A-602 Revised

Dry Bean Production HANDBOOK

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Dry edible beans (*Phaseolus vulgaris*) are a human food high in protein, phosphorus, iron, vitamin B_1, fiber, with no cholesterol. They are stored readily after harvest and can be easily transported. Dry beans are an imported staple in many areas of the world, especially Central and South America and Africa. Different cultures have developed a multitude of end products made with dry edible beans.

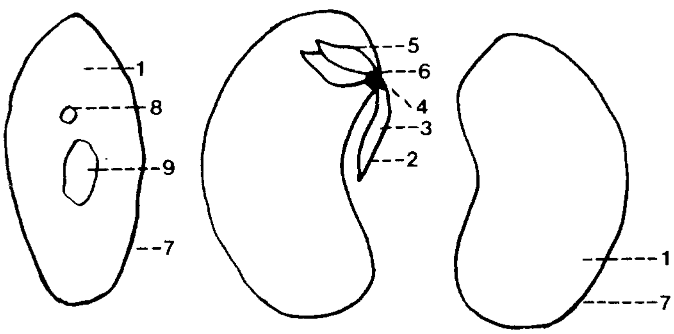
Dry beans are a relatively new crop to North Dakota. They have been grown on a large scale since the 1970s. Two classes of dry beans (navy or pea-bean and pinto) encompass the major commercial acreage. In 1989, North Dakota led the nation in total acreage of beans planted. Dry beans are generally grown under contract with a dry bean processing firm. These firms are located throughout eastern North Dakota and adjoining Minnesota counties.

The North Dakota Dry Edible Bean Council, the Minnesota Dry Bean Council and the Northarvest Bean Growers Association are organizations which promote and assist in marketing of dry beans. Dry beans are a crop that requires special cultural management and attention by the producer. Proper management is essential from field selection and planting through harvest and marketing for maximum profitability. The primary objective of this handbook is to help dry bean growers and related industry personnel to be proficient and successful.

Germination, Growth and Development

The dry edible bean (*Phaseolus vulgaris* L.) seed is an embryonic plant in a dormant state consisting of several diverse morphological features (Fig. 1). The seed is covered by a seed coat or testa with the hilum and micropyle found along one edge. The hilum is the scar left when the ovule separated from the funiculus (stalk) which had supported and attached it to the pod during development. The micropyle is the site of pollen tube entry during fertilization.

A bean seed split on its longitudinal axis consists of two conspicuous cotyledons and an axis consisting of several morphological features (Fig. 1). The cotyledons are simple leaves that arise from the first node of the primary stem, called the cotyledonary node. The function of cotyledons is to serve as a food storage organ during germination. They are the source of energy for seed and maintenance growth, development and subsequent emergence of the seedling.



1. Cotyledon (simple leaves)
2. Radicle
3. Hypocotyl
4. Cotyledonary node
5. First true leaves (unifoliate)
6. Epicotyl
7. Testa or seed coat
8. Micropyle (site of pollen tube entry during fertilization)
9. Hilum (scar resulting from the point of seed attachment)

Figure 1. Morphology of a dry bean seed.

The axis in a dry edible bean seed consists of a radicle, a hypocotyl, an epicotyl and two unifoliate leaves. The two immature simple leaves are attached on a node above the cotyledonary node. Between the two leaves is the terminal bud from which subsequent stems and leaves will develop. Root tissue of the plant will develop from the radicle.

The initial step of germination is the absorption of water by the seed. This causes a swelling of the seed resulting in the rupture of the seed coat. Growth begins with the elongation of existing cells and the initiation of cell division in the radicle followed by the development of root hairs (Fig. 2).

When anchorage is sufficient, elongation of the hypocotyl will begin, resulting in the eventual emergence of the hypocotyl arch and cotyledons from the soil. Following emergence, the hypocotyl arch will straighten and expansion of the first pair of true leaves occurs. This is followed by tissue development from the terminal bud. The cotyledons will wither and dry several days after emergence. The first two true leaves in dry beans are unifoliate (single bladed) while all subsequent leaves, which develop from terminal or axillary buds, are trifoliate (three-bladed).

If injury occurs to the terminal bud at any time during the plant's development, axillary buds located at the nearest junction of the leaf and stem (node) will take over the function of the terminal bud. If the injury occurs below the axillary buds located at the cotyledonary node, the plant will die since no more axillary buds exist below that point. This is not true in all legumes.

The number of days between seeding and emergence will depend on environmental conditions including soil temperature, moisture and compaction. Dry beans are classified as warm season annuals with an optimum germination temperature range of 68-86 degrees Fahrenheit. Minimum germination temperature is approximately 50-55 F.

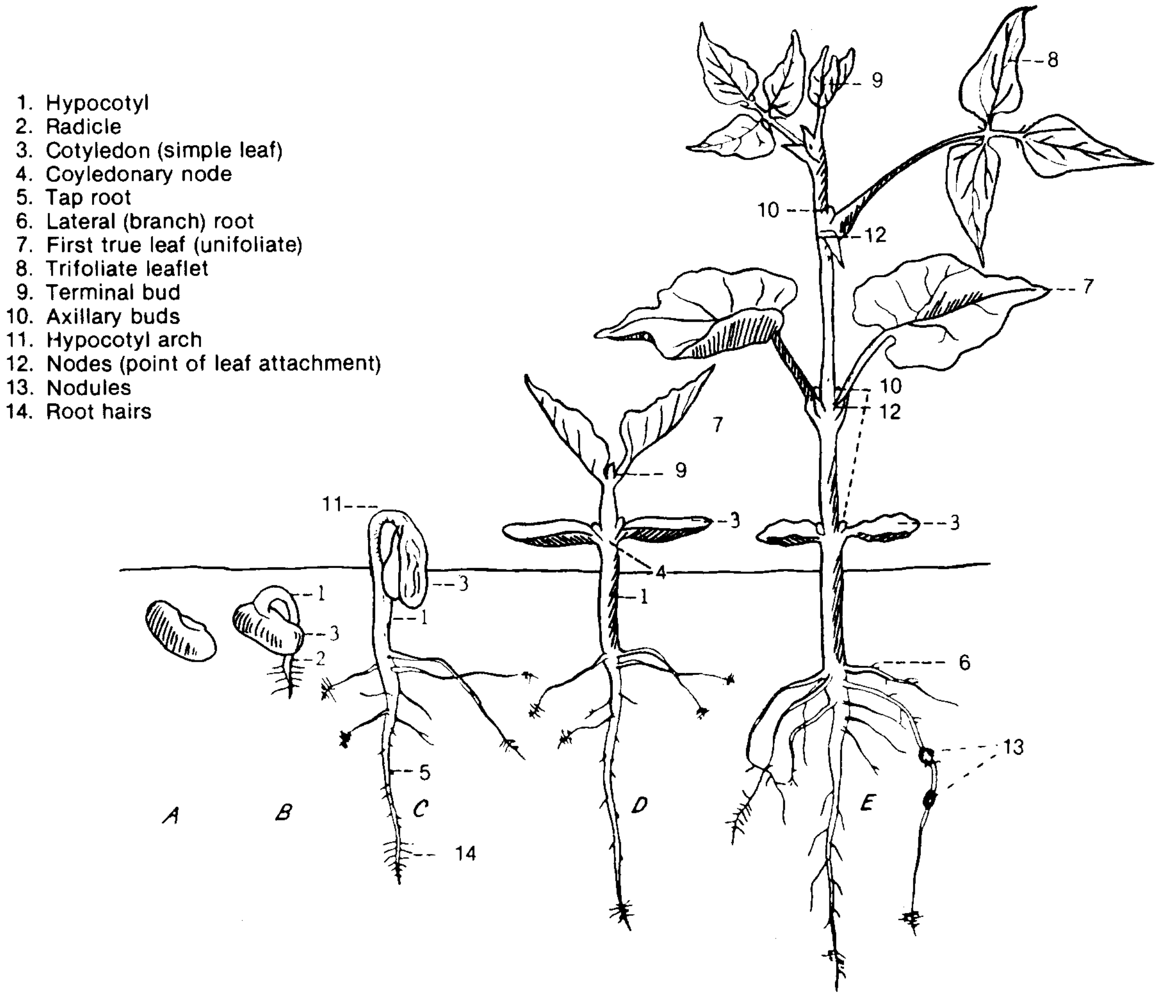


Figure 2. Seedling Development of the Bean.

Dry Bean Types

Two basic plant types are found in dry edible beans, determinate (bush) or indeterminate (vining or trailing). Cultivars may be classified according to plant types. For example, navy beans may be either of the bush or vining type. In the determinate type, stem elongation ceases when the terminal flower racemes of the main stem or lateral branches have developed. On indeterminate types, flowering and pod filling will continue simultaneously or alternately as long as temperature and moisture permits growth to occur.

In addition to the distinction between determinate and indeterminate plant types, four plant growth habits have been identified. These are: Type I - Determinate bush; Type II - Upright short vine, narrow plant profile, three to four stems; Type III - Indeterminate, prostrate vine; Type IV - Indeterminate with strong climbing tendencies. These growth habits have become useful in identification and classification of new upright bean cultivars.

Plant development for both determinate and indeterminate plant types has been divided into vegetative (V) and reproductive (R) stages as indicated in Table 1. Vegetative states are determined by counting the number of nodes on the main stem beginning at the unifoliate leaf node (V1). Reproductive stages are described with pod and seed characters in addition to nodes. The first pod developing on the plant is described and followed to full size. At the time of first bloom (R), secondary branching begins in the axis of lower nodes which will produce secondary groups of blooms or pods. It is important to follow the main stem, which is readily discernible on both determinate and indeterminate plants. A node is counted when the edges of the leaflets no longer touch.

Table 1. Stages of vegetative and reproductive development in determinate bush (Type I) and indeterminate (Type II) dry beans.

Stage No.	GENERAL DESCRIPTION* Vegetative stages	Days** from planting	Days between stages**	Nodal Count
V1	Completely unfolded leaves at the primary (unifoliate) leaf node.	10		1
			9	
V2	First node above primary leaf node. Count when leaf edges no longer touch.	19		2
			10	
V3	Three nodes on the main stem including the primary leaf node. Secondary branching begins to show from branch of V1.	29		3
V(n)	n nodes on the main stem, but with blossom clusters still not visibly opened.	A new node each 3 days		
V5	Bush (determinate) plants may begin to exhibit blossom and become stage R1.	50		5
V8	Vine (indeterminate) plants may begin to exhibit blossom and become stage R1.	40		8
	Determinate BUSH Type I Reproductive stages			
R1	One blossom open at any node	50		6
			3	
R2	Pods 1/2 inch long at first blossom position. Usually node 2 to 3.	53		
			3	
R3	Pods 1 inch long at first blossom position. Secondary branching at all nodes, so plant is becoming denser but not taller, 1/2 bloom.	56		
			3	
R4	Pods 3 inches long-seeds not discernible. Bush types may be shorter.	59		
			5	
R5	Pods 3-4 inches. Seed discernible.	64		
			2	
R6	Seeds at least 1/4 inch over long axis	66		
			6	

Stage No.	GENERAL DESCRIPTION* Vegetative stages	Days** from planting	Days between stages**	Nodal Count
	Determinate BUSH Type I Reproductive stages (continued)			
R7	Oldest pods have developed seeds. Other parts of plant will have full length pods with seeds almost as large as first pods. Pods will be developed over the whole plant.	72		
			18	
R8	Leaves yellowing over half of plant very few small pods and these in axils of secondary branches, small pods may be drying. Point of maximum production has been reached.	90		
			15	
R9	Mature, at least 80% of the pods showing yellow and mostly ripe. Only 40% of leaves still green color.	105		
	Indeterminate VINING Plant Type III Reproductive stages			
R1	One blossom open at any node. Tendrill will begin to show.	40		8
			3	
R1	Pods 1/2 inch long at first blossom position, (node 2 to 5 most plants). Blossom would have just sluffed.	43		9
			3	
R3	Pods 1 inch long at first blossom position. Pods are showing at higher nodes when blossom sluffs, 1/2 bloom.	46		10
			4	
R4	Pods 2 inches long at first blossom position.	50		11
			6	
R5	Pods 3 plus inches long, seeds discernible by feel.	56		12
			4	
R6	Pods 4.5 inches long with spurs (maximum length). Seeds at least 1/4 inch long axis.	6		
			10	
R7	Oldest pods have fully developed green seeds. Other parts of plant will have full length pods with seeds near same size. Pods to the top and blossom on tendril, nodes 10-13.	70		
			12	
R8	Leaves yellowing over half of plant, very few small new pods/ blossom developing, small pods may be drying. Point of maximum production has been reached.	82		
			12	
R9	Mature, at least 80% of the pods showing yellow and mostly ripe. Only 30% of leaves are still green.	94		

* Adapted from: Growth stages according to Marshall J. Lebaron (University of Idaho, College of Agriculture, Current Information Series No. 228, April 1974)

** Approximate number of days. This will vary from season to season and variety to variety.

A bean plant may have the same number of nodes when grown at two different locations but may differ in height because of the distance between the nodes. The dates on average days from planting and days between stages is very broad, and will vary from year to year and variety to variety.

The flower of the dry edible bean is typical of all legumes. Flower color varies with cultivars. Most beans presently grown in North Dakota have white flowers. Beans are normally self pollinated with less than 1 percent natural crossing.

Immature pods of most cultivars are green, turning yellow, and then light brown or tan as they mature. An exception is black bean cultivars, which may have light purple pods. Pods of the navy bean are more cylindrical as compared to the longer, wider, and more flattened pod typical of the pintos. The pods of dry beans are very fibrous as compared to the pods of snap beans. A satisfactory dry edible bean cultivar bears its pods above the ground, ripens uniformly, and does not shatter appreciably at maturity.

Production and Management

Planting and Stand Establishment

Dry edible beans should not be planted until the soil has reached a minimum temperature of 50 F at planting depth. Planting too early in cool, wet soil may result in reduced stands. In addition, frost may be a problem with early planted and emerged seedlings. The most common and recommended planting time in North Dakota is from May 15 through June 1. Delayed plantings may result in reduced yield and delayed maturity.

Row Spacing

Varieties with a Type I or Type II plant habit are commonly grown in rows spaced from 6 to 30 inches. Studies conducted at several North Dakota locations indicate a yield advantage for both dryland and irrigation for narrow planted rows in both Type I and Type II bean cultivars (Tables 2 and 3).

There are several potential problems, with growing dry beans in narrow rows. Weed control may be a problem since currently available preplant, preemergence and postemergence weed control chemical treatments may not provide complete weed control. This can be important since narrow rows cannot be cultivated to control weeds as easily as more widely spaced rows. The problem may be nullified to a certain extent with late emerging weeds, since dry beans grown in narrow rows, especially at higher populations, will shade and crowd small weed seedlings. Future development of broad spectrum postemergence herbicides would solve many of the potential weed problems of dry bean production in narrowly spaced rows. An alternative to all narrowly spaced rows would be a combination of 10-inch and 30-inch spaced rows arranged in a pattern to allow tractor movement through the fields for cultivation.

Harvest operations may need to be changed with more narrow row production of dry beans. Producers may direct combine Type I beans if the crop matures evenly and weeds are not a problem. The type III cultivars could possibly be straight combined with the proper type of header design and the foliage dried. Unfortunately, the type III cultivars, because of their growth habit, usually do not dry until after a hard frost. Uneven ripening is the primary reason Type III dry bean cultivars are undercut before harvest. Present equip-

Table 2. Pounds of bean seed per acre averaged over four plant populations of 'UI 114' pinto bean (Type III) grown under irrigation and dryland at four row spacings at several North Dakota locations from 1976 to 1978.

IRRIGATED

Row spacing (in.)	Oakes 1976	Oakes 1977	Oakes 1978	Carrington 1978	4 station year avg.	% yield of 30 inch row spacing
10	4455	4070	4485	3941	4238	124
20	3179	3788	3728	4011	3677	108
30	3151	3734	3367	3421	2418	100
40	2784	3584	3613	3712	3423	100
LSD (5%)	1040	NS	760	502		

DRYLAND

Row spacing (in.)	Fargo 1976	Fargo 1977	Fargo 1978	Carrington 1977	Carrington 1978	4 station year avg.	% yield of 30 inch row spacing
10	551	2600	1511	2276	818	1752	122
20	492	2072	2503	1841	660	1514	106
30	602	2153	2145	1629	627	1431	100
40	610	1864	2092	1441	726	1347	94
LSD (5%)	NS	479	NS	407	NS		

Table 3. Pounds of seed per acre averaged over four plant populations of 'Seafarer' navy bean (Type I) grown under irrigation and dry land at four row spacings at several North Dakota locations from 1976 to 1978.

IRRIGATION

Row spacing (in.)	Oakes 1976	Oakes 1977	Oakes 1978	Carrington 1978	4 station year avg.	% of 30 inch row spacing
10	2984	2892	4258	3648	3445	136
20	2076	2880	3276	3334	2892	114
30	1934	2444	2818	2942	2535	100
40	1576	1964	2613	2544	2174	86
LSD (5%)	598	330	757	507		

DRYLAND

Row spacing (in.)	Fargo 1976	Fargo 1977	Fargo 1977	Carrington 1978	4 station year avg.	% of 30 inch row spacing
10	735	2614	1946	729	1506	131
20	811	2478	1537	580	1352	118
30	648	2020	1284	644	1149	100
40	541	1438	1065	631	919	80
LSD (5%)	NS	786	404	NS		

ment could possibly be altered to undercut narrowly spaced rows. Other solutions may be the label clearance of a chemical for desiccation and/or the growing of more determinate (bush type) cultivars. Anticipated yield response to narrow row spacing determinate Type I pinto bean might be similar to that obtained with a Type I navy. Yields of type I pinto cultivars have been erratic under North Dakota conditions.

Dry bean production in more narrowly spaced rows possibly could alter the spread of white mold (*Sclerotinia sclerotiorum*) in areas where the disease is present. Under favorable growing conditions and high plant populations, increased and more rapid canopy development may result in more moisture and higher humidity at the base of the plant which could enhance the development of white mold. Narrow row spacing at populations equal to current recommendations will offset these conditions to a certain extent by the increase in interplant spacing in the row (Table 4). (See disease section).

Planting Rates

Planting rates vary from 40 to 65 pounds per acre, depending on row spacing, plant type and percent pure live seed. Navy beans range from 2,200 to 2,500 seeds per pound. Planting rates suggested for navy beans are 40 to 45 pounds per acre of pure live seed. Studies conducted at various plant populations do not indicate any significant advantage to having populations greater than 90,000 plants per acre for Type I navy beans (Table 4). Slightly higher planting rates are advised under irrigation.

Pinto beans range from 1,200 to 1,500 seeds per pound. Planting rates suggested for pintos are 50 to 65 pounds per acre of pure live seed. Populations of 70,000 plants per acre for Type III (Pinto) beans have been found to be adequate. In some instances, reduced yields were observed when plant populations were below these recommendations. Under irrigation, some lodging has been observed in the Type I cultivars at extremely low plant populations. No relationship between spacing and plant population was found in studies conducted in North Dakota.

Table 4. Living plants per 10 foot row of determinate and indeterminate dry edible bean at four row spacings and four plant populations.

	Type I			
	Plants/acre x 1000			
	60	90*	120	150
Row spacing (in.)	Plants/10 foot of row			
10	11	17	22	25
20	23	35	46	58
30	35	52	70	87
40	45	67	90	112

	Type III			
	Plants/acre x 1000			
	40	70*	100	130
10	8	13	19	25
20	15	27	38	50
30	23	40	57	74
40	31	54	76	99

*Currently recommended plant population.

Rates should be adjusted for low germination or cool, wet planting conditions. To obtain desired plant populations, overseed live seed by 10 to 15 percent to compensate for losses during emergence. The normal planting depth is about 2-2 1/2 inches. Seed should not be planted deeper unless the topsoil is dry. Plant seeds in moist soil if possible. Windbreaks of corn or sunflower can be planted in fields where winds could become a problem at harvest. Growers should test their planter on a hard surface and in the field at normal planting speeds to ensure proper depth and seeding rate.

Cultivation

Dry beans may be cultivated to control weeds, break soil crusting, increase water infiltration rates, and hill rows to ease the undercutting operation at harvest. Cultivation should be done with care so that roots are not pruned. Severe root pruning can injure the plant and delay or prevent normal development.

To avoid spreading bacterial blights, do not cultivate, harrow or enter bean fields when foliage is moist (refer to plant disease section). Soil compaction problems may develop if fields are worked when the soil is wet.

Growing Requirements

Dry edible beans are adapted to a wide variety of soils. They are not sensitive to soil type as long as it is reasonably fertile, well drained and free of conditions that interfere with germination and plant emergence, such as saline (salt affected) soils.

Saline soils affect germination, emergence and later plant growth. Plants that emerge on saline soils may become yellow and have stunted growth. The leaf edges of the affected plant will be brown and dead and often accumulations of salt may be seen on the leaf surface (refer to the section on fertility).

Dry edible beans 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 dry beans, but they are adapted to a fairly wide range of temperature. The optimum average growing temperature for field beans is 65 to 75 F. Dry edible bean production is more successful in areas where rainfall is light during the latter part of the growing season. It is essential that the crop be grown on a well-drained soil since beans are extremely sensitive to standing water or waterlogged conditions.

Dry edible beans are not tolerant to frost or to prolonged exposure to near-freezing temperatures at any stage of plant growth.

Hail Damage

The amount of crop damage caused by hail will depend on the intensity, size of hail stones and duration, as well as plant type and stage of development. Determinate (Type I) cultivars are likely to suffer greater losses than the indeterminate (Types II and III) cultivars, because Type II and III can compensate to a greater degree than can the Type I.

Severe hail damage can delay plant maturity. The earlier the stage of development at which the injury occurs, the greater the time available for recovery, resulting in less yield reduction. Hail will not directly affect seed quality unless a strike occurs on the pod.

Place in Rotation

Dry beans are a short season crop and will fit well into a variety of crop rotation plans. Important considerations for a place within a rotation in North Dakota include disease and weed control (refer to the sections on weed and disease control). Since available and recommended herbicides change, a prime consideration in a rotation is the ability to control volunteers from the previous crop as well as common weeds. If weeds can be controlled, dry beans may, under some situations, be a good replacement for summerfallow in a rotation. Dry beans mellow the soil, and plowing for the next year's crop is often not necessary.

Because of a number of potential disease problems, dry beans should not follow dry edible beans, soybeans, sunflower or mustard in a rotation. It is recommended that a three to four-year crop rotation be followed.

Fall plowing for seedbed preparation is preferable for production on heavy soils unless they follow a row crop. A firm seedbed free of clods and coarse debris is essential for establishment of good stands.

Performance of Dry Bean Classes in North Dakota

The majority of dry beans grown in North Dakota are of the pinto and navy types. Other classes of dry beans are grown on a limited acreage or not at all. Many of these classes have been tested by North Dakota State University for several years to determine their adaptability to North Dakota.

The advantage of growing different bean market classes is that each class of bean may command a different price in the marketing system. This diversity allows the producer to stabilize his income, since the different market classes do not always follow the same market trends. A disadvantage of growing more than one market class on a farm is that classes cannot be mixed. This would mean separate storage areas and equipment cleanout between harvest operations.

Local markets have not been developed for many of the less common market classes. A producer should have either a written contract or marketing agreement with a buyer before they are grown. A description of common dry bean cultivars and their performance is given in Circular A-654.

Several different bean classes are well adapted to production in North Dakota. Among these are the pinto, navy or pea bean, black turtle, small red or red Mexican, pink, great northern, light red kidney and dark red kidney. Most of these types have well developed markets, although not in North Dakota at this time. Several other types with very limited markets, including the cranberry, Swedish brown, and small white, have been tested. Many cultivars of these types have been evaluated and found not adaptable to North Dakota, mainly because of late maturity.

Market Classes and Cultivar Selection

Several dry bean market classes can be grown successfully in North Dakota. These market classes are generally described based on seed characteristics, notably color and shape. The predominant market classes grown in North Dakota are the ***pinto,*** a tan bean with dark brown mottling and medium seed size (38-42 g/100), and the ***navy*** (pea) bean, a white bean with seed size of 17-22 g/100 seed. Other classes include: ***black*** (or black turtle) beans, which produce seeds of similar size to the navy bean; the ***dark red kidney*** a large (50-60 g/100 seed) bean with a dark red color, ***light red kidney***, similar in size and shape to the dark red kidney but lighter in color; ***cranberry*** a medium-large (45-55 g/100 seed), white-red mottled bean; ***small red*** (or red Mexican), a red bean with a seed size slightly smaller than a pinto bean; ***pink***, a bean also similar in size to the pinto but with a pink seed coat color; and ***great northern***, a bean similar in size and shape to the pinto but with a brilliant white seed coat. The pinto, great northern, pink, and small red market classes are genetically closely related; the navy bean and black beans are closely related and also related to the pinto types, although more distantly than to each other; the kidney and cranberry are closely related (also to snap or garden beans) and distantly related to the other groups described.

A range of growth habits exists among cultivars within most market classes, including Type I (determinate bush), Type II (upright, short vine), and Type III (prostrate vine). Dry bean growers historically have grown navy bean cultivars possessing a Type I plant architecture and pinto cultivars exhibiting a Type III architecture. Efforts by plant breeders to improve upon yield stability, tolerance to environmental stresses, and increased yield have developed cultivars that are indeterminate but upright, with few branches. This architectural growth habit is referred to as upright, short vine, and given a classification as Type II. Cultivars with this growth habit generally have higher yield potential but are later maturing than some determinate (Type I) cultivars, although the grower should keep in mind that cultivars vary greatly in maturity. To date, most success in architectural improvement has been in the navy bean market class.

Several plant architectures are also found in the pinto market class. Generally, Type I pinto cultivars are more sensitive to certain environmental stresses than either Type II or Type III cultivars, resulting in poor yield stability over diverse growing conditions. The traditional Type III (prostrate vine) pinto cultivars are generally well adapted to many environments, although increased incidence of diseases, notably white mold, and specialized harvesting equipment detract from this architectural type. Recently, plant breeders have been successful in developing large seeded pinto bean breeding lines associated with a desirable Type II architecture; several of these lines will be released as cultivars in the near future.

Cultivar selection is one of the most important decisions a bean grower has to make. The ability of a cultivar to emerge vigorously from the soil, compete effectively with weeds during early seedling growth, and mature uniformly is of extreme importance. Architecture may be of lesser importance if the equipment necessary for harvest is available; however, the high placement of pods on plants would reduce potential soil staining and also give the grower an option of direct harvesting.

Maturity is a major factor in selection of a cultivar. Because of the relatively short growing season in most of North Dakota, dry bean cultivars that mature in excess of 100 days after planting should be selected with extreme caution. Seeds that are frost damaged are not marketable and are treated as "pick" at the dealer. Early (80-92 days) and midseason (94-96 days) cultivars generally perform well with little reduction in yield. Dry bean growers should keep in mind that high levels of available soil nitrogen will increase vegetative growth and delay maturities of all bean cultivars.

Resistance to prevalent diseases should also be considered when selecting a cultivar. Resistance to rust, for example, is not uniform among cultivars within a market class, or among market classes. Cultivar responses to the prevalent rust races vary greatly, and since the rust populations may change over time, previously resistant cultivars may become susceptible to newer races of rust (Table 5.)

Almost all cultivars show extreme susceptibility to white mold. Pinto bean cultivars processing a Type III architecture may have greater levels of infection because of the dense canopy formed. An avoidance type of resistance may be of benefit to reducing the level of disease in a bean field. Upright cultivars should prevent the formation of a dense, ground-hugging canopy, thereby altering the environment during the latter half of the growing season. Growers should keep in mind, however, that many of these upright cultivars are as susceptible genetically as Type III cultivars and could become infected if planted on a heavily infested field.

The frequency of beans showing infection by various root rot pathogens has been increasing in recent years. Tolerance to some of these pathogens exists, and the management practice of longer rotations and production of tolerant cultivars would effectively reduce the incidence of these diseases.

Table 5. Plant type and disease reactions of dry bean cultivars.

Class and		Plant	Blight		BCMV			Fusarium	White
Cultivar	Mat[3]	Type[2]	Common	Halo	Type	NY15	Root Rot	Mold	Rust[1]
Pinto									
Agate	M	B	S	S	R	R	T	S	S
Nodak	E	V	S	-	R	R	-	S	S-MR
Olathe	M	V	S	T	R	R	S	S	S-R
Ouray	M	B	S	T	R	R	S	S	S
Pindak	M	V	S	T	R	R	T	S	S-MR
UI-114	ML	V	S	T	R	R	T	S	S
UI-126	ML	V	S	T	R	R	-	S	S
UI-129	ML	V	S	T	R	R	-	S	S
Fiesta	E	V	S	T	R	R	S	S	S-MS
Gala	E	V	S	T	R	R	S	S	S
Topaz	E	V	-	T	R	R	-	S	MS
Othello	E	V	S	T	R	R	-	S	S-MS
RS-101	E	USV	-	-	-	-	-	-	S-MS

Some cultivar disease reactions adapted from North Central Regional Extension Publication 198.

[1] Reaction based upon inoculation with field collection of rust obtained in North Dakota, 1983.

[2] V=Vine, B=Bush, UV=Upright vine, USV=Upright short vine, S=Susceptible, T=Tolerant, R=Resistant, MS=Moderately susceptible, MR=Moderately resistant.

[3] RM=Relative maturity, E=Early, M=Medium, ME=Medium early, ML=Medium late, L=Late.

Class and Cultivar	Mat[3]	Plant Type[2]	Blight		BCMV		Root Rot	Fusarium Mold	White Rust[1]
			Common	Halo	Type	NY15			
Navy									
Bunsi	L	UV	S	T	R	R	-	T	MR
C-20	L	USV	S	T	R	R	-	T	MR
Fleetwood	L	B	S	T	R	R	S	S	S-MR
Midland	M	B	-	-	-	-	-	-	MR-MS
Upland	ME	B	S	T	R	S	S	S	MR
Wesland	M	B	-	-	-	-	-	-	MS
Snow bunting	E	B	S	T	R	S	S	S	S
Seafarer	E	B	S	T	R	R	S	S	S
Admiral	L	B	S	T	R	R	S	S	MR
Hyden	ML	V	S	-	R	R	-	S	MR
Rocket	L	B	S	-	-	-	-	-	MR
Singer	L	B	S	-	-	-	-	-	MR
Albion	E	B	S	-	-	-	-	-	MR
Mayflower	ML	USV	-	T	R	R	T	T	R
Agri-1	ME	B	S	T	R	R	-	S	MR
Pearl	M	B	-	-	R	R	-	T	MR
Small White									
Aurora	M	UV	S	T	R	R	S	T	MR-R
Zircon	M	V	S	T	R	R	S	-	MR-MS
Cranberry									
Mich. Imp.	L	V	-	-	-	-	-	S	R
Taylor Hort	E	B	-	-	-	-	-	-	R
UI-50	M	B	-	-	R	R	-	-	-
Small Red									
UI-37	E	V	S	S	R	R	S	S	S
UI-36	M	V	S	S	R	R	S	S	S
Garnet	M	V	-	-	R	R	-	S	S
NW59	ML	V	S	T	R	R	T	S	S
NW63	ML	V	S	T	R	R	T	S	S

Some cultivar disease reactions adapted from North Central Regional Extension Publication 198.

1 Reaction based upon inoculation with field collection of rust obtained in North Dakota, 1983.

2 V=Vine, B=Bush, UV=Upright vine, USV=Upright short vine, S=Susceptible, T=Tolerant, R=Resistant, MS=Moderately susceptible, MR=Moderately resistant.

3 RM=Relative maturity, E=Early, M=Medium, ME=Medium early, ML=Medium late, L=Late.

Class and Cultivar	Mat[3]	Plant Type[2]	Blight		BCMV		Root Rot	Fusarium Mold	White Rust[1]
			Common	Halo	Type	NY15			
Black									
Black Magic	ML	USV	S	T	R	R	T	T	R
Domino	ML	USV	S	T	R	R	T	T	R
Midnight	ML	USV	S	S	R	R	T	T	R
T-39	M	USV	S	T	R	R	T	T	R
Ebony	L	USV	S	T	R	R	T	S	R
Blk. Beauty	L	USV	S	T	R	R	T	T	R
UI-906	E	-	-	R	R	T	T	-	R
Light Red Kidney									
Manitou	L	B	S	S	S	S	S	T	R
Mecosta	L	B	S	T	R	R	S	T	R
Redloud	M	B	S	T	R	R	S	T	R
Redkote	L	B	T	T	R	R	S	T	R
Sacramento	E	B	S	S	S	S	S	T	R
Isbella	M	B	S	T	R	R	S	T	R
Dark Red Kidney									
Clarlevoix	L	B	S	S	S	S	S	T	R
Montcalm	ML	B	S	T	R	R	S	T	R
Great Northern									
Emerson	M	V	T	T	R	R	S	S	S
Harris	L	V	T	T	R	R	S	S	S
Valley	L	V	T	T	R	R	S	S	S
Beryl	M	V	-	-	-	-	-	S	-

Some cultivar disease reactions adapted from North Central Regional Extension Publication 198.

[1] Reaction based upon inoculation with field collection of rust obtained in North Dakota, 1983.

[2] V=Vine, B=Bush, UV=Upright vine, USV=Upright short vine, S=Susceptible, T=Tolerant, R=Resistant, MS=Moderately susceptible, MR=Moderately resistant.

[3] RM=Relative maturity, E=Early, M=Medium, ME=Medium early, ML=Medium late, L=Late.

Weed Control

Cultural Control

Weed control is important in dry bean production. Uncontrolled weeds can compete with beans and reduce yields, harbor insects and diseases, reduce the quality of the crop, and interfere with harvest. Dry beans are not very competitive, and weeds reduce dry bean yields significantly unless removed early in the growing season. Research at NDSU has found that as few as three green foxtail per square foot reduced dry bean yields 42 percent, while 10 plants per square foot reduced yields 73 percent.

Good cultural practices help minimize weed problems in dry beans. Crop rotations can prevent the buildup of certain weed problems such as wild mustard, black nightshade, common cocklebur, and perennial weeds. These weeds are especially troublesome in dry beans. Fields relatively free of these weeds should be selected for planting to dry beans. In addition, weeds can be introduced with the bean seed planted in the field. High quality seed that is clean of weed seeds should be planted to avoid the introduction of weeds such as black nightshade and common cocklebur that commonly infest dry bean fields.

Preplant tillage and/or after planting cultivation are cost-effective methods of controlling many annual weeds in dry beans. Weeds are most susceptible to tillage when they are small. Prepare the seedbed immediately prior to planting the crop to kill germinating weeds. Planting the crop in rows allows the use of a row crop cultivator to control the weeds between the rows. A rotary hoe or flex-tine harrow may be used to control weeds after planting but before the dry beans emerge, or after emergence when beans are in the one to two trifoliolate leaf stage. However, beans that break below the cotyledons will not survive, so cultivation during and soon after emergence could cause excessive crop damage. Cultivation is most effective when the beans 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 quickly. Dry beans should not be cultivated when the foliage is wet, since diseases such as bacterial blight can be spread easily under those conditions.

Chemical Control

Herbicides can be an effective supplement to cultural weed control practices. Navy beans generally have less tolerance to herbicides than pinto beans or soybeans. **CAUTION**: Use lower labeled rates of herbicide on navy beans than other dry beans unless prior experience or research has shown the higher rates to be safe.

Most herbicides registered for use in dry beans must be applied prior to crop emergence. Basagran is the only herbicide presently labeled for postemergence broadleaf weed control in dry beans. Some of the preemergence herbicides should be incorporated while others do not require incorporation. However, due to the dry environment in North Dakota, incorporation generally improves weed control with the herbicides that can be applied preemergence or preplant incorporated. Thorough incorporation is essential to provide good consistent weed control and avoid crop injury. Two incorporation passes with the second pass conducted at an angle to the first incorporation generally provides the most uniform incorporation and the best results.

Pesticides are often tank-mixed to improve pest control and reduce the number of trips across the field. However, tank-mixing also can result in compatibility problems, increased crop injury, and/or reduced weed control. Herbicide combinations commonly applied as tank-mixtures in soybeans include EPTC or chloramben plus trifluralin, ethalfluralin, pendimethalin, alachlor, or metholachlor. Refer to the herbicide labels for recommended tank-mixtures and their use. Unlabeled tank-mixtures should be tried on a small acreage the first time they are used and tested for compatibility before mixing the chemicals in the spray tank.

Sodium chlorate (Defol, Defol 6) can be used as a preharvest aid to desiccate dry beans and weeds. Sodium chlorate should be applied seven to 10 days before dry bean harvest. Sodium chlorate is a contact chemical, so thorough spray coverage of the foliage is essential for complete desiccation.

The following tables (Table 6 and 7) provide information on the use and relative effectiveness of herbicides registered for use on dry beans in North Dakota.

Table 6. Herbicides for weed control in dry edible beans.

Herbicide	Act. Ingred. lb/A (Formulation/A)*	Weeds	When to Apply	Remarks
Glyphosate (Roundup)	0.19 to 0.75 (0.5 pt to 1 qt)	Emerged grass and broadleaf weeds	Preplant or anytime prior to crop emergence	A nonselective, translocated, postemergence herbicide. No soil residual activity. Apply with a nonionic surfactant at 0.5% v/v.
EPTC (Eptam, Genep)	3 (1.75 qt)	Grass and some broadleaf weeds	Preplant incorporated	Incorporate immediately after application. Weak on wild mustard.
	4 to 4.5 (4.5 to 5.25 pt 7E, 40-45 lb 10G)		Fall incorporated after October 15 until freeze-up	
Trifluralin (treflan)	0.5 to 1 (1 to 2 pt 4E) (5 to 10 lb 10G)	Grass and some broadleaf weeds	Preplant incorporated, fall after September 1 or spring	Incorporated within 24 hours of application. No wild mustard control. Refer to the label for rotational restrictions.
Ethalfluralin (Sonalan)	0.5 to 1.7 (1.3 to 4.5 pt)	Grass and some broadleaf weeds	Preplant incorporated 2 to 3 inches deep	The low rate should be used on coarse textured, sandy soils. High rate should be used on fine textured soils for black nightshade control. Incorporate within 48 hours of application. No wild mustard control.
Pendimethalin (Prowl)	0.5 to 1.5 (1 to 3 pt)	Grass and some broadleaf weeds	Preplant incorporated	Use higher rates on fine-textured soils. Weak on wild mustard. Refer to label for rotational restrictions.
Alachlor (Lasso)	2 to 3 (2 to 3 qt)	Grass and some broadleaf weeds	Preplant incorporated	Weak on wild mustard. Use the higher rate on fine textured soils high in organic matter.
Metolachlor (Dual)	2 to 3 (2 to 3 pt)	Grass and some broadleaf weeds	Preplant incorporated or preemergence	Weak on wild mustard. Incorporation improves consistency of weed control. Use high rate on fine-textured soils.

* Formulation values are given for the most commonly used products and not included for most mixtures because of inadequate space.

Herbicide	Act. Ingred. lb/A (Formulation/A)*	Weeds	When to Apply	Remarks
Chloramben (Amiben)	1.8 to 2.7 (2.4 to 3.6 lb DS)	Annual grasses and broadleaf weeds	Preplant incorporated or preemergence	Often applied as a tankmixture with alachlor, metolachlor, trifluralin, ethalfluralin, or EPTC.
Bentazon (Basagran)	0.75 to 1 (0.75 to 1 qt)	Wild mustard, cocklebur, Canada thistle, wild and volunteer sunflower	Postemergence. Beans in 1st trifoliolate leaf stage or larger. Small seedling broadleaf weeds	Thorough spray coverage essential for good control. Addition of all oil concentrate may improve weed control, but also increases crop injury. A second application 7 to 10 days later may be required to control Canada thistle.
Sodium Chlorate (Defol)	6 (2 gal of 3 lb/gal conc.)	Desiccant	7 to 10 days to harvest	Thorough spray coverage of vegetation essential. Apply in 5 to 10 gpa by air or 20 to 30 gpa by ground. Most effective with warm sunny conditions.

* Formulation values are given for the most commonly used products and not included for most mixtures because of inadequate space.

Table 7. Relative herbicide effectiveness on weeds and persistence in soil.

Herbicide	Barnyardgrass	E. Black Nightshade	Common Cocklebur	Field Bindweed	Perennial Thistles	Foxtails (pigeongrass)	Kochia	Common Lambsquarters	Pigweed, Redroot	Russian Thistle	Sunflower, Volunteer	Wild Buckwheat	Wild Mustard	Wild Oats	Herbicide Persistence After 12 Months
Alachlor (Lasso)	G-E	G	N	N	N	E	F	F	G	F	N	F	P	P	N
Bentazon (Basagran)	N	F	G	F	F-G	N	F-G	F	F	P	E	P	E	N	N
Chloramben (Amiben)	G	G	P	N	N	G	F	E	E	G	N	G	G	F	N
EPTC (Eptam, Genep)	E	F-G	P	N	N	E	F	F	G	P	N	F	P	G	N
Ethalfluralin (Sonalan)	E	G	P	N	N	E	G-E	E	E	G-E	N	F	N	G	S
Metolachlor (Dual)	G-E	G	N	N	N	E	F	F	G	F	N	F	P	N	N
Pendimethalin (Prowl)	E	N	N	N	N	E	G	G	G-E	F	N	N	N	F-G	S
Trifluralin (Treflan)	E	N	P	N	N	E	G	G	G-E	G	N	F	N	F-G	S

E = Excellent G = Good F = Fair P = Poor N = None S = Seldom O = Often

This table is a general comparative rating of the relative effectiveness of herbicides to certain weeds and persistence of herbicides in soil. 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. Also, relatively dry and/or cool weather increases herbicide persistence while wet and/or warm weather reduces herbicide persistence.

Herbicide Injury Symptoms on Dry Beans

Herbicide related crop injury occasionally occurs and usually can be attributed to misapplication, extreme environmental conditions, chemical interactions, herbicide drift, or herbicide carryover. Herbicide injury symptoms often may be confused with other production problems. Crop stress from disease, insect feeding, nutrient deficiency, and environmental conditions can be mistaken for herbicide damage. Always consider the pattern of crop injury and all possible causes when investigating a crop injury problem. The following paragraphs describe typical injury symptoms on dry beans caused by various herbicides used in North Dakota.

Growth regulators (2,4-D, MCPA, Banvel, Tordon, Curtail, Curtail M, Stinger). Growth regulator herbicides are systemic chemicals which can be absorbed through the foliage, stem, or roots of the plants and translocated throughout the entire plant system. Affected plants exhibit injury symptoms within a few hours to several days after exposure. Bean stems and petioles become twisted, brittle, and may develop callous tissue. Leaves often develop parallel veins resulting in crinkling of the interlineal tissue. Banvel often restricts the growth around the margin of the leaves causing a cupped appearance. Dry beans are extremely susceptible to all the herbicides listed and the beans may die from severe injury. All the growth regulator herbicides listed can cause drift injury to dry beans. Tordon, Banvel, Curtail (M), and Stinger also can carry over and injure beans the year after herbicide application.

Amino acid syntheses inhibitors (Glean, Ally, Harmony Extra, Express, Pinnacle, Assert, Roundup). These herbicides kill plants by preventing the production of amino acids, essential building blocks for normal plant growth and development. Injury symptoms caused by these herbicides generally are not apparent until seven to 10 days after exposure. Injured plants will turn yellow and gradually die. Glean and Ally may carry over and injure dry beans for three years or more in North Dakota, especially on high pH soils.

Cell division inhibitors (Treflan, Sonalan, and Prowl). These herbicides are used on dry beans and generally are safe on the crop. Injury could occur with misapplication or extremely cool wet conditions during emergence. Crop injury would appear as swollen hypocotyls and short, stubby lateral roots with enlarged tips.

Photosynthetic inhibitors (Atrazine, Bladex, Sencor, Lexone). Bean plants will emerge normally and not exhibit symptoms until the leaves begin photosynthesis. Several days after emergence the leaves will turn yellow and die. Injury first appears around the margins of the leaves and progresses inward. Atrazine, Sencor, and Lexone may carry over from the previous growing season. Bladex generally will not carry over from the previous year.

Cell membrane disrupters (Gramoxone Super, Cyclone, Cobra, Blazer, Tackle). These herbicides are contact chemicals that only affect the plant tissue that the spray comes in direct contact with. Bean injury occurs within several hours and appears as dead leaf tissue. Gramoxone Super and Cyclone are much more injurious than the other herbicides.

Shoot inhibitors (Eptam, Genep, Lasso, Dual). Eptam and Genep cause cotyledon enlargement, leaf malformation and crinkling, thickened dark green leaf tissue, and delayed seedling emergence. Symptoms are visible one to several weeks after application. Lasso and Dual inhibit early seedling growth and cause a shortening of the leaf midvein, resulting in a heart-shaped bean leaf. Injury from these herbicides is most likely with cool, wet conditions during emergence.

Refer to the present year Agricultural Weed Control Guide (NDSU Extension Circular W-253) for the most recently registered herbicides on dry beans and additional information on herbicide use.

Fertilization

A fertile soil is needed for highest yields. Dry beans will respond favorably to added fertilizer nutrients when soil test levels are medium or low. Soil varies greatly in reserve nutrient levels, especially nitrogen. Always soil test to determine fertilizer needs. See Circular SF-780 or SF-882 for general fertilizer recommendations.

Nitrogen:

Dry beans are a legume capable of symbiotic nitrogen fixation. The need for fertilizer nitrogen is often discussed.

Nitrogen is a constituent of protein. Both the harvested bean and the crop residues left in the fields are high in protein. Rhizobial nitrogen fixation may not be adequate to provide the nitrogen needs of high yielding bean crops.

As an example, an 1,800-pound bean crop will leave from 1 to 2 tons of residue in the field. Calculations using 6.25 pounds of protein per pound of nitrogen, 22 percent protein content for the beans and 12 percent for the straw show the above ground portion of the plant will contain 120 pounds of nitrogen. Rhizobial nitrogen fixation seldom exceeds 40 pounds per acre when the plant is stressed at any point during the vegetative growth period. Additional nitrogen for the crop must be obtained from organic matter released or added fertilizer.

Organic matter nitrogen released to the crop will average about 15 pounds /growing season month in North Dakota. Maximum nitrogen release will occur on deep, high organic matter level soils that receive timely growing season rainfall.

Rhizobium Inoculation:

Inoculation should be routine for all legume crops, following instructions on the inoculum container. *Rhizobium phaseoli* is the proper strain for dry edible beans. (See plant disease section concerning inoculation problems in treated bean seed.)

Root infection in legume crops occurs with rhizobia from both soil borne and inoculum sources. Soil rhizobial populations decline in the absence of the host crop. Grain crop residues accelerate the decline, and the population level can be quite low following two or three grain crops. Inoculation at seeding time is usually required to restore satisfactory rhizobium activity.

Root nodulation and rhizobium activity is affected by plant vigor. Plants stressed by weather, insects, or disease seldom nodulate. Further, it is common for healthy, well-nodulated plants to slough nodules during periods of drought stress.

The center of active nodules should have a rich, pinkish-brown color. Immature nodules are creamy white. Ineffective nodules turn pale green and may slough from the roots.

Phosphorus and Potassium:

Yield responses to fertilizer phosphorus and potassium can be as dramatic with dry beans as with other crops commonly grown in North Dakota. Best yields are usually obtained on soils in which the residual level of these nutrients has been built up through good fertilization programs of previous crops. However, when soil test ratings are medium or lower, profitable yield increases can be expected from added P and K.

Broadcast applications have been shown to be effective when applied and plowed or disked in prior planting. However, the most efficient and profitable use of fertilizer P will be obtained if the fertilizer is placed in a band 1 to 2 inches to the side and 2 inches below the seed, especially on low and very low testing soils.

Dry beans are susceptible to damage if fertilizer is placed in contact with the seed. If planting equipment is not capable of placing the fertilizer to the side and below the seed, then broadcast all fertilizer and work it into the soil.

Zinc:

Navy bean varieties exhibit differential response to zinc fertility. The problem is most common in soils where calcareous subsoil has been mixed with surface soils and where high rates of phosphorus were used on the previous crop. Fertilizer containing 3 to 6 pounds of zinc in inorganic form (zinc sulfate or zinc oxide) or zinc chelates applied at 0.4 to 0.8 pounds of zinc per acre should be used in areas where the soil tests show low soil zinc levels.

Where zinc deficiency symptoms occur after emergence, the problem can be corrected by foliar application of zinc as early as possible. Good results have been achieved in North Dakota by application of 0.2 pounds of zinc per acre as a foliar spray. Early season detection and treatment are essential for satisfactory results.

Foliar applications after growth stage R1 (Blossoming) seldom increase yield.

Nutrient deficiency symptoms most common in North Dakota

Nitrogen: Shortages result in reduced growth and general yellowing of the leaves. The yellowing will be uniform across leaves.

Phosphorus: Deficiencies usually occur while the plants are quite small and during cold, wet springs. Plants will be stunted with small dark green leaves. In extreme cases leaves may be tinged with red. Plants will stand very erect.

Zinc: Zinc deficiency on beans affects primarily the older leaves, but the new leaves will be small and possibly mottled. The older leaves will first yellow, then necrotic areas develop along the margins and work toward the midrib.

Shortening of the internodes, producing a stunted, stubby plant, is also a typical symptom.

Other nutrient deficiency symptoms

First apparent in young leaves

Iron: New leaves develop light yellow color, first between viens. Later, the entire leaf becomes yellow. Necrosis and dying of tissue is usually absent until advanced stages of deficiency. The problem is restricted to alkaline soils.

Manganese: Chlorosis appears first between leaf viens of new leaves and then spreads to older leaves. Veins remain green even in advanced stages of deficiency. Chlorotic areas become brown or transparent, and ultimately marked necrosis of affected tissue occurs. Deficiency more general on alkaline soils.

First Appear on Old Leaves

Potassium: First indication of deficiency is ashen grey-green leaves at the base of plants. Leaves develop a bronze and yellowish-brown color, leaf margin becomes brown, specks develop along leaf veins and tissue deteriorates and dies. Roots are poorly developed and brown.

Magnesium: Chlorosis first appears between veins of old leaves while veins remain green. Leaf becomes brittle and its margins curl upward. Chlorotic areas turn brown and die in advanced stages. Occurs most frequently on acid soils.

Molybdenum: Distinctive mottling occurs in older leaves with veins remaining light green. New leaves are green at first but become mottled upon expansion. As deficiency is prolonged, puffing of chlorotic areas occurs and leaves curl inward, with necrosis along leaf tips and margins.

Apparent on Growing Tissue

Calcium: Stems become thick and woody with vegetative growth retarded. Root tips die with formation of small bulb-like enlargements on remaining tips. New leaves become chlorotic while old leaves remain green. New growth lacks turgidity.

Boron: New bud leaves and petioles become light in color, brittle, and often deformed in shape. Internodes short with rosetting pronounced at shoot terminals. In advanced stages, terminal buds die.

Non-Localized Symptoms

Copper: Leaves lack turgidity and exhibit a chlorotic condition as if bleached. Growth of plant greatly retarded. Most prevalent on peats and mucks.

Sulfur: Lower leaves become thick, firm and develop a yellowish-green color. Stems are hard, woody and are abnormally elongated and spindly.

Diseases of Dry Beans

Concepts and Principles

Diseases are caused by any agent (fungus, bacterium, virus, nematode, etc.) which interferes with the normal processes in a bean plant resulting in reduced yield. Injuries caused by insect feeding, cultivation damage, frost, salt and drought are not considered as disease.

There are three serious diseases of dry edible beans in North Dakota:

Bean Rust: Rust is a defoliating fungal disease which is an annual problem. The disease generally develops late in the season and can be controlled with fungicides.

Bacterial Blights: Blight can be caused by any of four different bacterial organisms. Blights are seedborne and spread by rainsplash. Blights cause defoliation. Copper fungicides are ineffective or expensive and genetic resistance to the most prevalent blight organism (Xanthomonas) is almost nil.

White Mold: White mold is a fungal rotting disease most serious in wet years. Fungicides, appropriately applied, can reduce losses. The pathogen attacks many broadleaf crops and weeds. Resistance is not available in commercially acceptable bean varieties.

Other diseases such as root rots, zinc deficiency, and virus diseases are important sometimes.

No dry bean field is disease free. A producer's goal should be to maximize yields and profits in the presence of these diseases. Dry beans need intensive management, including close and frequent observation (walking the field) to detect problem areas early.

Field identification of disease is often difficult because symptoms of disease vary with environmental conditions. Assistance in identifying diseased plants is provided by county extension agents, by the extension plant pathologists at NDSU, the plant diagnostic laboratory at NDSU, agricultural consultants, and by local bean dealers. It is important that an adequate sample (generally several complete plants including roots) representing a range of symptoms from slight to severe and supplemental information are provided. A plant disease diagnostic form helps describe the problem.

Diseases are a continual problem and control procedures must be planned for developing sustained production. Each condition which affects plant growth also affects the disease organism and the effectiveness of any control procedure. In general, conditions which favor rapid, lush plant growth also favor disease development. No single control procedure is best in every situation. Often a complex of disease interactions defies simple explanations or solutions.

Disease control begins with prevention. For up-to-date details see Circular PP-622 Rev., **Field Crop Fungicide Guide**, and Circular PP-576 Rev., **Dry Edible Bean Diseases**.

Three principles of bean disease control are:

Principle 1. Keep Pathogens and the Beans Separated

Geographic Separation

The soybean cyst nematode, which can also attack dry edible beans, was detected in 1979 as far north as central Minnesota. Do not bring soybeans or dry beans from affected areas into North Dakota.

Clean Seed Produced by Geographic Separation

Planting dry bean seed grown in arid regions of the country has been a technique for controlling bacterial blights of beans. Because of furrow irrigation, beans grow well but the bacteria reproduce poorly. The technique does not produce "blight-free" seed, but the seed contains considerably fewer bacteria than seed produced continuously in more humid regions. Stringent seed tests have allowed the North Dakota State Seed Department to monitor seed lots to ensure that North Dakota seed is of quality comparable to that produced by other states. Planting commercial beans as seed is a serious and generally unnecessary risk which cannot be lessened with seed treatments. Plant only certified high-quality seed.

On-Farm Separation (Rotations)

The best procedure for on farm separation is crop rotation. There is no "safe" rotation. Minimal rotations are acceptable as long as diseases/insects are not a problem. When disease losses occur, use extended rotations of four to five years to nonsusceptible crops. Whenever possible, avoid planting next to last year's bean field. Often severe disease starts in areas of fields adjacent to the previous year's beans.

Principle 2. Attack the Pathogen

Deep Plowing

Most bean pathogens do not survive long periods buried deep in the soil. Deep plowing of bean stubble soon after harvest reduces trash scatter and hastens bean straw (and pathogen) decomposition.

Chemical Sprays

Bean rust is easily controlled by protectant fungicides, provided these are applied before rust becomes serious. The sprays should be applied when rust is first detected in the field or rust is present in the region. Local dealers and county agents usually know about rust outbreaks in the area.

Sprays are mandatory if rust starts early in the growing season. Sprays are not recommended if rust is found in the field after the beans begin to mature (stripe). Sprays are also not profitable on crops infected heavily early in the season as poor yields will not justify the spray costs.

Sprays to control bacterial blights are not highly satisfactory. The sprays are not needed when weather is dry, as the blight spreads little. The sprays are ineffective when the weather is very wet and the bacteria spread rapidly.

Fungicide sprays can control white mold. Effectiveness varies, but control is best when the sprays are applied with a ground sprayer equipped with drop nozzles using a high water volume and high pressure to ensure total plant coverage. Fungicides should cover blossoms because blossoms are easily colonized by the fungus. Application(s) should be made in accordance with label directions. These protective sprays are most critical when weather is wet, vine growth is heavy, target yields are high, and white mold occurs in the area.

Seed treatments are designed to reduce early season damping off caused by a variety of soil fungi. Some treatments contain not only a fungicide, but also contain an insecticide and an antibiotic (streptomycin) which reduces the amount of surface-borne bacterial contamination. Because of the adverse effects of streptomycin on Rhizobium, we generally do not recommend seed treatment for beans inoculated with the nitrogen-fixing bacteria. Use of a granular inoculant in the furrow with treated seed may effectively induce nodulation (See section on Fertility).

Principle 3. Strengthen the Host

Resistance

Growing beans resistant to disease appears to be the easiest mechanism for control, but the process of breeding resistance into commercially acceptable varieties is difficult. In many cases, sources and strengths of resistance have not been identified. The currently grown cultivars already have resistance to several diseases but the remaining diseases, those now serious in North Dakota, are not well controlled by resistance. The rust pathogen, for example, has many strains and the strains in North Dakota are more diverse than anywhere else in the United States. In addition, the sexual stage was discovered in the state, which means that new forms of the rust fungus are continually being formed. It's expected that resistant varieties may be grown only a short time before a new strain of the fungus can again cause serious loss.

Resistance to the common blight organism is minimal, and breeders are currently seeking tolerant cultivars (lines that will yield better with the same amount of disease). Genetic resistance of most beans to white mold is also minimal, but the growth habit of the plant influences how rapidly the plant will dry. Upright plants dry faster and tend to escape infection. This explains in part why soybeans are less commonly infected by white mold than are dry beans. Some black turtle cultivars appear to have genetic resistance to white mold.

Fertilization

Foliar application of a zinc-containing compound to deficient beans (some navy bean varieties are especially sensitive to this deficiency) will increase yields. Excess nitrogen can cause lush plant growth, increase the potential for serious disease, and increase losses to frost. It is best to soil test prior to planting beans to insure that N-P-K levels are in balance.

Weed Control

Weeds can reduce bean vigor and reduce yields. In addition, they can cause the beans to dry more slowly following rain or dew and increase disease potential. Some weeds can serve as hosts for bean pathogens. Weed control is essential, but excess herbicide can predispose plants to root rot or even reduce stands. Cultivation may control weeds and reduce damage from root rot, because lateral roots form in the soil hilled up around the bases of the plants. Use caution, as close cultivation can prune shallow roots.

Row Spacing

Narrow rows can increase yields. They also increase the drying time of plants and reduce sunlight to lower leaves causing earlier leaf drop. White mold infections begin on dead leaves or blossoms. It is most serious in wet periods, and irrigators may have to suspend the final irrigation or two if white mold is present.

Crop Orientation

Planting bean rows parallel with the prevailing wind can increase airflow within the canopy and may reduce danger from rust and white mold.

Handling of the Seed

Careful handling of the bean seed and careful adjustment of the planter can reduce the amount of baldhead, a symptom of damaged beans. Damaged seed generally leads to a less vigorous seedling.

Deep Shanking Near the Planter Row

There is some evidence that root rots are more serious if a hardpan exists. Deep shanking (18 inches) near but not immediately beneath the planter row seems to significantly reduce root rot damage and allows roots to penetrate rapidly and deeply into the soil.

Symptoms, Characteristics and Controls

Rust (*Uromyces appendiculatus*)

Rust is very common. Pustules formed on leaves often have a yellow halo. Pustules are initially filled with red summer spores; black winter spores develop late in the season. Winter spores, and perhaps summer spores, overwinter on bean debris. In the spring, new races can develop from the inconspicuous sexual stage. Summer spores appear in July and can be wind-blown many miles. Plants are infected if they remain wet for 10-15 hours. The cycle repeats every 10-14 days. Rust is most severe on late planted and heavily fertilized beans.

CONTROL: Use protectant fungicides*. Since they are protectant fungicides, they must be applied before the rust infects the bean leaves. Spraying after striping of pinto beans does not increase yield. Early severe infection will cause nearly total loss so monitor fields carefully. Deep plow infected straw soon after harvest. Use a three + year rotation.

White Mold (*Sclerotinia sclerotiorum*)

White mold is a fungal disease which is most serious during wet weather. Wind-blown fungal spores colonize dead bean tissue (dried blossoms, leaves, etc.), then the fungus proceeds into living tissue and causes a watery soft rot. In wet weather, much white, frothy fungal growth appears on the surface of decaying tissue. Some of the fungal growth develops into dark, hard bodies called sclerotia. In the soil, most of the sclerotia die within a few years, but a few can survive nearly a decade. Sclerotia germinate into tiny mushroom-like fruiting bodies which produce spores. Fungus from sclerotia can also directly attack underground parts of some plants like sunflowers and, rarely, beans. Infected plants often wilt rapidly and appear bleached. Infected seed is discolored (often orange and chalky) and is lightweight.

CONTROL: Complete coverage of plants with benomyl (Benlate), thiophanate methyl (Topsin M) or iprodione (Rovral) is essential. Control is reduced by late application. Carefully monitor fields, and if disease is found, extend rotations by incorporating more grain crops. Use widely spaced rows to enhance drying. Upright varieties dry more quickly and have less disease. Plant rows in the direction of the prevailing wind. Deep plow infected straw and clean harvest equipment between fields.

Bacterial Blights

Blight diseases cause leaf lesions and defoliation, pod lesions, and shrunken discolored seed. The most prevalent disease is common blight (*Xanthomonas campestris* pv. *phaseoli*). Large irregular-shaped lesions are surrounded by a distinct yellow zone. Veins near the lesion are darkened. Infected pods develop greasy-appearing spots surrounded by red margins. Lesions exude yellow ooze when wet. A similar disease is called fuscous blight. Halo blight (*Pseudomonas syringae* pv. *phaseolicola*) is less prevalent, and pinto, great northern, and red Mexican varieties have some tolerance. Halo blight first appears as small water-soaked spots. The water soaked areas soon die leaving chocolate brown lesions. During cool weather, the lesions are surrounded by light green haloes up to 1/2 inch in diameter. The bacteria can cause pod lesions, but

*Check annual publications for lists of effective and registered materials. Read labels and use fungicides carefully.

these exude a white cream/ooze. Brown spot (*Pseudomonas syringae* pv. *syringae*) begins as water-soaked spots on leaves, but the spots remain small and become reddish brown. Haloes are absent.

All of the bacterial diseases are spread effectively by splashed rain, and water aids bacterial penetration into leaf pores or wounds. These pathogens are seed-borne but can survive in nondecomposed bean trash.

CONTROL: Plant high quality seed which is tested for low numbers of bacteria. Bury bean trash and use a three + year rotation. Use seed treated with streptomycin. Avoid cultivation when bean plants are wet. Copper sprays can be of some value in controlling blights but are ineffective when wet weather conditions favor disease spread.

Root Rot (*Fusarium solani* and *Rhizoctonia solani*)

Root rot is a chronic problem caused by several soil-borne fungi. Fusarium root rot is most common and also most serious in drought years. An indistinct brown lesion develops on the taproot and can cover all the roots. With adequate moisture, lateral roots form above the lesion. Plants are generally stunted with yellowed leaves. Infected plants form fewer pods and smaller seeds. Rhizoctonia causes chocolate-colored to dark red lesions which are much more distinct.

CONTROL: Extend crop rotations beyond four years. Root rot is less severe following wheat. If Rhizoctonia is present, avoid sugarbeets in close rotation. Some varieties are tolerant. Plant high-quality seed. Deep shanking adjacent to the planter row can reduce damage. Cultivating soil around stems can encourage lateral root development but can also prune shallow roots.

Bean Common Mosiac Virus

Infected plants are often stunted and spindly. Few pods are set and seeds are off-color and small. Infected leaves have irregular areas of yellowish tissue intermixed with areas of green. Leaves may be puckered, twisted, and elongated. Plants are seldom prematurily killed and yield loss depends on time of infection. The disease spreads by plant sap contamination of wounds, insects and infected seed. Plants with the I gene for resistance to the usual Serotype B strains can be killed if they are infected with viruses belonging to Serotype A. The reaction is called "black root."

CONTROL: Many commercially acceptable varieties have resistance to this disease. Many strains of the virus exist. Resistance may be against only a few strains. Information releases should announce the presence of new strains. Plant certified seed. Control insects.

Non-Parasitic Disorders

Sunscald: Small brown patches appear between the veins. These expand, often leaving large areas of dead tissue between apparently sound green veins. No controls are suggested.

Bronzing: Upper leaf surfaces are covered with small golden-brown spots which makes the leaf appear bronze in color. Bronzing is caused by ozone from industrial or urban pollution or meteorological phenomena.

Zinc Deficiency: New leaves are small with green and yellow patches or are uniformly yellowed. Dead areas in the leaves are common (pH 7 +) and where phosphorus levels are high.

CONTROL: Use fertilizer containing 3 to 6 pounds of zinc in inorganic form (zinc sulfate, for example). Apply zinc chelates to supply 0.4 to 0.8 pounds of actual zinc per acre in a chelated form.

Baldhead: Seedlings have no growing point. Cotyledons may or may not be attached; often they are broken. A few weak stems may develop from the axils of the cotyledons. Roots may be damaged and grow poorly. The problem is caused by mechanically damaged seed. Damage is more severe on navy than on pinto beans.

CONTROL: Buy seed from a dealer with high quality standards. Seed growers should thrash full windrows and harvest when pods are limber. Slow cylinder speeds and if possible use rubber protectors. Certain designs of bean thrashers produce less damage. Use bean ladders to reduce drop distances. Carefully handle seed in conditioning and shipping.

Insects Affecting Dry Beans

To date there have been few insect problems affecting dry bean production in North Dakota. However, the potential for certain insect problems exists every growing season. Of particular concern are grasshoppers, cutworms and armyworms. On occasion aphids, leafhoppers, bean leaf beetle, green cloverworm and seed corn maggot may also cause losses. A brief discussion of the habits, injury and economic thresholds pertaining to these insects follows. Control measures are given in the table at the end of the discussion.

Damage Assessment: Estimating potential damage by insects in beans is usually based on the insect population per foot of row or square yard and/or the percent of leaf tissue removed or damaged by the insect. Insect population per foot of row can be estimated by shaking plants over the inter-row space on which a strip of cloth or paper has been laid and counting total number of insect pests per foot of row that fall on the cloth or paper. Percent defoliation or damage is normally determined by simply estimating the amount of leaf loss based on visual inspection of several injured plants (leaf surface damage vs. total leaf surface, expressed as a percentage).

The growth stage of the plant is also very important because, under most conditions, moderate defoliation or damage early in the season has no appreciable effect on bean yield. However, as bean plants reach the flowering and pod filling stage, defoliation or plant damage is a greater threat to yield. At these critical developmental stages leaf feeding insects warrant greater concern. For example, available research data indicates the soybean plant (similar to dry beans) can sustain a 35 percent leaf loss up to pre-bloom and a 20 percent leaf loss at pod-set to maturity and not show a significant yield reduction.

Chewing Insects

Grasshoppers:

In North Dakota, Grasshoppers pass the winter in the egg stage. These eggs are laid in pods nearly 1 inch long and from 1/2 to 2 inches below the surface of the soil. Each egg pod consists of from 20 to 120 elongate eggs, securely cemented together, the whole mass somewhat egg-shaped and dirt-covered. A single female may deposit from eight to 25 egg pods. They are mainly deposited in uncultivated ground such as field margins, road sides and pasture land. Therefore, bean growers often can expect to find grasshopper damage occurring first along bean field margins adjacent to uncultivated land. In addition, grasshoppers that have moved into small grains or other crops that are normally harvested prior to dry beans frequently will move out of these crops into beans and other late crops as harvesting gets underway.

Grasshoppers are chewing insects. On beans they will attack the leaves and pods, creating holes or, with heavy infestations, removing all foliage except the stems.

Grasshopper control is advised whenever 20 or more adults per square yard are found in field margins or eight to 14 adults per square yard are occurring in the crop.

Cutworms:

Most cutworm damage occurs when bean plants are in the early stage of development. Damage consists of young plants being chewed off slightly below or at ground level. Certain species of cutworms such as the army cutworm and the variegated cutworm climb up on plants and chew on the leaves.

Cutworms feed primarily during evening hours, so their damage often will go undetected until considerable losses have occurred.

In checking bean fields for cutworms during the daytime, digging down an inch or two around recently damaged plants will usually reveal the presence of a grayish or gray-grown, grub-like larva, normally in a Cshaped position. If one cutworm or more is found per 3 feet or row and the larvae are small (3/4 inch long), the field should be treated.

Armyworms:

During certain years, armyworm populations will become high in North Dakota. Although this insect is normally more of a problem in small grain and corn, damage to dry beans and other crops can occur when their usual host plants become depleted.

Armyworms are similar to cutworms in that they are inactive during the daytime and feed at night. During the day they rest under plant trash, clumps of grass and areas of a field where crop plants may have lodged.

When full grown, armyworms are greenish-brown, with longitudinal stripes and a narrow broken stripe down the center of the back, bordered by a wide, somewhat darker, mottled one reaching halfway to the side; seen from the side there is a pale orange, white-bordered stripe.

Armyworm control is advised when 25-30 percent of the foliage is destroyed or if significant injury to pods becomes evident.

Green Cloverworm:

This insect is reported to be potentially the most serious pest of beans in the Midwest. However, populations have been negligible in North Dakota and very little treatment has been required.

The dark brown to blackish adult moth with a wing expanse of about 1 1/4 inches emerges in the spring and deposits eggs singly on leguminous plants. Eggs hatch and the small, greenish larvae begin to feed on the leaf tissue between the veins. They generally feed about two to three weeks. Mature larvae are green with three abdominable prolegs and two narrow white stripes down the side. When full-grown, they are about 1 1/4 inches long. This insect overwinters in the pupal stage in or beneath field debris.

Control of green cloverworm is normally not warranted until 25-30 percent of the foliage is destroyed. This usually requires from 10 to 15 larvae per foot of row.

Bean Leaf Beetles:

This beetle is brown to reddish brown, usually with three or four black spots and a black outside border on each wing cover. Bean leaf beetles feed on bean leaves and pods. The overwintering beetle lays eggs in soil surrounding host plants. The eggs hatch in one to three weeks and developing larvae feed on the roots for about two to three weeks but do little damage. The larvae are whitish, clearly segmented, and brown at both ends. After pupation in the soil, adults emerge and begin feeding on leaves; later on they feed on pods. Pod damage is probably most important because damaged pods are predisposed to secondary infection by bacteria and fungi, causing rotting and discoloration.

No North Dakota control guidelines are available due to extremely low beetle incidence. University of Missouri entomologists, however, suggest treatment when from 40 to 70 percent of the bean plants show feeding injury on one or more pods per plant.

Seed Corn Maggot:

Bean seed attacked by the seed corn maggot usually fails to sprout, or if it does sprout, the plant is weak and sickly. The pale or dirty colored yellowish-white maggots will be found burrowing in the seed. Injury is usually most severe in wet, cold seasons and on high organic matter land.

Winter survival occurs in the soil of infested fields in the maggot stage inside of a dark brown capsule like puparium about 1/5 inch long or as free maggots in manure or about the roots of clover. The flies, which are grayish brown in color and about 1/5 inch long, emerge during May. They deposit their eggs in the soil where there is an abundance of decaying organic matter or on the seed or seedling. The eggs hatch readily at temperatures as low as 50°F and the larvae and pupae may develop at any temperature from 52 to 92°F. The maggots burrow in the seed, often destroying the germ. When full-grown, they are a yellowish-white color, about 1/4 inch long, sharply pointed at the head end, legless and very tough skinned. They change to the pupal stage inside the brown puparium in the soil and in 12 to 15 days emerge as adults. Since the insect develops through its entire life cycle in about three weeks, there are probably several generations each season.

Besides corn and beans the seed corn maggot will also infest potatoes, peas, turnips and radishes.

Control of seed corn maggot in beans is best accomplished through the application of a seed treatment such as lindane or diazinon.

Sucking Insects

Leafhoppers:

The potato leafhopper will attack beans as well as potatoes and more than 100 other cultivated and wild plants.

The adults migrate into the northern states from areas of milder climate, instead of overwintering in the North. They are about 1/8 inch long by one-fourth as broad, of a general greenish color and somewhat wedge-shaped. They are broadest at the head end, which is rounded in outline, and taper evenly to the tips of the wings. The hind legs are long, enabling the insect to jump a considerable distance.

Large numbers of flying adults may appear rather suddenly in fields of beans as soon as these plants come up in early season. Except in cool, wet seasons, they are not attracted to potatoes until the plants are considerably larger. The possible reason is that bean plants are much higher in sugar content when they first break through the ground than potato plants are. Potatoes become sweeter as they grow older, and it is then that potatoes may become infested.

Beginning from three to 10 days after mating, the very small, whitish, elongate eggs are thrust into the main veins or petioles of the leaves on the underside by the female's sharp ovipositor. An average of two or three eggs are laid daily, and the females live about a month or more. The eggs hatch in about 10 days and the nymphs become full-grown in about two weeks. They usually complete their growth on the leaf where they hatched, feeding from the underside and increasing in size, greenness, and activity as they shed their skins; at the fifth molt they appear as adults.

Damage by leafhoppers results in the bean foliage becoming dwarfed, crinkled and curled. Rosettes or small triangular brown areas appear at tips of leaves, gradually spreading around the entire leaf margin. Such injury may cause plants to produce fewer pods and fewer beans per pod.

It has been demonstrated that the potato leafhopper feeds on the phloem cells of the veins, which become torn and distorted and the xylem tubes plugged so that food substances in the leaves are not properly translocated.

The economic threshold is one leafhopper per trifoliate leaf. Do not let infestations and damage progress to the point that yellowing is pronounced. If yellowing can be seen from the road or field margin, you have waited too long to initiate control.

Aphids:

Dry field beans in North Dakota have not been affected to any extent by aphids as of this writing. However, the bean aphid Aphis fabae has been detected in the state and should at least be considered a potential threat to the bean crop.

The bean aphid is less than 1/8 inch in length at full maturity. It is nearly black in color and feeds along stems and the undersides of leaves causing yellowing, wilting and stunting of foliage. Infested plants may become covered with a black "sooty" fungus which can develop on the honeydew (excrement) secreted by these aphids. Bean mosaic (common or bean virus 1) can be transmitted by the bean aphid. These diseases are discussed in the bean disease section.

Guidelines for control of bean aphids have not been established.

Two-Spotted Spider Mite:

The two-spotted spider mite, a relative of the spiders and only distantly related to insects, is a minute, rounded, eight-legged animal that feeds by sucking sap from the lower surface of the leaf. Affected leaves turn yellow to bronze and dry and fall off when severely attacked. A fine webbing with the small whitish to reddish mites under the leaves will identify the cause of the damage. Apply a spray as soon as the yellowing of leaves is noted. The mite is most abundant during dry spells, and several applications may be needed to obtain control of the mites during drought years.

Table 8. Insects Affecting Dry Beans

DRY FIELD BEAN INSECT CONTROL			
Pest	**Insecticide**	**Dosage (Actual Toxicant)**	**Remarks**
Aphids, Leafhoppers	Asana XL*	0.03 - .05 lb/acre	Do not apply within 21 days of harvest. Do not feed or graze livestock on treated vines.
	Di-Syston G	1-2 lb/acre (6-12 oz./1000 ft of row-any row spacing)	Band treatment at planting only. Avoid direct contact with seed. Pre-harvest interval, 60 days.
	Dimethoate EC (Cygon, De-Fend)	0.5 lb/acre	No pre-harvest interval. Do not feed vines.
	Guthion 2EC*	0.5 lb/acre	Do not apply within 30 days of harvest. Do not feed or ensile treated forage.
	Malathion EC or WP	1 lb/acre	Pre-harvest interval, 1 day.
	Orthene 75S	0.5 - 1 lb/acre	Do not apply within 14 days of harvest. Do not feed treated vines.
	Penncap-M*	0.5 lb/acre	Do not apply within 15 days of harvest. Read label for bee precautions.
	Thimet 20G*	4.5-7.0 oz/1000 ft of row-any row spacing	Band treatment at planting only. Avoid direct contact with seed. Pre-harvest interval, 60 days.
ARMYWORMS	Carbaryl (Sevin)	1-2 lb/acre	No pre-harvest interval. Treat at about 25-30% defoliation.
	Orthene 75S	0.75 - 1 lb/acre	Do not harvest for 14 days. Do not feed livestock treated vines.
BEAN LEAF BEETLE	Carbaryl (Sevin)	1 lb/acre	No pre-harvest interval.
	Guthion 2EC, WP*	0.5 lb/acre	Do not apply within 30 days of harvest. Do not feed or ensile treated forage to livestock.
	Methoxychlor WP	1 lb/acre	Pre-harvest interval 7 days.
	Orthene 75S	0.5 - 1 lb/acre	Do not harvest for 14 days. Do not feed treated vines.
CUTWORMS Treat when one cutworm or more per 3 ft of row occurs.	Asana*	.025 - .05 lb/acre	Do not apply within 21 days of harvest. Do not feed or graze livestock on treated vines.
	Carbaryl (Sevin)	1 - 2 lb/acre	No pre-harvest interval.
	Orthene 75S	0.5 - 1 lb/acre	Do not harvest for 14 days. Do not feed treated vines.

DRY FIELD BEAN INSECT CONTROL

Pest	Insecticide	Dosage (Actual Toxicant)	Remarks
GREEN CLOVERWORM	Asana*	.025 - .05 lb/acre	Do not apply within 21 days of harvest. Do not feed or graze livestock on treated vines.
Treat at about 25-30% defoliation	Guthion EC, WP*	0.5 lb/acre	Do not apply to dry beans within 30 days of harvest.
	Malathion ULV	8 oz/acre	Pre-harvest interval 1 day.
	Penncap-M*	0.5 lb/acre	Do not apply within 15 days of harvest. Read the label for bee precautions.
	Orthene 75S	0.5 - 1 lb/acre	Do not harvest for 14 days. Do not feed treated vines.
GRASSHOPPERS	Asana*	.025 - .05 lb/acre	Do not apply within 21 days of harvest. Do not feed or graze livestock on treated vines.
	Carbaryl (Sevin)	1-1.5 lb/acre	No pre-harvest interval. Treat when 8 or more grasshoppers per square yard occurs in the field.
	Orthene 75S	0.25 - 0.5 lb/acre	Do not harvest for 14 days. Do not feed treated vines to livestock.
SEED CORN MAGGOT	Lindane 30C Flowable	0.7 fl oz/100 lb seed	Lindane treated seed must not be used for or mixed with food or animal feed, or processed for oil.
	Thimet 20G*	4.5-7.0 oz/1000 ft of row	Do not place granules in direct contact with seed. Do not feed bean foliage within 60 days of harvest.
TWO-SPOTTED SPIDER MITE	Dimethoate EC* (Cygon 400)	1/4 - 1/2 lb/acre	Beans may be harvested on day of application. Do not feed treated vines. Do not apply if the crop or weeds in the treated area are in bloom
	Guthion 2EC*	1/4 - 1/2 lb/acre	Do not apply to dry beans within 30 days of harvest. Do not feed or ensile treated forage.
	Comite EC	1 1/2 - 2 lb/acre	Do not apply within 28 days of harvest. May cause spotting of pods.

* EPA has classified this insecticide as a restricted use pesticide. Restricted use pesticides are to be applied by certified pesticide applicators only.

Harvesting Dry Beans

Dry bean harvesting operations usually include pulling, windrowing and combining from the window or straight combining. Harvest and handle beans at the 15 to 18 percent moisture level to minimize splitting and seedcoat damage. Harvesting at lower moisture levels may result in an excessive percentage of split beans and checked seedcoats. Beans with checked seedcoats may split with further handling. Beans with less than 5 percent checked seedcoats may be marketed at a premium. In both the field and in the windrow, navy beans tend to lose moisture more rapidly than pinto beans.

Harvest dry beans before killing frost in the fall. Frozen immature beans are difficult to separate in processing, while unfrosted immature bean seeds will shrink when drying and can be separated.

Dry beans are ready for harvest when some of the pods are dry and when the majority of them have turned yellow. The nearly mature dry beans in the yellow pods will continue to ripen after they are cut. Too many dry pods at harvest will result in heavy shattering. Dry bean cutting and windrowing may be done at night or early in the morning when the plants are damp with dew in order to reduce shattering loss. All types, but especially white types, require a harvest period relatively free from rain to avoid seed discoloration.

Pulling and Windrowing

Dry beans may be pulled and windrowed in two separate operations or as a single operation. Blade type pullers normally are used to lift the crop from the soil. Pullers and windrowers are available as two-, four-, six-, and eight-row units. The number of rows to be placed in one windrow will depend upon the density of the crop and the size of combine used. Leave beans in the windrow only long enough for the lower stem and attached row parts to dry sufficiently for combining. The bean windrower can also be used when necessary to relocate windrows on clean, dry ground following a rain. Put bean plants in fluffy windrows, free of clods, stones, and dirt.

Bush type beans may be harvested with a straight-cut attachment on a combine. It is usually best to use the flexible cutter-bars and pickup reels. These operate much closer to the soil and save considerably more seed.

Special row crop headers are also available that can be used to straight cut bush type beans.

Combine Operation

Grain combines are frequently used for harvesting edible beans. Growers with large acreages use special bean combines. They usually have two cylinders specifically designed for bean threshing and special separating and cleaning units. Grain combines with spike-tooth cylinders are usually preferred over rasp bar cylinders as they tend to produce more aggressive threshing action without causing excessive seed breakage.

Rasp bar cylinders can work for beans, and the new rotary combines are very good. Rotaries tend to cause less impact on the seed, causing less seed crackage. Tests have shown significantly lower cracked and broken beans.

Combining should begin when beans reach 18 percent moisture content. Combine cylinders should be run only fast enough to do a complete threshing job. Some machines may need special speed reducers to obtain proper speed. High cylinder speeds and allowing the seed to become too dry substantially increases seed cracking and splitting. When beans are at 18 percent moisture, the cylinder should be operating at about 300 to 450 rpm. Under dry conditions a cylinder speed of 200 rpm may be necessary to prevent cracking. It is usually desirable to reduce the cylinder speed as the day progresses to compensate for additional drying. Maintain as great a concave clearance as possible and still do a good job of threshing. Initial concave settings should be 1/2 inch at the front and 1/4 inch clearance at the rear. As beans dry down, these settings should be increased. Check your operator's manual for recommended cylinder speed and concave setting. Manufacturer's recommendations apply to average or normal conditions and may require variation to meet specific field conditions.

It may be necessary to harvest only in the morning and evening when the pods are tough in order to hold shattering losses to a minimum and reduce the number of split beans and checked seedcoats. Crowd the combine cylinder to near maximum capacity without overloading. To do this, either use a faster travel speed or put more rows in the windrow. The additional straw going through the threshing mechanism will help cushion the beans and prevent damage.

Set the adjustable chaffer at 5/8 inch and the sieve at 7/16 inch. This should allow the threshed beans and some hulls to fall through the chaffer and the cleaning sieve will allow only threshed beans to fall through to the grain auger. Use a relatively high fan speed and direct the blast toward the forward one-third of the cleaning shoe. Check your operator's manual for specific recommendations. Check the tailings return periodically to note the quantity and composition or the material being returned to the cylinder for rethreshing. Any appreciable quantity of threshed beans in the tailing return indicates that the adjustable chaffer is set improperly. Completely threshed beans returning through the auger for rethreshing will increase the amount of split beans and checked seedcoats.

Check the grain tank for dirt and foreign material and for beans that are split or have checked seedcoats. Excess dirt and chaff generally indicate that the adjustable sieve is adjusted too wide or that the fan blast is inadequate or improperly directed. Excessive check and splits generally indicate one or more of the following:

1. The cylinder speed is too high.
2. The cylinder concave clearance is too small.
3. Too many concave bars or grates are being used.
4. Too many completely threshed beans are being returned through the tailings system.

Most combine manufacturers have a number of optional accessories available for use on beans. These usually are bean sieves, screens placed in the grain pan and along elevator tubes. These help to remove dirt and foreign material from the beans.

Always handle field beans carefully. Avoid dropping beans from great heights in unloading and handling. Beans check and crack when dropped, particularly on hard surfaces and when dry. Cushion or deflect fall of beans whenever possible. Keep elevator flight chains snug so that flights do not ride on beans.

Seed Certification

The purpose of all seed certification is to maintain and make available to the public high quality seed. Certified varieties are produced, handled and distributed to ensure proper identity and genetic purity. With dry edible beans, one of the main purposes of seed certification is to ensure low levels of seed-borne diseases. These diseases, which can cause serious losses, are bacterial bean blight, common bean mosaic, anthracnose and wilt.

All the major dry bean producing states have seed certification programs aimed at assuring the commercial grower seed of high genetic purity, low levels of serious seed-borne diseases and high mechanical purity. The North Dakota, Minnesota, Michigan, Idaho, Colorado, California, Nebraska and Wyoming seed certification agencies have all had experience with field inspection and seed certification of dry beans.

Bean disease organisms grow best in moist, warm environments and do not multiply well in dry colder environments. Historically, the majority of bean seed has been produced in the arid Western states where furrow irrigation is used and where humidity is usually low. The successful production of certified seed can be increased by implementing the following precautions. 1) Purchase foundation or registered seed. 2) Plant only certified seed and ask neighbors to only plant certified seed on bean acreage for other than seed purposes. 3) Plant on land that has not had dry beans on it for the three preceding years. There are areas in western and central North Dakota that are better suited to produce quality dry bean seed because of lower humidity and isolation from other beans. Many good seed producers in those areas are adding dry beans to their list of crops grown as certified seed. The North Dakota dry bean industry may be better served with a portion of its seed needs filled with quality North Dakota grown certified seed. North Dakota certification officials make two inspections per year, one during flowering and the second when pods are nearing maturity but most of the leaves are still on the plant.

North Dakota seed standards include a requirement that seed lots from fields which passed inspection also pass a bacterial bean blight test in the laboratory before harvested seed can be tagged with the official certification tag. This laboratory test is highly sensitive and is used to test North Dakota-produced certified seed for seed-borne bacterial blight. North Dakota dry bean certified seed standards are of comparable or better quality seed standards than the certification standards of surrounding states.

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