problem, because of cost. Incorporate in top 2 inches of soil by cultivation
		1 lb	Wheat and durum		
(cont. on next page)	Diallate (Avadex)	1 1/2 lb	Flax	Preplanting	

Weed	Herbicide	Rate per Acre	Crop	When to Apply	Remarks
FUMITORY (cont.)	Bromoxynil plus MCPA ester	1/4 to 1/3 lb plus 1/4 to 1/3 lb	Wheat and barley	After fumitory is established to boot stage of crop	Apply in 10 to 15 gal. water per acre. Other broadleaf weeds also will be controlled. Commercial mixtures (Brominal Plus and Bronate) are available.

CHEMICAL WEED CONTROL
For Perennial Weeds

Weed	Herbicide[1/]	Act. Ingred. Lb/A or Sq. Rd.	When to Apply	Remarks
FIELD BINDWEED Fallow or post harvest	2,4-D L.V. ester or oil soluble amine	1 to 2 lb/A	Regrowth 6 inches to bud stage.	Cultivate fallow until mid-July. Spray in late August or September. Respray in following year's crop.
Wheat and barley	2,4-D amine 2,4-D L.V. ester	3/4 lb/A 2/3 lb/A	Tiller stage of crop	Higher rates may injure crop but may be worthwhile, especially in small areas, to control bindweed.
Patches or individual plants in pastures or non-cropland[2/]	Picloram (Tordon 22K)	1 lb/A	When bindweed is actively growing	Tordon granules available. Do not use in areas with high water table. Do not graze dairy cattle on treated area.
	Dicamba (Banvel)	4 to 8 lb/A	When weed is actively growing	Apply to foliage and/or soil. Do not graze for 60 days or make hay for 90 days for dairy cows or graze or feed hay to beef cattle 30 days before slaughter.
LEAFY SPURGE On fallow	2,4-D L.V. ester	1 to 2 lb/A	4 to 6 inches	Cultivate or respray whenever regrowth is 4 to 6 inches high. Respray in following year's crop.
Pasture and Rangeland	2,4-D L.V. ester or oil soluble amine	1 to 2 lb/A	Early bud stage and fall	Apply both spring and fall for satisfactory control. Do not graze dairy cows for 7 days after treatment.
(cont. on next page	Picloram (Tordon 22K)	1/4 to 1/2 lb/A	Any time spurge is actively growing	Retreatment at the same time usually will be necessary the following year. Do not graze dairy cattle on treated area.

1/ Several soil sterilants will control perennial weeds. Follow directions on the label.
2/ Non-cropland means roadsides and waste areas not used to produce animal feed.

Weed	Herbicide[1/]	Act. Ingred. Lb/A or Sq. Rd.	When to Apply	Remarks
LEAFY SPURGE (cont.) Patches individual plants in pastures	Dicamba (Banvel)	4 to 8 lb/A	When spurge is actively growing	Apply to foliage and/or soil. Do not graze for 60 days or make hay for 90 days for dairy cows or graze or feed hay to beef cattle 30 days before slaughter.
	Picloram (Tordon 22K)	1 to 2 lb/A	Any time spurge is actively growing	During a single season do not use more than 10 gals. of Tordon 22K for any 100 acre area. Do not treat more than 20 acres of any 100 acre area. Tordon granules available.
CANADA THISTLE AND SOWTHISTLE Wheat and Barley	MCPA amine MCPA ester	3/4 lb/A 2/3 lb/A	Tiller stage of crop	Higher rates than listed may injure crop but may be worthwhile, especially in small areas, to achieve thistle control.
Fallow or post harvest	2,4-D	1 lb/A	6 inches tall and actively growing. Post harvest mowing promotes active regrowth	Cultivate fallow until mid-July. Spray in late August or September.
	Dicamba (Banvel)	1 to 2 lb/A		
Pasture and Rangeland	Picloram (Tordon 22K)	1/4 to 1/2 lb/A	6 inches tall and actively growing. For fall treatment, mowing promotes active growth	Retreatment at the same rate usually will be necessary the following year. Do not graze dairy cattle on treated area.
	Dicamba (Banvel)	1/2 lb/A		Do not graze dairy cows for 7 days or make hay for 37 days after treatment. Do not graze meat animals in treated areas within 30 days of slaughter.
	2,4-D	1 to 2 lb/A		Do not graze dairy cows for 7 days after treatment.
Patches or individual plants in pastures	Picloram (Tordon 22K)	1 lb/A	When thistles are actively growing	During a single season do not use more than 10 gals of Tordon 22K for any 100 acres. Do not treat more than 20 acres of any 100 acre area.
	Dicamba (Banvel)	4 lb/A		Do not graze for 60 days or make hay for 90 days for dairy cows or graze or feed hay to beef cattle 30 days before slaughter

1/ Several soil sterilants will control perennial weeds. Follow directions on the label.

Weed	Herbicide[1/]	Act. Ingred. Lb/A or Sq. Rd.	When to Apply	Remarks
QUACKGRASS	Dalapon (Dowpon)	6 to 11 lb/A	On fallow after 4 to 6 inches growth	Cultivate after 10 to 20 days.
	Atrazine (AAtrex)	4 lb/A	Apply 2 lb/A early spring and an additional 2 lb/A at planting time	Plant only corn year of application and year following treatment.
AROUND BLDGS., TELEPHONE POLES, ETC.	Atrazine, bromacil, monuron, prometone or similar products	See label	Any time during and prior to growing season. See label.	Use heavy rates for complete long-time soil sterility.

1/ Several soil sterilants will control perennial weeds. Follow directions on the label.

GLOSSARY OF CHEMICAL NAMES

COMMON NAME	TRADE NAME[1/] AND MANUFACTURER	CONCENTRATION AND COMMERCIAL FORMULATIONS[2/]
Alachlor	Lasso (Monsanto)	4 lb/gal L 15% G
Ametryne	Evik (Ciba-Geigy)	80% WP
Atrazine	AAtrex (Ciba-Geigy)	80% WP 4 lb/gal L
Barban	Carbyne (Gulf)	1 lb/gal L
Bromacil	Hyvar-X, Hyvar-XL (DuPont)	80% WP 2 lb/gal L
Bromoxynil	Buctril (Chipman) Brominal (Amchem)	2 lb/gal L
Bromoxynil and MCPA	Bronate (Chipman) Brominal Plus (Amchem)	2 lb/gal MCPA plus 2 lb/gal bromoxynil L
Butylate	Sutan (Stauffer)	6 lb/gal L, 10% G
Chloramben	Amiben (Amchem)	10% G 2 lb/gal L
Chlorbromuron	Bromex (Nor-Am) Maloran (Ciba-Geigy)	50% WP
Chloroxuron	Norex (Nor-Am) Tenoran (Ciba-Geigy)	50% WP
Cyanazine	Bladex (Shell)	80% WP 15% G
Cycloate	Ro-neet (Stauffer)	6 lb/gal L
Cyprazine	Outfox (Gulf)	1 lb/gal L
Dalapon	Basfapon (BASF) Dowpon M (Dow)	74% WSP
Dalapon and TCA	Dowpon C (Dow)	46.5% dalapon 26.2% TCA WSP
Desmedipham	Betanal-475 (Nor-Am)	1.3 lb/gal L
Diallate	Avadex (Monsanto)	4 lb/gal L 10% G
Dicamba	Banvel (Velsicol)	4 lb/gal L
Dicamba and MCPA	MonDak (Velsicol)	1.25 lb/gal dicamba 2.50 lb/gal MCPA L
Dinitramine	Cobex (U.S. Borax)	2.0 lb/gal L
Dinoseb (DNBP)	Several (various)	1, 3, 5 lb/gal L 10% G
Endothall	Endothal, Herbicide 273 (Pennwalt)	1.46 lb/gal L 3 lb/gal L, 5% G
Endothall (as a desiccant)	Des-i-Cate (Pennwalt)	0.52 lb/gal L

1/ "Several" means there are numerous trade names for the chemical. The mention of trade names does not imply that they are endorsed or recommended over those of similar nature not listed.

2/ G-granular, L-liquid, WP-wettable powder, WSP-water soluble powder.

COMMON NAME	TRADE NAME[1/] AND MANUFACTURER	CONCENTRATION AND COMMERCIAL FORMULATIONS[2/]
EPTC	Eptam (Stauffer)	6 lb/gal L 10% G
EPTC plus R-25788	Eradicane (Stauffer)	6 lb/gal L
Fluorodifen	Preforan (Ciba-Geigy)	3 lb/gal L
Linuron	Lorox (DuPont)	50% WP
MCPA	Several (various	Various L
Metribuzin	Lexone (DuPont) Sencor (Chemagro)	50% WP
Monuron	Telvar (DuPont)	G, L, WP Various
1,8-naphthalic anhydride	Protect (Gulf)	Seed treatment
Paraquat	Ortho Paraquat (Chevron)	2 lb/gal L
Phenmedipham	Betanal (Nor-Am)	1.3 lb/gal L
Picloram	Tordon 22K, Tordon 10K, Tordon Beads (Dow)	10%, 2% G 2 lb/gal L
Propachlor	Ramrod (Monsanto)	65% WP 20% G
Propazine	Milogard (Ciba-Geigy)	80% WP
Pyrazon	Pyramin (BASF)	80% WP
Pyrazon and dalapon	Pyramin Plus (BASF)	27% pyrazon 18.5 dalapon WP
Simazine	Princep (Ciba-Geigy)	80% WP 4% G
TCA	TCA (various)	4.76 lb/gal L 79.3% WSP
Triallate	Far-go (Monsanto)	4 lb/gal L 10% G
Trifluralin	Treflan (Elanco)	4 lb/gal L 5% G
2,4-D	Several (various)	L, G Various
2,4-DB	Butyrac (Amchem) Butoxone (Chipman)	L Various

1/ "Several" means there are numerous trade names for the chemical. The mention of trade names does not imply that they are endorsed or recommended over those of similar nature not listed.

2/ G-granular, L-liquid, WP-wettable powder, WSP-water soluble powder.

CURRENT RESEARCH REPORTS

SEED TREATMENT

Dr. V. D. Pederson, Plant Pathology Department

Seed treatment with fungicides and insecticides is an economical method of providing protection for the seed during germination and early stages of seedling development. Each year insects in the soil and fungi on the seed or in the soil combine to reduce emergence and stands of crops. Seed that will germinate 95 percent or better in laboratory germination tests will often produce only 60-75 percent seedling stands when planted in the field. Poor stands with less than optimum tillering and competition from weeds can and often does result in less than optimum yields. In addition to stand reduction certain fungi that are seed borne will cause smuts of barley and wheat. These diseases directly affect yield when the infected plants produce only smutted heads.

Significant increases in stands or yields cannot always be proven experimentally. However, over the years the odds are in favor of seed treatment. Successes in improving stands and in controlling the smuts of barley and wheat are sufficient to recommend seed treatment as a low-cost insurance against potential significant losses.

Each year seed treatment trials are conducted at the North Dakota State University Experiment Stations to compare the effectiveness of new experimental chemicals with those now cleared for use on small grains. We are constantly searching for those that will be more effective, safer, and easier to use, longer lasting and more economical than those now used.

Effect of Seed Treatment on Stands, Smut Control and Yield of Nordak Wheat at Two Locations in North Dakota, 1974

		Nordak Wheat					
		Grandin			Carrington		
Treatment	Rate (Oz/cwt)	% Stand	Loose[1/] Smut	Yield (Bu/Ac)	% Stand	Loose[1/] Smut	Yield (Bu/Ac)
CK	0	61	10	37.0	55	12	20.2
TCMTB (Cover Up-L)	1.5	61	NC[2/]	36.2	44	NC	21.3
Maneb 50% (Agsco DB Yellow)	4	68	NC	35.8	60	NC	22.5
Maneb 50% + Lindane 18.75% (Agsco DB Green)	4	69	NC	40.0	57	NC	20.6
Carboxin (Vitavax 200)	3	68	4.4	37.0	66	5.6	23.2
Phenyl Mercury Ammonium Acetate (Mistomatic)	1.5	67	NC	39.7	57	NC	21.0
Captan 75%	4	68	NC	37.5	63	NC	21.8
Thiram 75%	4	69	NC	37.3	57	NC	24.5
Polyram 53.5%	4	64	NC	36.3	48	NC	24.5
LSD .40		2		1.5	5		2.6

1/ Average number of smutted heads per 12 foot row.
2/ NC = No Control of Loose Smut.

Effect of Seed Treatment on Stands, Smut Control and Yield of Dickson Barley at Two Locations in North Dakota, 1974

		Dickson Barley					
		Grandin			Carrington		
Treatment	Rate (Oz/cwt)	% Stand	Covered[1/] Smut	Yield (Bu/Ac)	% Stand	Covered[1/] Smut	Yield (Bu/Ac)
Ck	0	67	35	58.2	65	12	57.6
TCMTB (Cover Up-L)	1.5	78	15	62.5	63	6	64.3
Maneb 50% (Agsco DB Yellow)	4	83	3	70.2	58	2	54.3
Maneb 50% + Lindane 18.75% (Agsco DB Green)	4	71	2	70.8	89	2	67.4
Carboxin (Vitavax 200)	3	81	0	65.9	63	0	63.6
Phenyl Mercury Ammonium Acetate (Mistomatic)	1.5	82	14	62.5	64	3	67.2
Captan 75%	4	77	23	64.6	63	8	62.9
Thiram 75%	4	77	17	63.4	67	5	58.4
Polyram 53.5%	4	81	7	66.0	61	3	62.7
LSD .40		6	3	2.7	5	2	3.2

1/ Average number of smutted heads per 12 foot row.

REMOTE SENSING - APPLICATION FOR AGRICULTURE

Dr. V. D. Pederson, Plant Pathology Department

In the world around us we recognize objects and evaluate them by the color and intensity of light that is reflected back from the objects to our eyes. We are remotely sensing the qualities of the objects by means of our light sensitive sensors - the eyes.

Our eyes are marvelous pieces of equipment but the wavelengths of light that they detect are limited. We cannot see x-rays, ultraviolet, infrared or the microwave portions of the electromagnetic spectrum. We can only detect a relatively small portion of the spectrum which we define as "visible" light. The remainder of the spectrum is invisible to our eyes but not to specialized electronic sensors or to certain kinds of photographic film.

To our eyes healthy vegetation is green because more green light (wavelengths of 500-600 nanometers (nm) is reflected than other portions of the visible spectrum. However, in reality, far more near infrared light (700-900 nm) is reflected from healthy vegetation illuminated by sunlight. This infrared portion of the spectrum can readily be detected by infrared color film. The film is sensitized in such a way that infrared light is represented in the photograph as a bright red color, red as yellow, green as blue and blue as black. This special film allows us to record differences in infrared reflection from crops and by interpretation to determine the health of the crop. A vigorously growing, healthy crop will appear bright red in the photograph whereas a crop growing under stress of low fertility, drought, disease or insects will appear dull red to green or blue.

Virtually any condition that affects the health or vigor of a plant affects its infrared radiation. These effects can often be detected by infrared color film before they can be detected by eye.

Some diseases such as potato late blight can be detected early enough so spray programs can be started to prevent spread of the disease in the field.

Farmers who have their fields photographed by services now available in North Dakota should realize that infrared color film can only provide a record of infrared radiation at a particular time. Interpretation of the photograph requires knowledge of the crop. Inspection of the photograph should be followed up by thorough inspection of the field. Only then can information from the photograph be interpreted correctly. Although stress conditions may easily be detected on photographs, the precise reasons for the stress must be determined by ground surveys.

A number of applications of remote sensing for agriculture by aerial infrared photography have been suggested. As techniques of interpretation are developed, the following applications and perhaps many more will become routine for on farm use.

- Fertilizer recommendations.
- Evaluating soil moisture and field drainage patterns.
- Determining soil salinity.
- Measuring density of weed populations and effectiveness of herbicide application.
- Detecting insect infestations and evaluating effectiveness of insecticide applications.
- Early warning of plant diseases affording timely and effective application of fungicides.
- Surveying and estimating crop yields.

On-going research in the Plant Pathology Department at North Dakota State University is designed to test the feasibility of using remote sensing in several of these applications to agriculture.

WHEAT LEAF RUST

Dr. Glen Statler, Plant Pathology Department

Leaf rust, caused by the fungus *Puccinia recondita* is potentially one of the most destructive diseases of wheat in North Dakota. Although most commercial varieties of spring wheat are resistant to leaf rust, resistance is not permanent since the natural leaf rust population is constantly changing. There are several examples of once resistant varieties rusting due to changes in the natural leaf rust population.

Rust nurseries are planted each year at four locations to measure resistance of the commonly grown hard red spring wheat varieties and breeders lines. Table 1 shows the percent severity and reaction types of several commonly grown hard red spring and durum wheats at Carrington in 1974.

Table 1. Leaf rust severities and reaction types on wheat at Carrington in 1974.

Variety	Percent severity and reaction type[1/]
Spring Wheat	
1. Thatcher	70S
Tioga	60S
Manitou	60S
Era	10MS-5R
Chris	5MS-5R
W.S. 1809	5MS-tMR
Ellar	5S
Lark	tMS
Bounty 208	tR-tMS
Olaf	5R
Bounty 208	tR-tMS
Bonanza	tR
Waldron	tR-tMS,10S
Durums	
1. Wakooma	15MS-10MR
Botno	20MS-tR
Rolette	10MS-5MR
Wascana	5MS-5MR
Leeds	5R-tMS
Rugby	5R-tMS
Ward	5MR-3MS
Crosby	tMS-tMR

1/ Percent severity preceds reaction type S = susceptible; R = resistant; MR = moderately resistant; MS = moderately susceptible; t = trace. A dash indicates a range in severity or response. A comma separates two distinct reactions (segregating).

Many of the commercially grown hard red spring and durum wheats have susceptible reaction types with low severities. Higher severities could result in significant yield losses. Several fields of winter wheat surveyed in the southeastern and southwestern areas of North Dakota in 1974 were severely rusted. Severities of 40-50S on the flag leaf in the milk stage of growth undoubtedly reduced yields.

The best way to control leaf rust is with resistant varieties or by using fungicide sprays. (One application of Manzate 200 or Dithane M-45 at 1 1/2 to 2 pounds per acre at heading and a second application about 10 days later is currently recommended.) Fungicide spray trials have been conducted since 1971 at N.D.S.U. to evaluate the potential destructiveness of leaf rust. Yield increases ranged from 0 for resistant varieties up to 30% or 14 bushels per acre for susceptible varieties when leaf rust was controlled with fungicides. Yield losses depend on rust severity, varietal susceptibility and environmental conditions conducive to rust development.

Since yield losses up to 30% or 14 bushels per acre have been reported for susceptible varieties, a cost-return table could be used to estimate profit or loss by spraying. The three variables are yield per acre, the price of wheat, and rust severity (approximate % loss), all of which must be considered before a decision to spray is made. Cost-returns in the following table are based on a potential yield of 45 bushels per acre and wheat at $4.57 per bushel.

Net Profits for Controlling Foliar
Diseases by Fungicides

% Loss	Bu/A	Net Return/A1/
0	45	-
5	43	$ 3.59
10	41	12.73
20	36	35.58
30	31	58.43

1/ Net return is yield increase times $4.57 per bushel, minus cost of the two applications of protectant fungicide (approximately $5.55/A).

Since the foliar protectants presently on the market control not only leaf rust but also leaf spots, the present market value of wheat makes fungicidal control of leaf disease on susceptible varieties profitable. Results from fungicide spray trials conducted in North Dakota clearly demonstrate the destructiveness of wheat leaf rust when susceptible varieties are planted. The data also show a direct relationship between rust severity and yield loss as well as between the rate of rust development and yield loss. Considering the present market value of wheat, coupled with the knowledge that leaf rust causes yield loss, susceptible varieties should not be planted unless a fungicide spray program is planned. Since environmental conditions are favorable for rust development each year in certain parts of the state the development and use of resistant varieties saves millions of dollars annually for North Dakota growers.

WEED CONTROL RESEARCH

John D. Nalewaja and Stephen D. Miller
Agronomy Department

The discussion below will relate to research with herbicides which are in the more advanced stages of development and may have full or experimental label within the next few years.

The 1974 growing season was somewhat less than optimum for research because of the late seeding, June drought, and August hailstorm at Fargo. Inspite of the season however, valuable information on weed control was obtained.

Wild oats control - The wild oats control research program is very extensive, including experiments on the biology of the wild oat plant, crop rotations, and herbicide evaluation and development.

In the area of biology of wild oats, experiments are in progress on the germination and dormancy of wild oat seeds as influenced by tillage, depth, and time in the soil. The variation in the wild oats as to response to herbicides and in growth habit in North Dakota is under study to determine competition ability and potential tolerance to herbicide treatments.

Wild oat seed survival was less when the seeds were left on the surface than when tilled into the soil; and seed buried in the soil at Fargo lost 76% viability and at Williston lost 83% viability by the June following fall burial. Viability tended to be greater with the deeper burials.

Several new herbicides were evaluated for wild oats control in 1974. The discussion which follows will present information on some of these new herbicides relative to general observations.

Difenzoquat (Avenge) is a herbicide which controls wild oats in the 2 to 4-leaf stage. Barley has good tolerance to difenzoquat. Some wheat varieties appear nearly as susceptible to difenzoquat as wild oats while others are quite tolerant. Difenzoquat had an experimental permit for use in barley in 1974 and may have label clearance in 1975. Wild oats control with difenzoquat generally was good in 1974 with 72, 93, 73, and 97% control with 10 oz/A at Fargo, Langdon, Minot, and Williston, respectively. The addition of herbicides for broadleaf weed control to difenzoquat was successful without affecting wild oats control. In 1973, wild oats control with difenzoquat was variable, but may have been related to the wetting agent or environmental conditions.

SD-29761 is a herbicide which is chemically related closely to Endaven, commercially sold in Canada. The earliest possible commercial usage of SD-29761 would be for the 1976 season. Wild oats control has been very consistent with SD-29761. The wild oats control in 1974 averaged over Williston, Minot, and Langdon was 91% with 4 oz/A applied at the 5-leaf stage and 96% with 8 oz/A applied at the 3.5-leaf stage. Wild oats is most susceptible to SD-29761 at the 5-leaf stage, but with higher rates control can be obtained with earlier applications as wheat tolerance is good. Thus, the rate of SD-29761 may depend upon the wild oats stage at treatment and the stage of treatment upon the wild oats density. With moderate to heavy infestation the elimination of early wild competition would probably more than compensate for the cost for the extra chemical needed with early application. Wild oats control with SD-29761 is reduced if applied with most broadleaf herbicides.

MSMA is an old herbicide which was evaluated for wild oats control in the mid-1960's. At that time MSMA was abandoned because the compound is an arsenic which was thought to have environmental problems. Apparently the environmental problems with these organic arsenics have been resolved and there is a renewed interest in them. MSMA was quite erractic in performance, but this may have been related to temperatures at application. The rate may need to be adjusted for the temperature. MSMA also can be effective on wild mustard and foxtail.

HOE-23408 is a new herbicide which appears promising for wild oats control in wheat and barley. HOE-23408 is still in the development stage, but early application is more effective than later applications. Mixture of HOE-23408 with broadleaf herbicides reduced wild oats control. One of the most interesting features of HOE-23408 is that it is effective in controlling foxtail. Results with HOE-23408 have been somewhat variable, but with further research the variability may be understood and overcome.

Flax - EPTC was evaluated again this year at Fargo and most of the other experiment stations in the state. Weed control generally was excellent. The tolerance of flax was marginal with stand reductions occurring at 3 lb/A at some locations and consistent stand reductions at 5 lb/A. However, based upon appearance, flax seed yields from EPTC treated plots will probably be higher than from most other plots (yield data has not been determined at this time) because of the good weed control obtained. The successful use of EPTC in flax will require adjustment of rate according to soil type and precise application (see 1975 weed control guide for further comments).

Asulam (Asulox) was evaluated again for weed control in flax. Results were good at Fargo; but the herbicide was somewhat less effective at some of the other experiment stations. Asulam controls wild oats and several other annual grassy and broadleaved weeds. Asulam is presently marketed in Canada.

Bromoxynil was evaluated at 8 oz/A for possible expansion of the label which now is at 4 oz/A. In previous years 8 oz/A had caused some flax leaf burn but no permanent damage. However, with the hot weather in 1974 during application, the 8 oz/A treatment caused severe damage to flax.

Soybeans and Pinto beans - Bentazon applied postemergence did not injure beans at rates of 2 lb/A. One-half and 1 lb/A gave good control of most broadleaved weeds. Wild mustard was one of the most susceptible broadleaved weeds to bentazon. Bentazon has had an experimental permit for the past two years and is expected to have full label in soybeans in 1975.

Nitralin (Cobex), profluralin (Tolban), and fluchloralin (Basalin) all were similar in effectiveness to trifluralin (Treflon) with some variation in rate required.

Corn - Propachlor (Ram-rod) alone or in combination with other herbicides continued to generally give better weed control than alachlor (Lasso) at a comparable rate. Further, alachlor was again more effective when soil incorporated than when surface applied.

Sunflowers - The dinitroanalins mentioned in the discussion of weed control in soybeans all had excellent safety to sunflowers.

PERENNIAL WEED CONTROL

Calvin Messersmith
Agronomy Department

Spot treatment of perennial weed patches is a good preventive weed control measure to minimize the spread of new infestations over a large area. However, the area infested is too small to use a conventional farm sprayer and mixing a liquid herbicide formulation is a time-consuming nuisance for the small area involved. Granular herbicides can be spread by hand with preparation limited to reading the label for use directions and obtaining a suitable measuring device like a quart jar.

The herbicide in granules is taken up through the root system of the perennial weeds, so rainfall is needed to leach the herbicides into the root zone. The granules can be applied at any time of year, but a late August or September treatment generally gives the best results in North Dakota because many plants are killed following rains, the injured plants are more susceptible to winter killing, and the herbicide can kill the remaining plants and germinating seedlings the following spring. Herbicide breakdown is minimal during the cool fall and winter months. Spring granular applications can be quite effective with adequate rainfall after herbicide application, but the longer term residual effectiveness may be reduced because herbicide breakdown is more rapid during the warm summer months. Limited rainfall after spring herbicide application may result in herbicide breakdown without sufficient leaching for effective perennial weed control.

An experiment for leafy spurge control compared the effectiveness of dicamba (Banvel) and picloram (Tordon) as liquid and granular formulations. The treatments were applied on September 28, 1973. The leafy spurge stems were alive but some of the leaf tips had been killed by frost. A killing frost occurred 20 days after treatment on October 18, 1973. Percent control based on reduction of leafy spurge density was evaluated visually on June 6 and September 11, 1974.

As shown in the table, dicamba granules and liquid were effective similarly for leafy spurge control on June 6, 1974 evaluation. But the dicamba granules were more effective than the liquid formulation for the September 11, 1974 evaluation. Picloram pellet and liquid formulations were equally effective for leafy spurge density reduction.

Dicamba is available commercially as a 5% active ingredient granule (Banvel 5G), but picloram pellets probably will not be available in 1975. Both dicamba and picloram are very injurious to trees and other broadleaf plants, so it is necessary to observe the label restrictions for areas of application.

These data support the general observation that late August through September, also, is a desirable time to use postemergence herbicides like 2,4-D, dicamba, and picloram for perennial weed control. Frequently, the kill of the entire plant including the deep root system will be greater from the fall application than from a June or early July treatment. The advantage of fall treatment has been observed in experiments to control leafy spurge, Canada thistle, and field bindweed (creeping jenny). Mowing, cultivation, or herbicide treatment in early summer is desirable to prevent seed production by the perennial weed and the regrowth is sprayed in the fall.

Perennial weeds should be relatively large for postemergence spraying; preferably the stems should be one foot long or greater, and up to the flowering stage. Since the underground root system of perennial weeds is relatively large, a greater leaf and stem surface area must be sprayed to get adequate herbicide absorption and translocation to kill the root system.

Table. Fall applications of dicamba and picloram for leafy spurge control. (Messersmith)

Chemical	Rate active ingredient lb/A	Quantity product per acre	Percent control June 6	Percent control Sept 11
Comparison of dicamba granular and liquid formulations				
Dicamba, 5% granules	4	80 lb/A	84	54
Dicamba, 5% granules	6	120 lb/A	95	82
Dicamba, 5% granules	8	160 lb/A	98	88
Dicamba, liquid	4	1 gal/A	82	19
Dicamba, liquid	6	1.5 gal/A	88	50
Dicamba, liquid	8	2 gal/A	98	66
Control	-	--	0	0
LSD (.05)			12	23
Comparison of picloram pellet and liquid formulations				
Picloram, 5% pellets	1	20 lb/A	85	75
Picloram, 5% pellets	2	40 lb/A	98	93
Picloram, 5% pellets	4	80 lb/A	100	99
Picloram, liquid	1	0.5 gal/A	95	76
Picloram, liquid	2	1 gal/A	100	94
Picloram, liquid	4	2 gal/A	100	100
Control	-	--	0	0
LSD (.05)			8	9

SEEDSTOCKS PROJECT

David C. Ebeltoft
Agronomy Department

Hard Red Spring & Durum Wheat

Pre-release increases of D6674 (Ward) Durum and ND497 (Olaf) Hard Red Spring Wheat during the winter of 1971-72 resulted in the seeding of an estimated 407,000 acres of Ward and 300,000 acres of Olaf in 1974. Had there been no initial southern increase of these two varieties, it would have been 1975 before the foregoing plantings would have been possible.

In December of 1973, the North Dakota Agricultural Experiment Station released the three Durum varieties Crosby, Botno and Rugby. All three were increased in Arizona in 1973-74, thus, enabling North Dakota farmers to have substantially more acres on increase during the 1974 season.

In January 1974 two Hard Red Spring Wheat varieties were released by the North Dakota Agricultural Experiment Station. Seed of Ellar (pronounced L-R) was made available to every county. Tioga, a sawfly resistant variety, was allocated to 21 counties where sawfly problems exist or have been known to exist.

Sunflowers

The Agricultural Research Service, United States Department of Agriculture in cooperation with the North Dakota and Texas Agricultural Experiment Stations developed and released in March 1974 four cytoplasmic male-sterile and two fertility restorer sunflower lines suitable for production of large-seeded confectionery Sunflower hybrids. The Seedstocks Project made winter increases of these lines and made the germplasm available to sunflower breeders and hybrid sunflower seed producers.

The cytoplasmic male-sterile lines have been designated HA 285, HA 286, HA 287 and HA 288. The fertility restorer lines have been designated RHA 280 and RHA 282. Hybrids involving these lines have been designated numbers derived from the last two and last digits of female and male parents, respectively; e.g., cms HA 285 x RHA 280 is designated Hybrid 850. In the case of a three-way hybrid, the last digit of the second female is added; e.g., (cms HA 285 x HA 286) x RHA 280 is designated Hybrid 8560.

Flax

Only 3 varieties of Flax, Linott, Foster and Raja, were increased this year. These were increased because of their resistance to the new flax rust races 370, 371 and 372. The supplies of Foster and Raja are limited. The Linott will not be of the Foundation class.

FOUNDATION SEEDSTOCKS

Until December 15th of each year, Foundation Seedstocks are available only to recognized producers of Registered or Certified seeds. Those growers wishing to produce Registered seed must secure Foundation seed for planting and Certified seed producers must secure at least Registered seed for seeding. The Registered grade is omitted in some crops with generations going from Foundation to Certified. Following is a list of seeds that the Seedstocks Project will have available.

Crop	Variety	Location
Wheat	Olaf	AgSeFa*, Carrington, Williston, Minot
	Ellar	AgSeFa, Carrington, Williston, Minot
	Tioga	Minot, Williston
	Waldron	AgSeFa
	Justin	Williston
Durum	Crosby	Carrington, Williston, Langdon, AgSeFa
	Botno	Carrington, Minot, AgSeFa, Williston
	Rugby	Minot, Langdon
	Ward	Minot, Williston, Langdon
	Rolette	Langdon, Williston
	Wells	Minot
	Leeds	AgSeFa
Barley	Beacon	AgSeFa, Langdon
	Nordic	AgSeFa, Minot
	Dickson	AgSeFa
	Larker	AgSeFa, Minot
	Bonanza	AgSeFa
	Conquest	AgSeFa
Flax	Linott	Minot
	Foster	Langdon
	Raja	Langdon
Sunflowers	Sundak	AgSeFa
	Sputnik	AgSeFa
	Peredovik	Minot
Soybeans	Evans	AgSeFa
	Hodgson	AgSeFa
	Ada	AgSeFa
	Swift	AgSeFa
Grasses	Nordan	AgSeFa
	Vinall	AgSeFa
	Lodorm	AgSeFa

* Agronomy Seed Farm

Location	Station	Superintendent	Phone**
Casselton	Agronomy Seed Farm	LeRoy Spilde	347-4743
Carrington	Carrington Irrigation Station	Howard Olson	652-2731
Langdon	Langdon Branch Station	Robert Nowatzki	256-2582
Minot	North Central Ag. Exp. Station	Ben Hoag	838-1434
Williston	Williston Branch Station	E. W. French	572-2747

** Telephone to reserve or inquire about seed purchase or reservations, or write or visit the location. Seed prices and delivery information available at location.

HYBRID CORN PERFORMANCE TRIALS

H. Z. Cross
Agronomy Department

The North Dakota hybrid corn performance testing program is an on-going project designed to provide corn growers and the corn seed industry with information regarding hybrid adaptation to the various corn production areas of North Dakota. Data is obtained and published regarding yield and other important characteristics such as maturity, lodging resistance, plant and ear height, and test weight. The trials contain both irrigated and dry land sites. Oakes and Sheldon are the two irrigated sites, while Mooreton, Fargo and Larimore are the dryland sites reported herein.

Performance of a hybrid over a period of years gives a much better estimate of adaptation than single year data. The extreme differences in yield or moisture content at harvest which may be induced by individual seasons are leveled off in the several year averages presented in Tables 1 through 7. Grain trial averages are presented in the first four tables, while silage yields are covered in the last three tables.

The 1974 yield results were not available at the time of writing so are not included in the averages. These data will be available in the near future in the 1974 North Dakota Hybrid Corn Performance Testing Circular.

Table 1. East Central Area Grain Trial Average. Ear Moisture Percentage at Harvest and Yield Performance.

			EAR MOISTURE PERCENTAGE				BUSHELS PER ACRE			
			1972-73	71-73	70-73	69-73	1972-73	71-73	70-73	69-73
Brand	Hybrid		2 yrs	3 yrs	4 yrs	5 yrs	2 yrs	3 yrs	4 yrs	5 yrs
Pioneer	3990	SX	19.6				112.9			
Funks	G-4082	3X	22.3	20.8	18.5		116.9	102.4	95.6	
ND Exp	B564	SX	23.4	21.5	19.1	22.2	112.7	106.3	100.1	97.3
Funks	G-5150	DX	24.1	23.2			117.7	110.2		
Sokota	SK27	3X	24.3				115.9			
ND Exp	B676	2X	25.2				121.7			
Sokota	TS24	SX	25.3				110.9			
NDHybrid	502	DX	25.3	23.9	21.6	24.1	109.3	100.1	92.9	91.9
ND Exp	B569	SX	25.5	22.6	20.3		115.8	104.6	96.7	
ND Exp	N120	DX	25.6	23.9	21.5	23.7	116.0	104.3	94.6	93.7
ND Exp	B186	2X	25.6				127.2			
WMaster	EP15	3X	26.0				114.4			
Sokota	MS31	MS	26.3				123.1			
Pioneer	3959	3X	27.6	25.9	23.0	25.4	114.6	101.5	93.7	92.6
Sokota	MS-24	3X	27.6	24.7	22.4		119.4	109.0	99.9	
Acco	U-313	3X	27.9	25.1	22.6		121.5	105.3	95.4	
Acco	U-323	3X	27.9	26.1	23.8		126.7	111.0	99.0	
Renk	RK2	SX	28.2	25.8			127.1	118.6		
Funks	G-4180	3X	29.4	27.9			121.8	110.4		
Renk	RK6	SX	29.6				122.8			
Pioneer	3816	4X	30.8				118.2			
WMaster	EPX-2A	SX	31.5	27.6	23.7		118.8	108.3	99.9	
Acco	U326	3X	32.0				118.8			
Acco	UC1900	SX	32.0	30.3	27.2	29.8	118.0	107.2	97.2	94.1
Pioneer	3932A	SX	32.2				125.3			

(Continued on next page)

Table 1. (Continued)

Brand	Hybrid		EAR MOISTURE PERCENTAGE 1972-73 2 yrs	71-73 3 yrs	70-73 4 yrs	69-73 5 yrs	BUSHELS PER ACRE 1972-73 2 yrs	71-73 3 yrs	70-73 4 yrs	69-73 5 yrs
WMaster	7180	SX	32.4				121.4			
Renk	R95	3X	32.5	31.2			126.5	101.4		
Acco	UC1301	SX	33.2				125.5			
LSD .05			4.2	3.3	2.8	1.9	8.7	14.1	8.5	7.3

Table 2. Southeastern Area Grain Trial Averages. Ear Moisture Percentage at Harvest and Yield Performance.

Brand	Hybrid		EAR MOISTURE PERCENTAGE 1972-73 2 yrs	71-73 3 yrs	70-73 4 yrs	69-73 5 yrs	BUSHELS PER ACRE 1972-73 2 yrs	71-73 3 yrs	70-73 4 yrs	69-73 5 yrs
ND Exp	B676	2X	24.4				108.9			
WMaster	EP15	3X	24.9				96.3			
Trojan	TXS85	2X	26.0	25.2	24.4	23.0	106.4	108.2	109.4	102.4
Acco	U-313	3X	26.8				96.1			
Sokota	MS31	MS	27.6				113.6			
Renk	R95	3X	28.1				117.3			
Sokota	MS-35	3X	28.5	28.3	27.2	26.3	117.9	116.6	119.0	109.6
Sokota	TS-49	SX	29.4	30.4	30.1	36.7	120.6	120.6	120.9	109.6
Pioneer	3816	4X	30.7				99.3			
Acco	UC1900	SX	30.9	30.8	30.3	29.2	118.6	117.1	119.3	107.8
Renk	RK6	SX	31.1				101.3			
WMaster	EPX-2A	SX	31.9	30.4			100.2	97.2		
Pioneer	3932A	SX	33.0				105.7			
LSD .05			2.1	3.2	2.1	12.0	22.0	8.1	6.4	8.1

Table 3. Irrigated Oakes Area Grain Trial Averages. Ear Moisture Percentage at Harvest and Yield Performance.

Brand	Hybrid		EAR MOISTURE PERCENTAGE 1972-73 2 yrs	71-73 3 yrs	70-73 4 yrs	69-73 5 yrs	BUSHELS PER ACRE 1972-73 2 yrs	71-73 3 yrs	70-73 4 yrs	69-73 5 yrs
Pioneer	3990	SX	13.0				139.9			
Kingscrost	PX20	SX	18.4				155.5			
ND Exp	N120	DX	19.5	23.0	21.2		138.2	141.1	139.5	
Sokota	MS31	MS	19.5				153.4			
Pioneer	3959	3X	19.7	23.0	21.2		141.3	145.9	146.3	
Acco	U-323	3X	22.2	25.4			155.6	159.1		
Funks	G-4180	3X	23.0	26.4			163.2	162.7		
Agsco	2XB	SX	23.8	26.8	25.2		144.6	146.9	142.8	
Pioneer	3932A	SX	24.2				152.1			
Renk	R95	3X	25.5	28.7			162.4	163.9		
Renk	RK6	SX	25.6				148.6			
Acco	UC1301	SX	26.1				168.5			
Acco	U326	3X	26.4				169.7			

(Continued on next page)

Table 3. (Continued)

Brand	Hybrid		EAR MOISTURE PERCENTAGE 1972-73 2 yrs	71-73 3 yrs	70-73 4 yrs	69-73 5 yrs	BUSHELS PER ACRE 1972-73 2 yrs	71-73 3 yrs	70-73 4 yrs	69-73 5 yrs
Sokota	TS-49	SX	26.7	29.4	27.4		171.1	172.0	173.1	
Acco	UC1900	SX	28.2	31.0	27.6		161.6	163.4	159.5	
LSD .05			2.8	1.3	2.4	0.0	15.9	11.9	10.2	0.0

Table 4. Northeastern Area Grain Trial Averages. Ear Moisture Percentage at Harvest and Yield Performance.

Brand	Hybrid		EAR MOISTURE PERCENTAGE 1972-73 2 yrs	71-73 3 yrs	70-73 4 yrs	69-73 5 yrs	BUSHELS PER ACRE 1972-73 2 yrs	71-73 3 yrs	70-73 4 yrs	69-73 5 yrs
Pioneer	3990	SX	32.3				85.7			
ND Exp	B569	SX	38.4				92.6			
ND Exp	N122	DX	38.4	36.0	31.2	32.7	87.7	89.3	88.4	90.0
Funks	G-4082	3X	38.5	35.3	30.0		84.3	85.4	85.0	
Agsco	2XAA	SX	39.9				88.7			
Renk	RK2	SX	41.3	38.7			92.6	99.3		
ND Exp	B564	SX	41.8	39.0	33.7	34.9	71.5	77.7	78.0	80.8
Pioneer	3959	3X	44.8	40.6	34.9	36.5	84.0	87.0	85.2	84.4
LSD .05			6.8	4.4	3.6	2.6	10.1	9.0	6.4	7.9

Table 5. Irrigated Oakes Area Silage Trial Averages. Dry Matter Percentage at Harvest and Yield Performance.

Brand	Hybrid		DRY MATTER PERCENTAGE 1972-73 2 yrs	71-73 3 yrs	70-73 4 yrs	69-73 5 yrs	TONS PER ACRE 1972-73 2 yrs	71-73 3 yrs	70-73 4 yrs	69-73 5 yr
Acco	PRP105	DX	34.5				32.6			
Acco	PRP100	DX	38.8	36.7			29.2	30.5		
ND Exp	402	DX	40.4				27.2			
Pioneer	3959	3X	43.3	41.0			26.2	27.0		
LSD .05			2.2	3.1	0.0	0.0	6.7	8.5	0.0	0.0

Table 6. Northeastern Area Silage Trial Averages. Dry Matter Percentage at Harvest and Yield Performance.

Brand	Hybrid		DRY MATTER PERCENTAGE 1972-73 2 yrs	71-73 3 yrs	70-73 4 yrs	69-73 5 yrs	TONS PER ACRE 1972-73 2 yrs	71-73 3 yrs	70-73 4 yrs	69-73 5 yrs
Acco	PRP95	DX	35.3	33.6	33.7	33.0	15.3	17.3	16.5	17.4
Pioneer	3959	3X	36.4	34.9	36.4		15.4	16.8	16.1	
ND Exp	ND121	DX	37.4				15.5			
Pioneer	3872	DX	37.8	36.7	38.8	38.3	15.5	17.0	16.0	16.6

(Continued on next page)

Table 6. (Continued)

			DRY MATTER PERCENTAGE				TONS PER ACRE			
			1972-73	71-73	70-73	69-73	1972-73	71-73	70-73	69-73
Brand	Hybrid		2 yrs	3 yrs	4 yrs	5 yrs	2 yrs	3 yrs	4 yrs	5 yrs
ND Exp	N122	DX	39.9				15.8			
LSD .05			2.5	1.6	3.9	4.6	2.9	2.5	1.7	1.8

Table 7. Irrigated Southeastern Area Silage Trial Averages. Dry Matter Percentage at Harvest and Yield Performance.

			DRY MATTER PERCENTAGE				TONS PER ACRE			
			1972-73	71-73	70-73	69-73	1972-73	71-73	70-73	69-73
Brand	Hybrid		2 yrs	3 yrs	4 yrs	5 yrs	2 yrs	3 yrs	4 yrs	5 yrs
Acco	PRP110	DX	37.0	34.6	35.5		20.9	20.3	20.4	
Pioneer	3778	3X	38.8				19.5			
Acco	PRP105	DX	39.2	36.2	37.1	37.7	18.9	18.3	16.5	20.1
Pioneer	3662	DX	39.4				17.8			
ND Exp	B454	SX	49.8				17.6			
LSD .05			3.1	4.4	2.3		3.8	2.6	1.4	

OAT IMPROVEMENT

G. S. Smith
Agronomy Department

Along with Minnesota and South Dakota, North Dakota in recent years has been among the top three oat producing states. Primarily, oats are grown for livestock feed, but increasingly the oat food processors are looking to this region, as oats becomes relatively less profitable to grow father east.

Whether for feed or food, the high protein potential of oats is important. This rising interest in protein content and quality in oats affords a major breeding objective to be combined with increasing yield potential in new varieties. At present leading oat varieties are inclined to be high in yield but low in protein (Cayuse, Kelsey, Random). Among the adapted varieties inherently high in protein, (Dal, Spear, Goodland), only Dal has given acceptable yields, and then only in eastern North Dakota.

The oat breeding program is directed toward combining higher protein with high yielding potential, both characters which are complex in their inheritance. Accomplishment of this goal would improve the competitive position of oats as a "cash crop".

Along with yield and protein, the oat breeder is also giving major attention to resistance to both stem rust and crown rust, two diseases which take a heavy toll in eastern North Dakota. Stronger straw also is required for growing under the improved cultural conditions which will be required for profitable oat culture. Good test weight and high groat percentage are two other characters which must be improved in the oat of the future.

An expanded oat breeding program is underway at NDSU designed to accomplish the above goals. No new North Dakota lines are yet available.

A cultural study of the effects of six nitrogen fertilizer treatments upon six standard oat varieties grown on "old land", indicates that protein content and yield both can be increased with appropriate fertilizer applications. The study has not yet been completed.

WINTER WHEAT PRODUCTION

John R. Erickson
Agronomy Department

Successful production of winter wheat in North Dakota requires the use of winter-hardy varieties and proper cultural practices. A substantially larger acreage of winter wheat could be grown in the southern half of the state if proper management practices are followed. Higher yields and better labor distribution are the main advantages of growing winter wheat. The winter wheat acreage replaces a portion of the spring seeded acreage and allows spring seeding to be completed earlier. Winter wheat harvest is a week or more earlier than spring wheat and permits more efficient use of harvest equipment. Winter wheat is seeded in early to mid-September when the weather is usually favorable.

The hazard of winterkill is the major disadvantage of growing winter wheat, although good management will reduce this risk. If survival is poor, the field may be over-seeded with spring wheat or tilled and reseeded. Usually a uniform 50-60% stand of winter wheat will tiller enough to give a normal yield if weeds are controlled.

Some of the management practices that are helpful in producing winter wheat are as follows. Choosing a variety with good winterhardiness is very important. Table 1 is a listing of survival data for some varieties at several locations this past year. Froid is the most winterhardy variety currently available.

Seedbed preparation is vital also in producing winter wheat. Table 1 contains data comparing seeding on soybean stubble vs. fallow. Survival was better on stubble for all varieties. Preparing a very firm seedbed aids survival by reducing soil heaving during the winter from frost action and also provides more favorable moisture conditions for fall stand establishment. Shallow tillage, not more than 3-4 inches deep, will result in a firm seedbed. Seeding should not be done on fall plowing.

Seeding at the proper time and rate are important in producing winter wheat. The first half of September is optimum, although seeding slightly later in southern areas is possible. Seeding too early may result in losses from root rot and wheat streak mosaic. Plants that grow too big in the fall are more susceptible to winter-killing as well as wasting water and fertilizer. A seeding rate of 45-60 lbs/acre is optimum. Higher rates are not helpful and lower rates may reduce yields. A hoe drill is preferred for seeding on fallow. At least 4-inch wide shovels should be used to form adequate ridges between furrows. A press drill may be used, particularly when seeding into stubble where more protection is provided.

Other production practices, such as weed control, are very similar to those for spring seeded grains. If soil tests indicate a nitrogen deficiency, most of this should be applied in the spring to avoid excessive fall growth. Adequate phosphate fertilization at seeding is beneficial for winter survival.

Table 1. Hard Red Winter Wheat Percent Survival

Variety	Williston	Minot	Fargo Soybean	Fargo Fallow	Mean
Froid	90	53	85	70	75
Winoka	87	20	78	50	59
Bronze	60	34	45	35	44
Centurk	80	28	13	7	32
Sundance	83	33	65	59	60

SUNFLOWER HYBRIDS A PROGRESS REPORT

G. N. FICK, (USDA)

Efficient production of hybrid sunflower seed was made possible with the discoveries of cytoplasmic male-sterility in France in 1968 and of fertility restoration in the United States in 1970. Cytoplasmic male-sterile lines and fertility restorer lines suitable for the commercial production of hybrids were subsequently developed and released by the ARS, USDA, sunflower programs at Fargo, North Dakota, and College Station, Texas. Sunflower hybrids produced by this method have been tested extensively in North Dakota and Minnesota since 1972.

Yield data on four oilseed hybrids, which should be available for commercial production in 1975, are shown in Table 1. In the tests at Fargo and Casselton, the average yield of the four hybrids was 15 percent greater than that of the open-pollinated variety Peredovik. At Grand Forks and Carrington, however, the hybrids failed to show a yield advantage over Peredovik. These data suggest that the hybrids may not be as stable as the open-pollinated varieties in their performance over a range of different environmental conditions. More widely adapted hybrids are expected to become available as additional research and testing of new hybrids is conducted. Preliminary yield data from 1974 tests indicate that several hybrids do in fact show improved stability over environments.

One of the major advantages of the oilseed hybrids available for commercial production in 1975 appears to be the improved disease resistance (Table 2). All hybrids produced using the USDA restorer lines RHA 271 and RHA 274 are resistant to downy mildew. Most of the hybrids for 1975 are also resistant to rust and Verticillium wilt. Another advantage appears to be the greater degree of self-compatibility of the hybrids over the open-pollinated varieties. This trait is is expected to alleviate the requirement for high insect pollinator populations. Greater uniformity for height and maturity are other pluses for the hybrid varieties.

Parental lines suitable for the production of confectionery hybrids were developed and jointly released March 1, 1974, by the Agricultural Research Service, USDA, and the North Dakota Agricultural Experiment Station, NDSU. Performance data on five confectionery hybrids that can be produced from these lines are shown in Table 3. The average yield of the five hybrids was 7 percent more than that of the open-pollinated variety Sundak, and 58 percent, 77 percent, and 87 percent more than the yields of Dahlgren 694, Commander and Mingren, respectively. Light to moderate rust was present in the three tests and probably contributed to the superior yeilds and test weights of the resistant hybrids over those of the rust susceptible varieties. Seed increase of the parental lines and very limited hybrid seed production were conducted in North Dakota and Minnesota in 1974. Large scale hybrid seed production is expected in 1975 with considerable hybrid seed to be available for commercial production in 1976.

Additional performance data on both oilseed and confectionery hybrid varieties from tests conducted in North Dakota in 1974 will be available in the near future in the 1974 North Dakota Experiment Station Variety Tests on Oilseed Crops circular. Descriptive information and comparative yield data from Minnesota sunflower variety trials are published annually in University of Minnesota Agricultural Experiment Station Miscellaneous Report 24. The results from these tests should be useful to growers in selection of sunflower hybrids and/or open-pollinated varieties in 1975 and future years.

Although considerable progress in the development of sunflower hybrids has been made, several problems remain to be solved. Oilseed hybrids resistant to the three major sunflower diseases can be produced, but additional testing is still required to determine the highest yielding and most widely adapted hybrid combinations. Susceptibility of the confectionery sunflowers to downy mildew, including the hybrids, is a problem. Additional research is required on Sclerotina and phoma disease resistance. The possibilities of developing parental lines resistant to insects, such as the midge, must be explored. Research on these and other problems which threaten sunflower production in this area have been initiated and will be continued. As improved hybrids become available, the acreage devoted to the hybrid varieties is expected to rapidly increase.

Table 1. Yields (lb/A) of Peredovik and four oilseed sunflower hybrids grown at four locations in North Dakota, 1972-73.

	Location			
Variety	Fargo	Casselton	Grand Forks	Carrington
Peredovik	1704	1756	1494	1213
Hybrid 896	2117	2134	1509	780
Hybrid 8941[1]	1853	2147	--	1120
Hybrid 891[1]	2183	1632	--	--
Hybrid 894[1]	2067	1809	--	--

[1] Not tested in 1972

Table 2. Agronomic, oil, and disease characteristics of Peredovik and four oilseed sunflower hybrids grown at Fargo, 1973.

					Disease Resistance[1]		
Variety	Days to 50% flowering	Height, inches	Test Weight, lb/bu	% Oil	Rust	Downy Mildew	Verticillium Wilt
Peredovik	71	60	26.1	41.2	MS	S	MS
Hybrid 896	72	63	28.9	45.8	R	S	R
Hybrid 8941	71	63	30.6	45.4	R	R	MR
Hybrid 891	74	57	30.1	45.0	R	R	R
Hybrid 894	72	60	28.0	40.9	MR	R	R

[1] R = resistant, MR = moderately resistant, MS = moderately susceptible, S = susceptible.

Table 3. Performance of five confectionery hybrids compared with Sundak, Dahlgren 694, Mingren and Commander grown at Fargo and Casselton, North Dakota, and Crookston, Minnesota, in 1973.

Variety	Days to 50% flowering	Height, inches	Rust	Test Weight, lb/bu	Yield lb/A	% Over 20/64	Nutmeat %
Hybrid 860	67	65	R	22.6	2,228	85.5	52.9
Hybrid 850	68	71	R	23.8	2,086	54.8	57.1
Hybrid 872	67	61	R	24.0	1,865	36.1	57.9
Hybrid 852	66	66	R	25.1	1,812	16.2	61.6
Hybrid 862	68	61	R	23.0	1,581	24.6	61.1
Sundak	68	67	R	24.1	1,784	44.8	57.5
Dahlgren 694	66	63	S	21.0	1,213	43.5	53.5
Commander	66	63	S	21.5	1,079	45.7	54.5
Mingren	66	63	S	20.8	1,025	43.0	53.8

FLAX RUST IN 1974

D. E. Zimmer, G. Statler, and G. Wehtje

New and potentially dangerous races of flax rust were discovered in the flax growing region in 1973. These races, unlike all previous North American races, attacked varieties with the N^1P genes for resistance, leaving only Linott, Foster and the little known Canadian variety Raja resistant. Since there was insufficient planting seed of resistant varieties to seed the flax acreage in 1974, several growers had to plant susceptible varieties and run the risk of yield reduction from rust. Flax researchers throughout the area were concerned and carefully monitored the rust situation throughout the season.

Flax rust surveys conducted during the growing season of 1974 established that a light infestation late in the season occurred generally throughout the flax producing area, the only exception being the droughty area in south central North Dakota and adjacent areas in South Dakota, where no rust was found. Rust was first reported in early July on volunteer flax in Manitoba and on early seeded flax in eastern South Dakota and north central North Dakota. Weather conditions were not particularly favorable throughout the region for rust development, consequently the only large area where moderate rust developed was in isolated fields of susceptible varieties in north central North Dakota and adjacent areas of Manitoba and Saskatchewan (Figure 1).

Twenty-five field collections of rust were made from the flax producing area of the U.S. Pathogenicity tests on sets of differential varieties demonstrated that all collections belonged to race group 370 in that they were capable of attacking all varieties containing the N^1P genes for resistance. This was anticipated since most of the collections were made from fields of either Nored, Summit, Windom and B5128 or other varieties known to contain the N^1P genes.

As evidenced from the data in Table 1, no potentially destructive new races were identified within the collections. Nevertheless, several previously unknown races were detected attacking a number of single-gene lines in addition to the N^1P gene lines. The L^6 gene which conditions resistance in the variety Linott remains effective, thus Linott can be grown in 1975 without fear of any loss from rust. Of concern was the discovery, however, of some rust susceptible plants in the variety Linott. The rust collected on these plants was also identified as belonging to race group 370, thus such plants in Linott were probably a result of admixture. This low frequency of occurrence will not contribute significantly to a rust build-up.

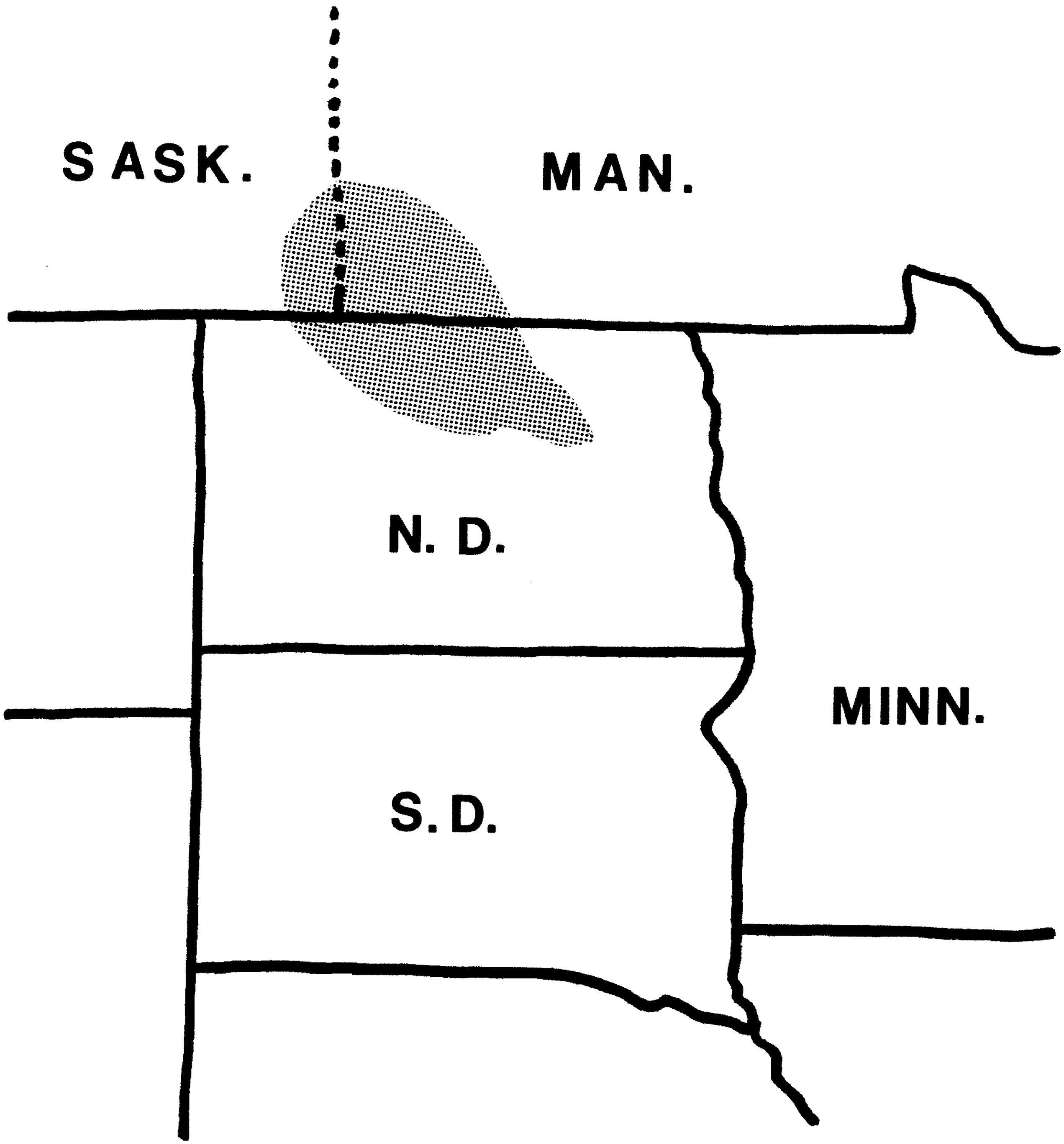

Figure 1. Shaded area corresponds to the area where flax rust was moderate to heavy in isolated fields of susceptible varieties in 1974.

Table 1. Distribution of virulence and avirulence among 25 field collections of flax rust on flax varieties possessing single genes for resistance.

Variety	Gene	Number of Collections	
		Virulent	Avirulent
Ottawa 770B	L	0	25
Dakota	M	25	0
Bombay	N	0	25
Stewart	L^2	0	25
Cass	M^3*	0	25
Koto	P	25	0
Clay	K	5	20
Polk	N^1	25	0
Birio	L^6*	0	25
Kenya	L^4	6	19
Akmolinsk	P1	0	25
Abyssinian	P2	0	25
Leona	P3*	0	25
Wilden	L^5	4	21
Williston Brown	M^1	24	1
Victory A	M^4	11	14
Bison	L^9	25	0
Bolley Golden	L^{10}	0	25
Linore	L^{11}*	0	25
CI 1888-8	P^4*	0	25
CI 2008-4	M^6*	0	25

* Conditions resistance to all North American races.

DOWNY MILDEW OF SUNFLOWERS

D. E. Zimmer
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SITUATION AND ACTION -

The sporadic occurrence of downy mildew of sunflowers from field to field, from date of planting to date of planting, and from year to year, has caused great concern among farmers and has caused some to abandon growing sunflowers. Research was conducted to explain the sporadic occurrence of downy mildew and to propose management practices that growers can use to minimize the risk of losses from downy mildew.

RESEARCH FACTS -

Whether downy mildew occurs on any given field depends upon three conditions: (1) the presence of a susceptible variety in a state of proneness, (2) the presence of the causal fungus in an infectious condition, and (3) the presence of a disease-favorable environment. If all three conditions exist, a downy mildew outbreak is certain.

Sunflowers are susceptible to systemic infection for only a short interval of time, generally 2-15 days after seeding. If the seedlings are exposed to infection during this interval, then a high percentage of systemically infected plants are likely. If they are exposed to infection at a later date of development, systemic infection is unlikely but root infection and local foliar lesions, which have little influence on yield, may occur.

Seedlings grown under cool temperatures remain in the interval of susceptibility to systemic infection for a longer period than seedlings grown under higher temperatures.

Systemic infection does not result from seed-borne inoculum, but rather from soil-borne inoculum existing in the field before planting or from wind-borne inoculum blown into the field from volunteer plants in neighboring fields. All fields planted to sunflower since 1970 harbor some residual downy mildew inoculum, and whether downy mildew occurs to a lesser or greater degree depends upon favorable climatological and biological factors.

The influence of date of planting and precipitation on the occurrence of downy mildew in a field known to be heavily infested with mildew established a close association between the amount of precipitation 3-14 days following seeding and incidence of downy mildew (Figure 1). If this period was relatively free of rain, little or no systemic symptoms developed. However, if this period was permeated by periods of enough rain to establish free soil moisture for only 4 hours, systemic infection was likely. In general, the heavier the rainfall the greater the incidence of systemic infection. This generality may be modified when the precipitation occurs on the fringes of the interval of seedling susceptibility (June 15 planting date in 1973). If heavy rainfall occurs within 3-5 days after seeding, poor stands frequently result in sunflowers planted on heavily mildew infested soil. Although many of the surviving plants show systemic symptoms, the importance of downy mildew is most probably underestimated when losses are based only upon counts of systemically infected seedlings.

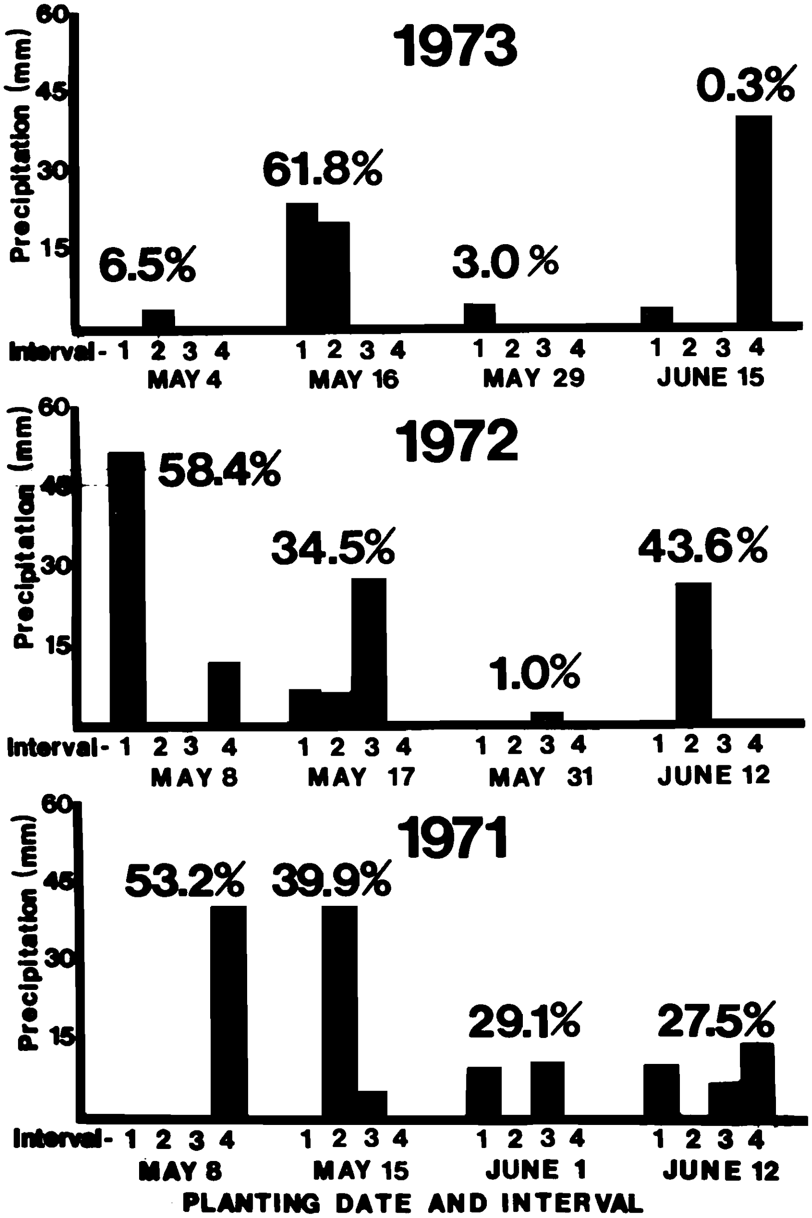

Figure 1. The percentage of systemically downy-mildew-infected plants that resulted from planting on heavily mildew-infested land at four dates during each of 3 years, and its relationship to the amount of precipitation at four 3-day intervals after planting.

Interval 1 = 3rd to 5th day after planting.
Interval 2 = 6th to 8th day after planting.
Interval 3 = 9th to 11th day after planting.
Interval 4 = 12th to 14th day after planting.

CONTROL MEASURES -

We do not have at our disposal means to control the occurrence of rainfall after seeding, thus other means to minimize losses must be employed. The following are guidelines to avoid large-scale losses from downy mildew.

1. Grow downy mildew resistant varieties, if available.

2. Follow a 4-year rotation.

3. Avoid planting sunflower until the soil temperature will support rapid germination, thus minimizing the duration of seedling susceptibility.

4. Plant sunflowers on a well prepared seedbed. A firm seedbed promotes puddling of water during light rain showers.

5. Control volunteer sunflowers as early as feasible in the spring to eliminate wind-borne inoculum.

6. Avoid planting susceptible varieties adjacent to a field that was heavily infested with mildew the previous year.

7. Do not plant susceptible varieties of sunflower on land known to have a history of downy mildew.

Sunflower Research Highlights - 1974

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Department of Entomology

The growing season, 1974 can be characterized entomologically as a season in which no crop, major or minor, escaped infestation by noxious insect species. Sunflower was no exception. In fact, outbreaks of three species resulted in economic losses to this crop and aggravated an already serious problem caused by late planting due to excessive moisture followed by drought conditions in the mid and late season.

A multifaceted research program continues to be directed to the major economic species of the sunflower pest complex. This program includes the following:

A. Sunflower beetle (*Zygogramma exclamationis*):

Major infestations of this species were again experienced in 1974. Outbreaks were more widespread than noted in 1973. An emergency request for use of toxaphene for control of this species was again granted by the EPA. High temperatures and drought conditions which prevailed during this period caused a much reduced residual longevity of toxaphene. Failure to control this insect was noted from many areas of the region. Where growers utilized the maximum rate, 2 pounds actual, with aerial applications of 5 gallons of water or ground applications of 15-20 gallons, control failures were markedly reduced. It is hoped that a clearance for use of toxaphene on sunflower will be obtained prior to the 1975 growing season. The NDSU Pesticide Laboratory, Dr. Douglas Bristol, Director, will be conducting residue analyses on sunflower seed collected from test plots in North Dakota, South Dakota and Minnesota pursuant to the filing of a formal request for clearance.

A petition for clearance of the organophosphate, "Supracide" for use on sunflower was filed with EPA on July 19 by CIBA-Geigy. If cleared for use in 1975, "Supracide" will be recommended for control of the sunflower insect complex (including the sunflower beetle) at the rate of 1# actual per acre. In tests with this compound during 1973 and 1974, a single application provided nearly 100% control of the sunflower beetle.

B. Sunflower midge (*Contarinia schulzi*):

The severest infestations since 1971 were experienced this year. Initial emergence occurred at about the same period as noted in previous years, the second week of July.

A major emergence of adults occurred during the period immediately following the rains of July 19-20. Sunflowers in which bud development was in the 2-3" diameter range were most severely infested. Had applications of endosulfan (Thiodan), toxaphene or methyl parathion been applied during the 2-4 days following the rains, midge damage would have been significantly reduced. In test plot studies, Supracide at both 1/2 and 1 pound actual, has been outstanding in control of the midge when applications were properly timed.

At least three of the major breeding lines currently under study appear promising in providing increased tolerance to this insect. These include parental lines HA89, HA99 and HA273 and some hybrids utilizing these lines.

C. Stalk and Head Moth (Suleima helianthana):

Major infestations of this species were again noted in 1974. Of the presently planted commercial varieties, HS52 is the most tolerant. Light damage to this cultivar has been recorded. Because the egg-laying period and subsequent larval emergence extends over a several week period in June, chemical control of this insect does not appear feasible. Plant resistance to this insect appears promising. There are several parental and hybrid lines that do not support high infestations; in others larval feeding is negligible.

D. Cutworms:

Despite favorable climatic conditions, cutworm infestations were nearly non-existent in sunflowers in 1974. A petition for registration of carbaryl (Sevin) bait is pending. Cooperation of the IR-4 Committee at Rutgers University and the Union Carbide Corporation in obtaining this registration is acknowledged. It is hoped this registration will be completed prior to the 1975 season. To date none of the major parental lines or promising hybrids have any tolerance or resistance to the two major species of cutworms encountered in this region.

E. Weevil Complex:

1. Bionomics of a weevil complex found in sunflower fields in southwestern North Dakota in late 1973 has been defined. Larvae of this three species complex feed either in the roots or beneath the epidermis of stems just above the soil line. None of the commercial cultivars presently grown are resistant to feeding by this species. Greatest damage by this complex is found in areas with sandy or sandy-loam soils. All these species overwinter as fully-grown larvae and complete their development the following spring. Adult activity extends through much of June. Fall tillage studies are underway to determine the effects of this operation on overwintering larvae. Chemical control of adults appears at this time to be the only practical approach. Performance studies have not been conducted to date; they will be commenced in 1975.

2. A second weevil complex of three species was found to be feeding in developing sunflower heads in 1974. Feeding damage by adults was found to be negligible. However, larvae from one of these species infests sunflower seeds. Each larva apparently completes its development on a single seed. Infestations in fields in southeastern and south-central North Dakota to 50% have been recorded. Up to 80% of the seeds in a single head have had larval infestations. Mature larvae drop from the seeds into the soil to overwinter. Research has commenced to define the bionomics of these species and to evolve an appropriate means of control.

WIREWORM CONTROL TRIALS IN CORN - 1974

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Introduction: Investigations of certain granular insecticides for the control of wireworms in corn was continued in 1974. The location of the 1974 wireworm control trial was on the Harry Hakanson farm one mile north of McLeod, North Dakota. Pretreatment wireworm counts were determined by examining square foot soil samples to a depth of 10-11 inches. Ten such samples were taken at ten pace intervals in the area of the corn field where wireworm damage was most severe the previous year and where later in the trial, corn stand counts were taken.

The first soil sample contained eleven wireworms and the remaining nine averaged 2-4 wireworms per sample. This is an extremely high infestation since one wireworm per two soil samples is considered to be a serious enough infestation to warrant control measures in corn.

Materials and Methods: Eight different granular insecticides and one seed treatment were included in the 1974 wireworm control trial. The insecticides and rates of application (actual toxicant per acre) are given in Table I.

The treatments were applied in a random block design (see field plot design). The treatments included both six inch band applications as well as certain insecticides applied in the furrow as noted in the field plot design. Gandy granular application equipment was used on a 4 row John Deere corn planter. The seeding rate was 20,500-21,000 kernels per acre and the variety of corn planted was Northrup King PX 420. Planting and treatment date was May 29, 1974.

Stand counts were taken on June 27 and July 8 in order to determine the efficacy of each of the test compounds in providing plant protection. The stand counts were made in 50 feet of row across all three replicates. Table II shows the final stand counts and statistical analysis of these counts.

Post-treatment wireworm mortality counts were taken on June 27. The counts were taken in the same manner as the pretreatment counts with each sample taken out of the center of treatment rows selected at random 10 pace intervals. The results of the post-treatment wireworm counts are presented in the summary and conclusions section of this report.

Table I. Insecticides and Rates of Application Used on the Harry Hakanson farm, McLeod, North Dakota.

Insecticides	Rates Per Acre
Bay 92114 10G	½ lb.
Bay 92114 10G	3/4 lb.
Bay 92114 10G	1 lb.
CGA 12223 15G	2 lbs.
Counter 15G	1 lb.
Counter 15G	2 lbs.
Counter 15G (F)	1 lb.
Counter 15G (F)	1½ lbs.
Counter 15G (F)	2 lbs.
Counter 15G (F)	4 lbs.
Dyfonate 10G	1 lb.
Dyfonate 10G	1½ lbs.
Dyfonate 15G	1 lb.
Dyfonate 15G	1½ lbs.
Dyfonate 20G	1 lb.
Dyfonate 20G	1½ lbs.
Furadan 10G (F)	1 lb.
Furadan 10G (F)	2 lbs.
Furadan (seed treatment)	4 ozs./bu.
Furadan (seed treatment)	8 ozs./bu.
Lorsban 10G	1 lb.
Lorsban 10G	1½ lbs.
Lorsban 15G	1½ lbs.
Mocap 10G	1 lb.
Thimet 15G	1 lb.

NOTE: (F) denotes in-furrow treatments; with the exception of Furadan 4 and 8 oz. seed treatments, the rest are band treatments.

Field Plot Design - Harry Hakanson Farm, McLeod, North Dakota.

Block I	Block II	Block III
Bay 1/2#	Dyfonate 10G-1 1/2#	Check - 1 row
Counter 1#	Lorsban 10G-1#	Counter 1#
Dyfonate 10G-1#	Dyfonate 20G-1 1/2#	Counter 2# (F)
Furadan 1# (F)	Check - 2 rows	Furadan 2# (F)
Lorsban 10G-1 1/2#	Counter 1# (F)	Bay 1#
Thimet 1#	Bay 3/4#	Dyfonate 20G-1 1/2#
Dyfonate 15G-1 1/2#	Check - 1 row	Mocap 1#
Check - 2 rows	Furadan 2#	Check - 2 rows
Counter 2# (F)	Counter 1#	Dyfonate 10G-1#
Lorsban 15G-1#	Dyfonate 15G-1#	Lorsban 10G-1#
Mocap 1#	Check - 2 rows	Counter 2#
Bay 1#	Bay 1/2#	Bay 1/2#
Counter 2#	Counter 4# (F)	Dyfonate 10G-1 1/2#
Dyfonate 20G-1 1/2#	Thimet 1#	Thimet 1#
Check - 2 rows	CGA-2#	Check - 2 rows
Furadan 2# (F)	Counter 2# (F)	Lorsban 15G-1 1/2#
Lorsban 10G-1#	Furadan 1# (F)	Counter 1 1/2# (F)
Dyfonate 10G-1 1/2#	Check - 2 rows	Bay 3/4#
Counter 1 1/2# (F)	Lorsban 15G-1 1/2#	Thimet 1#
Thimet 1#	Thimet 1#	Furadan 8 oz./bu.
Dyfonate 20G-1#	Bay 1#	Furadan 4 oz./bu.
Check - 2 rows	Counter 2#	Check - 2 rows
Furadan 4 oz./bu.	Dyfonate 10G-1#	Counter 1# (F)
Furadan 8 oz./bu.	Lorsban 10G-1 1/2#	Lorsban 15G-1#
Bay 3/4#	Check - 2 rows	CGA-2#
Lorsban 15G-1 1/2#	Dyfonate 15G-1 1/2#	Counter 4# (F)
Counter 4# (F)	Counter 1 1/2# (F)	Dyfonate 15G-1 1/2#
Dyfonate 15G-1#	Dyfonate 20G-1#	Lorsban 10G-1 1/2#
Check - 2 rows	Furadan 4 oz./bu.	Check - 2 rows
Counter 1# (F)	Furadan 8 oz./bu.	Dyfonate 20G-1#
CGA-2#	Mocap 1#	Furadan 1# (F)
Mocap 1#	Check - 1 row	Dyfonate 15G-1#

Table II. 1974 Wireworm Control Trials in Corn with Banded and In-Furrow Granular Insecticide Treatments on the Harry Hakanson Farm, McLeod, North Dakota.

Insecticides	Rate Per Acre	Plants Per 50 Feet of Row Block Numbers I	II	III	Total	Mean	Range Test*
Furadan	1# (F)	51	60	59	170	56.7	a
Counter	2# (F)	52	57	59	168	56.0	a b
Furadan	2# (F)	58	52	57	167	55.7	a b
Thimet	1#	47	51	53	164	54.3	a b
Counter	2#	57	50	52	159	53.0	a b c
Counter	4# (F)	50	60	47	157	52.3	a b c d
CGA 12223	2#	58	45	53	156	52.0	a b c d
Counter	1½# (F)	48	52	52	152	50.7	a b c d
Thimet	1#	47	51	53	151	50.7	a b c d
Counter	1#	45	54	49	148	49.3	a b c d e
Furadan	8 oz./bu.	50	50	43	143	47.7	a b c d e f
Counter	1# (F)	49	42	52	143	47.7	a b c d e f
Mocap	1#	48	44	44	136	45.3	a b c d e f
Dyfonate	15G 1½#	54	31	50	135	45.0	b c d e f
Dyfonate	10G 1½#	43	40	51	134	44.7	b c d e f g
Dyfonate	15G 1#	41	48	37	126	42.0	c d e f g h
Dyfonate	20G 1½#	39	37	47	123	41.0	d e f g h
Dyfonate	10G 1#	45	42	36	123	41.0	d e f g h
Bay 92114	½#	39	44	39	122	40.7	d e f g h
Dyfonate	20G 1#	38	38	41	117	39.0	e f g h i
Bay 92114	1#	43	37	36	116	38.7	e f g h i j
Bay 92114	3/4#	33	42	35	110	36.7	f g h i j
Furadan	4 oz./bu.	36	34	30	100	33.3	g h i j
Lorsban	10G 1#	26	37	37	100	33.3	g h i j
Lorsban	15G 1½#	35	28	29	92	30.7	g h i j
Check		38	22	29	89	29.7	h i j
Lorsban	10G 1½#	27	18	44	89	29.7	h i j
Check		22	41	22	85	28.3	i j
Check		29	32	23	84	28.0	i j
Check		25	28	20	73	24.3	i j

* Any two means with a common letter are not significantly different at the .05 level of significance as determined by Duncan's New Multiple Range Test.

Summary and Conclusions: Analysis of variance for comparison of differences among treatments yielded an "F" of 7.83. Testing of differences between individual treatments by Duncan's multiple range test gave the results shown in Table II. Rows treated with Furadan (1 and 2 lb. rates in furrow) and Counter (2 lbs. in furrow) showed the highest stand counts. Rows treated with Thimet (1 lb. banded), Counter (2 lbs. banded), Counter (4 lbs. in furrow) and CGA 12223 (2 lbs. banded) gave stand counts comparable to the preceding treatments. In general, all treatments above Dyfonate 15G (1 lb. rate) showed significant differences from all three of the checks (untreated) plot means. Dyfonate appears to be marginally effective at the higher rate (1½ lbs.) while Lorsban, Bay and Furadan seed treatment at low (4 oz./bu.) rates do not seem to be effective materials based on these stand count studies.

The post-treatment wireworm mortality counts for ten square foot soil samples were as follows:

Sample No.	No. Wireworms
1	0
2	1 alive - 2 dead
3	1 dead
4	0
5	1 alive - 2 dead
6	1 dead - 1 dead adult
7	3 dead - 1 moribund
8	1 moribund
9	1 dead - 1 moribund
10	1 dead - 1 alive

Acknowledgements: Appreciation is expressed to the following for cooperation and assistance during the work on the 1974 wireworm control trials:

Harry Hakanson - farmer, McLeod, North Dakota (land and equipment).

Howard Perkins - graduate research assistant, North Dakota State University, Fargo, North Dakota (field help).

Dr. Robert B. Carlson - Associate Entomologist, North Dakota State University, Fargo, North Dakota (statistical advice).

Chemical companies that provided insecticides used in the wireworm control trials:

American Cyanamid Company
Chemagro Chemical Company
CIBA - Geigy Chemical Company
Dow Chemical Company
Mobil Chemical Company
FMC Corporation
Stauffer Chemical Company

A special thanks goes to American Cyanamid, Chemagro, Dow, Mobil, FMC and Stauffer Chemical Companies for grants-in-aid.

Sunflower cultivars respond to nitrogen and plant population.
By Dr. J. C. Zubriski, Soils Dept., NDSU

Field trials have been conducted annually in southeastern North Dakota since 1971 to evaluate effects of nitrogen, phosphorus, and plant population on seed yields and on some quality factors of oil and confectionery sunflower cultivars. The total number of trials conducted was twelve: seven were with oil cultivars, and five were with confectionery cultivars.

Nitrogen fertilizer increased seed yields, oil yields by oil cultivars, and percentage of large seeds by confectionery cultivars. However, nitrogen fertilizer reduced oil concentration of oil seeds and percentage of medium seeds of confectionery cultivars. Yield response to nitrogen was obtained at all locations because soil tests at planting time for nitrate nitrogen to a depth of 2 feet were less than 55 lbs. N per acre.

Phosphorus fertilizer failed to increase yields in 10 of 12 trials. A response to phosphorus was not obtained at seven trials even though soil test levels for phosphorus were medium or at lower categories. Phosphorus fertilizer had little effect on oil concentration of oil seeds and on seed size of confectionery seeds. Lack of response to phosphorus cannot be explained by soil test data.

Increasing plant population increased seed yields, oil yields by oil cultivars, and percentage of medium seeds by confectionery cultivars. Increasing plant density of confectionery cultivars to 19,360 plants/acre reduced percentage of large seeds to levels approaching undesirable for large seeded cultivars.

Results of this research show that nitrogen fertilizer and plant population have relatively large effects on seed yields and smaller effects on oil concentration of oil seeds and seed size of confectionery seeds. Response to phosphorus fertilizer were small and poorly correlated with soil tests for phosphorus.

The average data for oil cultivars are presented in Table 1 and for confectionery cultivars in Table 2.

Table 1. Oil-type sunflower: influence of nitrogen, phosphorus, and plant population on average seed yield, head diameter, oil concentration, and oil yield (average of seven trials).

Treatment	Seed yield, lbs./A.	Head diameter, inches1/	Oil Conc., %	Oil yield, lbs./A.
Nitrogen, lbs N/A				
0	1958 c2/	5.4 c	48.1 a	941 b
50	2537 b	6.1 b	46.3 b	1179 a
100	2717 a	6.2 a	45.3 c	1233 a
Phosphorus, lbs P/A				
0	2360 a2/	5.9 a	46.6 a	1101 a
18	2448 a	5.9 a	46.6 a	1143 a
Plants per acre				
14,520	2016 c2/	6.4 a	46.2 a	934 c
19,360	2348 b	6.0 b	46.5 a	1095 b
29,040	2848 a	5.2 c	47.0 a	1339 a

1/ Measured on 5 trials only.
2/ Averages with columns for treatment followed by different letters are significantly different at 5% probability level.

Table 2. Confectionery sunflower: influence of nitrogen, phosphorus, and plant population on average seed yield, head diameter, and percentage of large and medium size seeds (average of five trials).

Treatment	Seed yield, lbs./acre	Head diameter, inches1/	Large seeds, %2/	Medium seeds, %3/
Nitrogen, lbs N/A				
0	2106 c4/	7.1 c	52.1 c	25.2 a
50	2504 b	7.4 b	59.5 b	21.0 b
100	2647 a	7.6 a	61.1 a	19.2 c
Phosphorus, lbs P/A				
0	2392 a4/	7.3 a	57.8 a	21.6 a
18	2446 a	7.4 a	57.3 a	22.0 a
Plants per acre				
11,616	2056 c4/	7.9 a	63.2 a	18.1 b
14,520	2344 b	7.4 b	58.6 a	21.4 b
19,360	2858 a	7.0 c	51.0 b	25.9 a

1/ Measured on three trials.
2/ Percent on 20/64 inch round hole screen.
3/ Percent on 18/64 inch round hole screen but passed through 20/64 inch round hole screen.
4/ Averages within columns for treatment levels followed by different letters are significantly different at 5% probability level.

NOTES

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Bowman

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Washburn

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Mandan

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Bulletin 472: The Major Soils of North Dakota
Bulletin 473: Soil Survey Report-County General Soils Maps-North Dakota
Extension Bulletin 2: Salt Affected Problem Soils in North Dakota
Extension Bulletin 5: Tillage for Profit in North Dakota
Extension Bulletin 9: How to Learn More About North Dakota's Major Natural Resource - Soil
Extension Bulletin 14: North Dakota Crop Rotations for Profit
Extension Bulletin 15 & 16: The Agro-Climatology of North Dakota.
Extension Bulletin 21: How Fertilizer Moves in Soil
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