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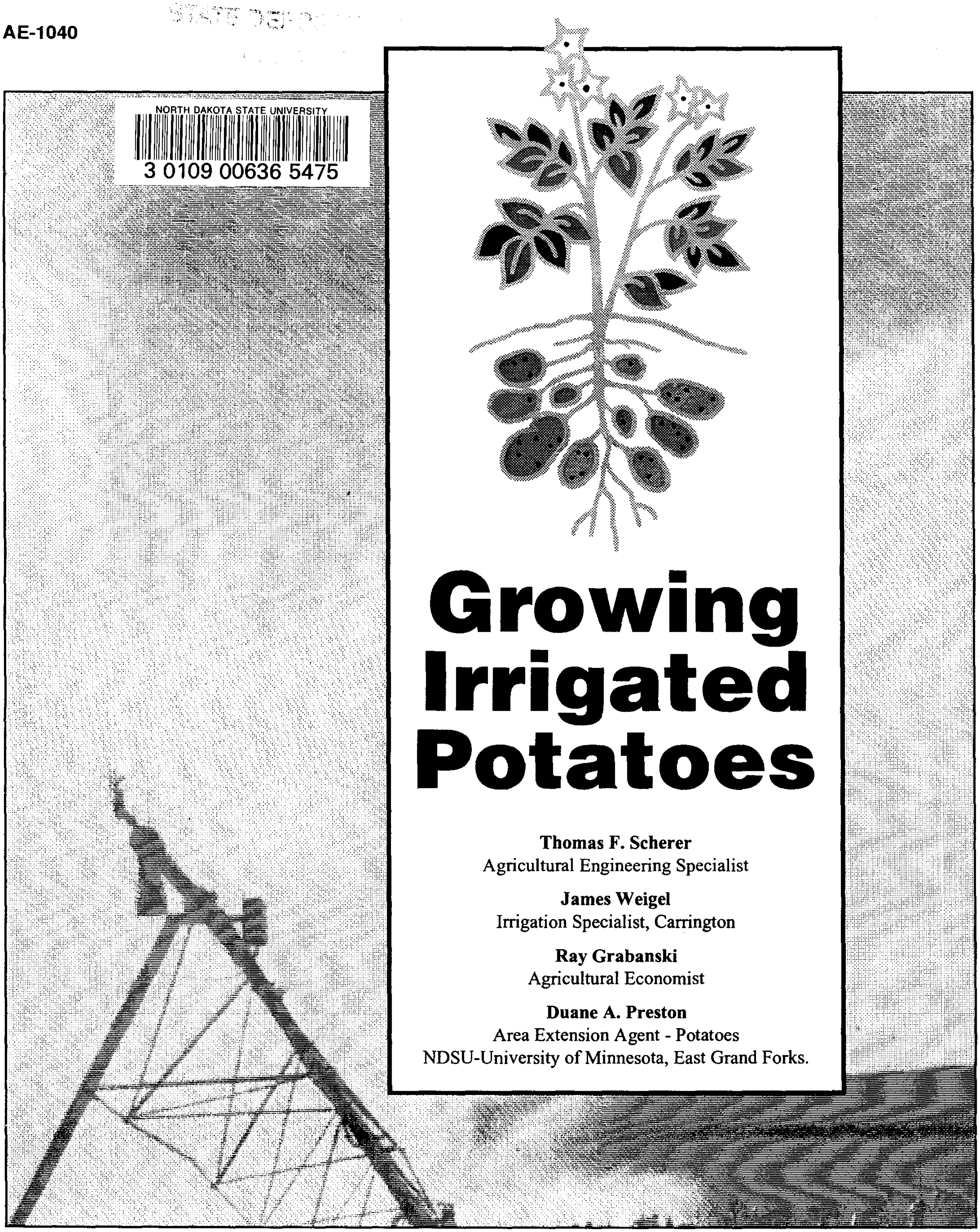

Growing Irrigated Potatoes

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■ Production Considerations

Production of irrigated potatoes requires specialized equipment and a substantial capital investment. Before investing in this enterprise, the following questions must be considered:

1. Is your soil type suitable for irrigation?
2. Is there an adequate water supply for irrigation?
3. Can the proper water permits be obtained for the potential irrigable land?
4. What potato production and irrigation machinery will have to be purchased?
5. Do you have potato production experience? Irrigation experience? If not, do you have potato production or irrigation consulting services available?
6. Do you know how to market your potatoes (which can include forward contracts, an adequate sales outlet, trucking and transportation, storage, and a potato broker)?
7. Have you determined the profitability of the other crops in your irrigated cropping rotation?

Before going into irrigated potato production, you should not only be knowledgeable about the cultural aspects of potato production, but equally knowledgeable about the economic aspects, which include fixed investments, labor and operating capital requirements, price risk, potential annual costs and returns, market grading criteria, storage requirements, delivery expectations and marketing alternatives.

■ Planting Season

The planting season for potatoes extends from about April 15 to June 15, though planting on light textured soils in southeastern North Dakota may be as early as the first week of April. In general, late varieties used for processing and early maturing varieties for the fresh market should be planted first. Early maturing table varieties destined for storage may be planted in late May or early June.

■ Varieties

Potato yield response to irrigation will vary depending on whether they are short season or long season varieties. In general, the full season varieties will show the greatest response to irrigation. Most varieties that have performed well under dryland conditions also perform well under irrigation. Market demand will generally dictate the selection of a variety or varieties to grow.

There are three types of potatoes grown under irrigation: smooth red skinned varieties (used primarily for the fresh market), smooth white skinned varieties (used in processing; chips, French fries, and dehydrated products), and russet skinned varieties (used for the fresh market, processing and dehydrated products). Within each of these types there are early and late maturing varieties.

A desirable characteristic for potatoes used in processing is a high percentage of total solids. Depending on the variety, total solids can range from 16 to 21 percent. For many varieties, the percentage of total solids is often one to two points lower under irrigation than under dryland conditions. Russet Burbank, however, maintains about the same level of total solids under both irrigated and dryland conditions.

Due to the high percent total solids, good storage characteristics, and appropriate shape, the Russet Burbank variety is the most popular variety grown under irrigation. However, other varieties were higher yielding on irrigated potato trials.

Yield Potential

Irrigated potato variety trials have been conducted on light textured soils (sands and loamy sands) in various areas of North Dakota since 1941. The first trials were begun at the Williston Research Center. From 1975 through 1986, the trials were conducted at the Karlsruhe irrigation site where the 12-year average for all varieties was 294 hundredweight per acre (cwt/ac). Irrigated trials were begun at the Carrington Research and Extension Center in 1989. Irrigated variety trials have been conducted at the Oakes Research Test Area since 1987 and, as shown in Table 1, contain many current variety favorites.

The major advantages of irrigated potato production are higher yields, earlier production and drought protection. Yields of potatoes grown under irrigation in North Dakota have averaged about double those of dryland potatoes. From nine years of NDSU experiment station variety trial research prior to 1989, average yields on irrigated potatoes were 321 cwt/ac, with a high of 463 cwt/ac and a low of 188 cwt/ac. This compares with a statewide dryland average of 159 cwt/ac from 1980 to 1988, with a high of 185 cwt/ac and low of 115 cwt/ac.

Table 1. Oakes Irrigation Potato Variety Yield Trials (cwt/acre)*.

Variety	Color	1987	1988	1989	1990
Norchip	White	491	450		
Norkotah	Russet	521	425	430	437
Norgold	Russet	516	394		
Norking	Russet	419	348	373	438
Russet Burbank	Russet	397	315		467
Shepody	Russet	502			657
Viking	Red	524	375		
Red Norland	Red	503	360	438	622
Reddale	Red		414		
Red Pontiac	Red			515	779

* These yields are from small research plots and may not reflect what can be obtained on larger acreage. The results do demonstrate the variation in yields by year and variety.

Marketing

It is important to establish a marketing plan before planting potatoes. This may mean contract growing for a processor, an arrangement to sell through a marketing association or broker, or gambling on the open market at the end of the growing season.

The major markets for potatoes are for the process potato market, the fresh market and for seed. Seed production is the most technically demanding because of the need to meet rigid disease-free standards for certification.

In recent years, the main demand for irrigated potatoes has been for French fries where processors prefer the Russet Burbank variety. Proper irrigation management can produce a uniform russet potato shape which is long and consistent. Also, the total solids or potato density can be maintained such that high quality French fries can be produced with minimum waste.

A large portion of the potatoes used for processing are grown under contract, which reduces the risk involved in marketing but also limits the possible profit. Without a contract, there is a risk of not finding a market after incurring costs around $1100/acre. From 1985 to 1989, North Dakota potato prices fluctuated from a low of $2.65/cwt in May/June of 1986 to a high of $10.60/cwt in May 1989. Price fluctuations of this magnitude emphasize the need for managing price risk through some type of forward contract before incurring the large capital investment required with irrigation.

■ Production and Cultivation Practices

Seed bed preparation before planting will be determined by the previous crop in the rotation pattern. Occasionally, during dry years with no snowfall and little spring rain, a pre-plant irrigation will be required to facilitate planting and emergence of the potatoes.

Seeding Rate and Depth

The amount of seed needed for planting depends on variety, distance between rows, the spacing within rows and the size of the seed pieces (Table 2). Seed pieces should be cut from tubers no larger than 10 ounces for round varieties and 12 ounces for Russet Burbank. Seed pieces cut from smaller tubers are more uniform in size, give better plant stands and usually more tubers per hill.

A healthy 1.5 to 2 ounce seed piece is considered best to establish a vigorous plant. Plants from seed pieces smaller than 1.5 ounces are generally slower to emerge and have less vigor. Small seed pieces are also more likely to decay before the plant becomes established. Seed pieces cut larger than 2 ounces result in higher seed costs with little potential benefit.

Irrigated potatoes can be spaced closer within the row than under dryland conditions. Seed spacing is based on varietal characteristics such as tuber-set, resistance to hollow heart and resistance to the development of misshapen tubers. Wider spacings (10 to 12 inches) are recommended for varieties with heavy tuber-set, smooth tubers, and those that are resistant to the development of hollow heart and misshapen tubers. Closer spacing (8 to 10 inches) is recommended for varieties with poor tuber-set to reduce the

Table 2. Quantity of seed potatoes needed to plant an acre of potatoes with different seed piece sizes and spacings (cwt).

Distance between rows (inches)	Distance between seed pieces (inches)	1 1/2 ounces	Average Seed Size 1 3/4 ounces	2 ounces	2 1/2 ounces
		(cwt)	(cwt)	(cwt)	(cwt)
36	8	20.4	23.8	27.2	30.6
	10	16.3	19.0	21.8	24.5
	12	13.5	15.8	18.1	20.4
38	8	19.3	22.6	25.8	29.0
	10	15.5	18.1	20.6	23.2
	12	12.9	15.0	17.2	19.3
40	8	18.4	21.4	24.5	27.6
	10	14.7	17.2	19.6	22.1
	12	12.3	14.3	16.3	18.4

number of oversized tubers. Hollow heart is caused by excess moisture and excess nitrogen which results in very rapid growth of the tuber. Since a potato grows from the inside out, a hollow center can result from this rapid growth, thus the name hollow heart. Close spacing is an effective way to reduce hollow heart.

Generally the center of the seed piece should be planted 2 to 4 inches below field level and covered with 2 to 3 inches of soil. Shallow covering usually results in quicker emergence, less seed decay, less blackleg and less rhizoctonia attacking the sprouts. However, the best seed depth will vary somewhat with soil moisture and temperature. Moist soil temperatures averaging from 50 to 60°F favor wound healing in the soil with minimum seed decay. Very deep planting may result in poor wound healing leading to seed decay, particularly if heavy rains follow planting.

Weed Control

Weeds reduce potato yields by competing for water, nutrients and light. Also, certain weed species can cause difficulty in harvesting, release toxins that inhibit crop growth and harbor insects, diseases or nematodes that may attack potatoes.

An effective weed control program includes environmentally sound cultural, mechanical and chemical weed control methods. Crop rotations, cultivation and the use of different herbicides help avoid the buildup of resistant weed species. Certain herbicide residues from previous years can damage potatoes. Use a planned weed control program and avoid herbicides that will injure or reduce growth of subsequent crops. Always read the pesticide label for information on crop rotations and intervals.

Tillage and herbicides are the two primary means of controlling weeds in potatoes. Cultivators, harrows and rotary hoes are commonly used. The first tillage operation after planting is usually a "blind" cultivation or harrowing before the crop emerges. The number of tillage operations will vary, but three cultivations and two harrowing operations are common.

After emergence, inter-row cultivation is used to control weeds and to form a ridge or hill over the seed-piece and developing tuber. Besides controlling weeds, the ridge or hill helps protect tubers from sunburn (tuber greening), late season frosts, excessive rainfall or irrigation and reduces the amount of soil to be moved at harvest. One danger of excessive cultivation and deep cultivation of potatoes is root pruning. Potatoes are a shallow rooted crop, with roots growing laterally 10 to 18 inches and downward to a depth of 3 feet. Root pruning may be a problem with late cultivations, reducing the overall growth potential of the potato plant.

A recent survey indicated only 37 percent of the potato acreage (dryland and irrigated) was treated with an herbicide for weed control. The percentage of treated acreage should increase in the years ahead as many producers attempt to reduce the number of tillage operations.

Herbicides labelled for injection into irrigation systems and recommendations for use in the control of weeds in potatoes can be found in NDSU Extension Circular W-253 (Revised), the current year's Agricultural Weed Control Guide, or the current years NDSU Crop Production Guide.

■ Fertilization

A potato crop makes a large demand on the soil for nutrients. The amount a 300 cwt/ac crop of potatoes will use depends on potato variety, climate, soils, and irrigation system management. The average nutrient demand is:

Nitrogen	200 lbs.
Phosphorus ($P_2 0_5$)	60 lbs.
Potassium ($K_2 0$)	300 lbs.

One-third to one-half of these nutrients are found in the vines and returned to the soil. The remainder is removed with the harvested tubers and must be replaced. The partitioning of nitrogen in a potato plant as it occurs during the growing season is shown in Figure 1. Other nutrients are seldom found to be deficient for potatoes in North Dakota soils unless the soil is very sandy or the pH tests above 8.0. Land that has been leveled can be deficient in zinc.

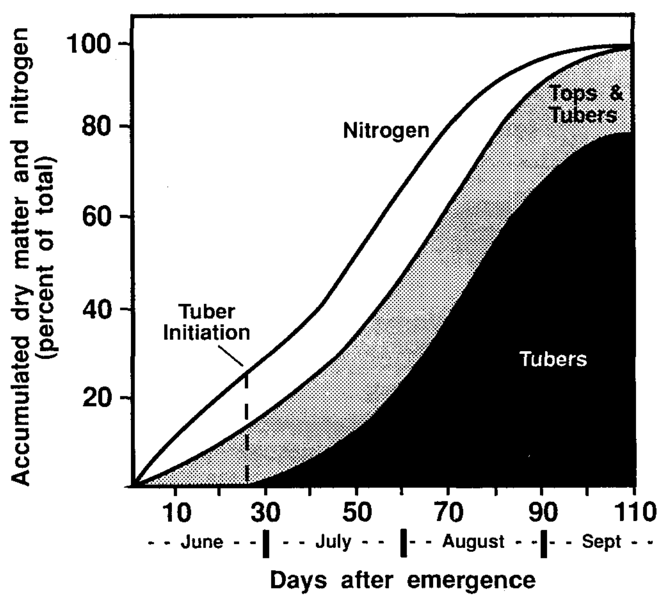

Figure 1. Nitrogen uptake of potatoes in relation to dry weight accumulation. (Adapted from Saltanpour, *American Potato Journal*, 46:111-119, 1969.)

Soil Testing

The best way to determine the amount of fertilizer to apply is by a soil test. Fields should be tested every year for nitrate-nitrogen and every two to four years for phosphorus and potassium. Recommendations for nitrogen, phosphorus and potassium based on soil test results are shown in Table 3.

Fertilizer Application

Application of all the required nitrogen in a single preplant operation is inefficient for irrigated potatoes. Fertilizing to achieve maximum utilization of nitrogen in potatoes on irrigated sandy ground requires split applications. A rule of thumb would be 80 to 100 pounds per acre of nitrogen applied preplant and the remaining nitrogen needs applied as urea or 28 percent liquid solution at hilling. Additional nitrogen becomes available to the plants through soil nitrification during the growing season. This occurs at about 15 pounds per acre per warm season month. Based on plant analysis, additional nitrogen may be applied through the irrigation system. Studies on irrigated potatoes at the Oakes Research site show little to no advantage of applying more than 200 pounds per acre of total nitrogen to reach optimum yields.

All fertilizer products can be used in potato production. Dry product blends that match soil test needs and are broadcast applied prior to seedbed preparation offer management and application convenience. Also, during the hilling operation, the fertilizer is moved to the row with the soil which concentrates nutrients in the active root growth zone. Equal management convenience can be obtained with a variety of fertilizer products that are sidedress applied in bands that the root system intercepts early in the vegetative growth stage.

Petiole Sampling for Nitrogen Management

Petiole sampling to determine the nitrogen status of the potato plant during late vegetative growth and tuber bulking can be an effective tool for both high yield production and groundwater nitrate contamination protection. The petiole is that part of the potato plant connecting the leaf blade with the stem.

Nitrogen demand during vegetative growth, the three to four weeks after seeding, is high. Uptake is rapid and nitrogen stored in vegetative growth later translocates to the tubers. However, lysimeter studies at the Oakes research site have shown that from April to early May, 43 percent of yearly drainage and 37 percent of annual nitrate loss takes place. Hence, preseason nitrogen fertilization that exceeds growth needs during this period increases the risk of drainage loss. Petiole analysis can help manage crop nitrogen needs under high leaching potential, irrigated potato production.

Petiole samples should be taken several times during the growing season, ideally once per week. This helps establish petiole nitrate trends. Soil samples to a depth of 18 inches should be taken in conjunction with the petiole samples and analyzed for soil nitrate levels.

Petiole nitrate analysis at the end of vegetative growth should be about 25,000 parts per million (ppm). During tuber bulking, petiole nitrate should be maintained above 15,000 ppm through either sidedressings or nitrogen application through the pivot. This will assure rapid, uniform tuber growth when other crop growth stresses are avoided. Petiole nitrate levels at which yield declines occur decrease as the season progresses. Early in the tuber bulking period, petiole nitrate levels as low as 14,000 ppm can occur with recovery and without yield loss. However, knobby tuber growth and lowered marketing quality may accompany growth recovery. Petiole nitrate levels below 10,000 to 12,000 ppm early in the tuber bulking season prompt early leaf senescence. Leaf dying or senescence promotes early maturity and the end of tuber growth.

Table 3. Nutrient recommendations for potato.

			Soil Test Phosphorus, ppm					Soil Test Potassium, ppm				
Yield goal	Soil N plus fertilizer N required	Bray-I / Olsen	0-5 / 0-3	6-10 / 4-7	11-15 / 8-11	16-20 / 12-15	21+ / 16+	0-40	41-80	81-120	121-160	161+
cwt/a	lb/acre-2'		lb P_2O_5/acre					lb K_2O/acre				
200	80		90	65	40	10	1	150	105	65	20	0
300	120		135	95	55	15	0	225	160	95	30	0
400	160		180	125	75	25	0	300	210	125	40	0
500	200		225	160	95	30	0	375	265	155	50	0

Subtract the amount of nitrate-nitrogen in the top 2 feet of soil from the N figures to determine the amount of nitrogen to apply. The N figures were determined from soil samples taken between September 1 and April 1.

Fertigation

Using a pump to inject a measured amount of liquid fertilizer into the flow of water is know as fertigation. Application of fertilizer through the irrigation system should be accomplished using equipment approved by state mandated rules and regulations. Backflow protection equipment must be installed at the main water pump.

Injection pumps which use either pistons or a diaphragm are available. The piston pumps have a larger capacity and are generally used for injecting liquid fertilizer. They are available with either a single or double piston and range in capacity from less than 1 to over 300 gallons per hour (gph). The most common have a maximum capacity of 18 gph using a single piston and 36 gph with a double piston. Diaphragm pumps can inject chemicals with precision and are best suited to injecting smaller amounts of chemicals.

To accurately determine the amount of nitrogen fertilizer to apply, the grower needs to know the fertilizer formulation, the number of acres irrigated and the number of hours to complete the irrigation. The injection pump should be calibrated and checked regularly to ensure it is injecting the desired amount of fertilizer.

Anhydrous ammonia should not be injected into irrigation systems pumping high bicarbonate (HCO_3) level water. It will generally cause an ammonium carbonate (NH_4CO_3) precipitate that will plug sprinklers and could cause the system to collapse. Liquid urea (20-0-0) and urea-ammonium nitrate (28-0-0) are preferred nitrogen sources for fertigation.

Residual Nitrogen Carryover From Crop Rotation

With a good crop rotation, a certain amount of residual nitrogen will be carried over for use by potatoes. Potatoes following any legume such as soybeans, alfalfa, dry beans, and clover will benefit. Potatoes following corn, small grains or sugarbeets may not inherit much residual nitrogen. Soil sampling before planting will indicate how much residual nitrogen is left in the soil.

Groundwater Protection

The key to substantially minimizing risk to surficial aquifers is controlled management of inputs. Results from many studies indicate that groundwater contamination occurs when nitrogen fertilizer, pesticides, and water are not well managed. Excessive application and poor timing are regarded as the main causes. This type of management is not economical, nor does it protect vulnerable water resources. Irrigated agriculture offers significant opportunity for controlled application of inputs.

The need to follow practices that utilize water and nitrogen efficiently is particularly important for the safety of drinking water supplies. Producers can maintain yields and protect surficial aquifers by matching pesticides, nitrogen and water to potato crop needs at different growth stages.

■ Pest Control

Irrigation not only improves the yield and growth potential of potatoes but also increases the number of pests that feed on them. The timely application of water during the growing season provides an almost ideal environment for weeds, insects and disease organisms, so the effort to control these pest may be greater than under dryland conditions.

Insects

The insects affecting potatoes in North Dakota are primarily aphids, Colorado potato beetles, potato flea beetles, wireworms and leafhoppers. The application of a systemic insecticide at the time of planting will usually control these insects through the middle of July. If insects become a problem after the middle of July it may be necessary to apply foliar sprays. Insecticides can be applied by aerial application or, if labelled, can be applied through the irrigation system.

It should be noted that the Colorado potato beetle has developed a high degree of resistance to the synthetic pyrethroid insecticides, so they may not provide reliable control. In situations where poor control has occurred with this class of insecticides, growers are advised to switch to another class of insecticide such as an organophosphate or carbamate compound. More information on insect control can be found in NDSU Extension Bulletin E-881, Potato Insect Control, and the current year's NDSU Crop Production Guide.

Disease

Potatoes should not be grown more often than every three years on the same piece of land. This will reduce carryover of potato leaf diseases such as early blight and late blight. Potatoes should be monitored in late June for both early and late blight. Early blight is the most common disease on potatoes. Fungicide applications should begin when early blight is beginning to show up on the lower leaves of the plants.

Late blight can cause the greatest losses. When conditions are favorable for its development, this organism may infect plants at any time following emergence. Late blight only occurs with extended periods of cool weather. It can spread rapidly and is very destructive. Prompt action is essential when this disease is detected.

Foliar fungicides can be used to control these diseases by preventing the entry of the fungus into the plant. To have the maximum effectiveness, fungicides must be on the foliage before the fungus spores contact the leaves. Labeled fungicides can be applied through the irrigation system. Information about fungicides can be found in the current year's NDSU Crop Production Guide or the current year's Plant Disease Control Guide.

Short rotations of potatoes and dry beans should be avoided. Pythium, which causes leak in potatoes, causes a root rot in dry beans. Pythium is favored by wet, hot soil conditions, so it is more likely to be a problem under irrigation. Potatoes can be infected with white mold. However, this disease is usually no problem except when rotated with dry beans under irrigation or seeded on white mold infected sunflower ground.

Irrigation Requirements

The potato exhibits sensitivity to moisture stress over much of the growing season. High yields and high quality production are achieved by maintaining relatively high available moisture levels. The average seasonal water use for potatoes is near 18 inches. The average daily water use, cumulative water use and rooting depth are illustrated in Figure 2. Water use rates begin at about 0.04 inches per day when the crop emerges. The use rate increases to over 0.24 inches per day when the crop completely shades the ground. As the potatoes achieve full tuberization, water use will decrease. The frequency and amount of irrigation will depend on the water-holding capacity of the soil, the crop growth stage, and the prevailing weather conditions.

Water-Holding Capacities of Soil

The water holding capacity of the soil has a great influence over when and how often irrigations are required. Different textures of soil have different available soil water-holding capacities. The variation in water-holding capacities of general soil textures is shown in Table 4. Note that the more water a soil has available to the plant, the less frequent the irrigations should be. For example, the potatoes are using 0.2 inches of water per day and you want to irrigate when the root zone moisture depletion reaches 40 percent. For a sandy loam soil (using an 18 inch rooting depth) that holds 1.5 inches of water per foot, you would irrigate every four to five days. For a fine sandy loam that holds 1.9 inches per foot, you would irrigate every five to six days but have to apply a larger amount of water than on the sandy loam soil.

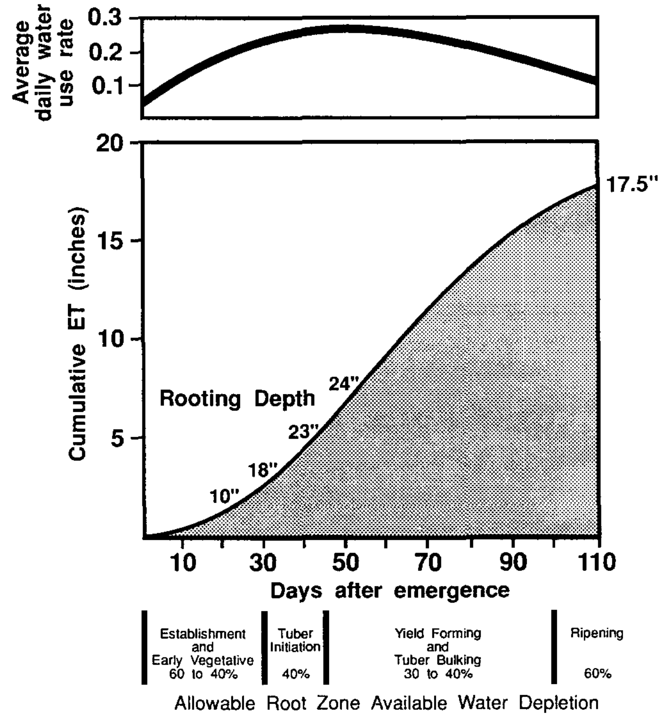

Figure 2. Seasonal evapotranspiration and irrigation management criteria for potatoes. (Adapted from Stegman, NDSU Research Reports)

Table 4.Approximate Available Soil Moisture Holding Capacities for Various Soil Textures.

Soil Texture	Available Moisture Inches/Inch	Available Moisture Inches/Foot
Coarse Sand and Gravel	0.04	0.5
Sand	0.07	0.8
Loamy Sand	0.09	1.1
Sandy Loam	0.13	1.5
Fine Sandy Loam	0.16	1.9
Loam and Silt Loam	0.20	2.4
Clay Loam and Silty Clay Loam	0.18	2.1
Silty Clay and Clay	0.16	1.9

To show how the number of days between irrigations is calculated for the sandy loam soil, multiply the 1.5-foot rooting depth by 1.5 inches per foot water-holding capacity. This gives a total of 2.25 inches of available water in the root zone. Next multiply the 2.25 inches by .40 (40 percent depletion) which gives 0.9 inches of water that can be depleted. Now divide the 0.9 inches by the 0.2 inches that is being used each day and that gives 4.5 days. This calculation assumes you are starting with a root zone that is at its maximum water-holding capacity, generally referred to as its "field capacity."

Effective Rooting Depth

Potatoes are a shallow rooted crop. Typically, roots grow laterally 10 to 18 inches and downward to a depth of about 3 feet. Root extension to this depth is usually completed within 30 days after plant emergence. Root distribution is heavily concentrated near the soil surface. About 90 percent of the roots will be found in the top 2 feet. Irrigation timing and amount should be based on the soil moisture depletion in the top 12-18 inches of coarse textured soil profiles and in the top 18 to 24 inches of finer textured soil profiles.

Growth Stages

The growth, development and water requirements of the potato plant can be divided into the following four stages:

VEGETATIVE. This stage of growth begins after planting when the eyes break dormancy and produce sprouts. This stage has a duration of 15 to 30 days and ends prior to tuber initiation. Stored soil moisture and spring rains are usually sufficient during this period to provide adequate moisture for proper development. However, soil moisture monitoring should be started soon after emergence. For disease control, irrigation should be avoided between planting and emergence. If the soil is dry prior to planting, irrigate before planting rather than after.

TUBER INITIATION. This stage of growth begins when tubers develop at the stolon tips. Approximate duration of this stage is 10 to 14 days. Stored soil and spring moisture supplies are usually adequate during this period. However, soil moisture levels should be watched closely because water stress during this period can reduce the number of tubers produced per plant.

TUBER BULKING. A constant rate of increase in tuber size and weight occurs during this stage, unless a growth-limiting factor is present. This stage can last from 60 to over 90 days, depending on the length of the growing season and presence of pathogens. **Tuber size and quality is closely related to moisture supply in this period.** Research has shown that the total yield of potatoes is most sensitive to water stress during mid-bulking. Mid-bulking occurs three to six weeks after tuber initiation. However, water stress any time during this period will have an effect on the total yield. Tuber growth is retarded by moisture stress and does not resume uniformly when moisture again becomes available. New growth and enlargement will take place at the top end while the other portions of the tuber remain stunted. Thus, especially in some long tuber varieties, constricted areas develop that are related to the stage of tuber growth at the time the moisture stress occurred. Other deficiencies in quality such as growth cracks and knobbiness are also related to moisture stress followed by periods of adequate or surplus moisture.

MATURATION. This stage of growth begins with canopy senescence. Older leaves gradually turn brown and die. This condition spreads throughout the vines and leaves eventually resulting in canopy loss. Tuber growth rates are lower than during tuber bulking. Potato plants require less water for tuber bulking during this stage because of reduced evapotranspiration from the dying leaves.

Irrigation Scheduling

Scheduling of irrigations using rational or scientific methods is essential to good irrigation management. Over the years, a number of scheduling methods along with appropriate decision criteria have been developed. Soil sampling using the feel method is probably the most common method of scheduling. However, mechanical devices which measure soil moisture potential such as tensiometers and soil moisture blocks have proven to be accurate, reliable and inexpensive. Electronic methods which measure soil moisture levels based on the changes in electronic properties of the soil are also available.

An irrigation scheduling procedure called the "checkbook" method has also been used successfully. The checkbook method is a soil moisture accounting method using potato crop water use values along with soil water-holding capacities to predict the time and amount of water needed to replenish what has been removed from the root zone. This method is available in North Dakota in either manual or computerized versions.

■ Harvest Considerations

Maturity and Vine Killing

Potatoes are considered mature when they have reached a good marketable size, separate easily from the stolons and can be harvested with a minimum amount of tuber skinning. Tubers generally do not mature until after the vines die. However, with the use of fungicides and insecticides, plants usually remain green until frost. It is usually necessary to kill the plants by applying vine desiccants or rotobeating in order to harvest early and extend the harvest season. Early termination of the plants is also used to control tuber size or supply early markets. Maturity is hastened by spraying plants 10 days to three weeks before harvest with a chemical desiccant. The desiccants currently labelled for use on potatoes can be found in NDSU Extension Circular W-253 (revised), the current year's Agricultural Weed Control Guide.

Irrigation for Bruise Control

Bruising of harvested potatoes is becoming an important concern to the fresh pack and processing companies. Descriptive terms such as blackspot, shatter, cracking and pressure bruising are all used to identify potato tuber injury. Although most bruising is caused by mechanical handling during harvest and transportation, research has shown that irrigation can be used to reduce bruising during the harvesting process. On sandy soils, a soil moisture content between 60 and 80 percent of field capacity (40 to 20 percent depletion) provides conditions for a desirable soil load into the harvester with optimum separation of potatoes and soil and minimum tuber damage. If the soil is dry before harvest, a final irrigation should be applied at least one week prior to harvest to raise the soil moisture content and also raise the tuber hydration level. Air temperature also has a significant effect on bruising. Harvesting when the tuber temperature is less than 45°F will increase shatter and cracking of the tubers.

■ Economic Analysis

A procedure to estimate the potential costs and returns resulting from the commercial production of potatoes is provided in Table 5. The figures in the budget represent estimated costs for irrigated production of high quality Russet Burbank potatoes. They reflect the level of expenses and returns to be expected based on the anticipated yield of the Russet Burbank variety and price of good quality potatoes for French fry processing.

The crop budget in Table 5 is estimated based on available information on production costs at the time of printing for this bulletin. **Farmers must project costs and returns based on their current farming operation.** The cost estimates will change from year to year, so they serve only as a guide.

Budgeting assumptions used for estimating costs of machinery, labor, and irrigation equipment are discussed below.

Machinery Costs

Machinery costs in this budget were determined by economic and engineering estimates based on an average farming industry use and costs for a specific machine.

The cost of required potato machinery and equipment in this budget is $138,780. This includes a six-row potato row marker ($12,860), a seed filler ($6,660), two 20-foot potato truck boxes ($27,300), a six-row potato planter ($36,765), a two-row potato harvester ($49,860), and a potato cultivator ($5,335). Other non-potato machinery that should be available on a traditional North Dakota crop farm includes tractors, tillage equipment, sprayers, trucks, and fertilizer handling equipment. Costs for non-potato equipment are also included in this budget.

The economic life of each machine is taken as 10 years. Salvage value at 10 years of life ranges from 16 to 30 percent according to the current agricultural engineer's yearbook. All machinery is assumed to be bought new and depreciated by the straight line method over its 10-year life.

The purchase cost for equipment is based on a survey of dealers, companies, and extension agents. The estimated annual use of a machine is based on the number of hours a typical commercial farmer would use that particular machine in one year. (Purchase cost, annual use, acreage covered, and cost per acre estimates are available in Bulletin AG-FO-2308, "Minnesota Farm Machinery Cost Estimates," available from your county extension agent or the NDSU Extension Agricultural Economics Department.)

For example, the two-row potato harvester is assumed to cover 240 acres, while the six-row planter covers 320 acres. Tractor use was estimated at 500 hours of use for less than 100 horsepower, 550 hours for 100 to 150 horsepower, 600 hours of annual use for 150 to 200 horsepower, and 500 hours of annual use for tractors over 200 horsepower. Machinery fixed costs are spread out over the assumed acreage or hours of use, which means these assumptions have a big effect on machinery costs/acre. When machinery covers more acres or is used more hours annually, costs per acre decline. If machinery covers less acres annually, machine costs will be more than the budgeted amount. However, per acre costs will be lowered by purchasing used machinery.

Interest and insurance rates are assumed to be 12 percent and 0.75 percent of new cost, respectively. Housing cost is assumed to be 33 cents per square foot of shelter space needed per year. Formulas used in the calculations on Table 5 are:

1. Depreciation per year = $\dfrac{\text{purchase cost - salvage value}}{\text{years you will use machine}}$

2. Interest per year = $\dfrac{\text{purchase cost + salvage value}}{2}$ X int. rate

3. Insurance per year = $\dfrac{\text{purchase cost + salvage value}}{2}$ X rate

4. Equipment Housing =
price per square-foot X square – feet of shelter space

Operating Expenses

Fuel use is calculated by multiplying fuel consumption by fuel price, with fuel consumption estimated to be .06 gallons of diesel fuel per horsepower hour. Price of fuel is $0.95/ gallon for diesel. All power units are assumed to be diesel powered. Lubrication cost is assumed to be 10 percent of fuel cost. Formulas for estimating repair and maintenance costs estimate total accumulated repair costs according to the accumulated hours of use; the total costs are then broken down to a per hour cost estimate.

Labor

Labor per acre is calculated by using the work performance rate on the implement. All labor is paid for in the production budget ($5/hour for unskilled, $8.25/hour for skilled labor), therefore positive returns represent returns to management and risk, not labor.

Irrigation Equipment

The following development costs are for a center pivot irrigation system covering 132 acres. One well is assumed to provide an adequate water supply of 800 gallons per minute for the system.

1. Irrigation system: $33,000 to $38,000 for full quarter section, 132-acre, center pivot system. Also included is a chemigation check valve, gate valve, flowmeter, pressure gauge and a chemigation pump with a storage tank.
2. Pipeline from the well to the pivot(s); an 8- or 10-inch pipeline is recommended to reduce the friction loss depending on the distance and capacity of the system.
3. Electrical wire for a safety circuit from the well to the pivot.
4. Power to operate the irrigation system:
   a) Electric drive - power cable, construction contracted with the local REC; or engine and generator ($2,500)
   b) Hydraulic drive - engine and hydraulic pump
5. Well costs: $12,000 to $18,000. Includes test holes and site selection, drilling, testing, and developing of well ($125 - $175/ft completed) plus screen and casing.
6. Pump and motor for the well: depends on depth to water, feet of lift, system pressure and capacity to be pumped. Electric power would be $13,000, Diesel power would cost $17,000 including gear head, fuel tank, etc.

Equipment costs are calculated using an annual straight line depreciation and a zero salvage value for a full quarter section (132 acre) system.

	New Cost	Est. Life	Per Acre Depreciation
Irrigation System	$38,000	15 yr.	$19.20
Pipeline & Wire	9,204	20	3.49
Deep Well	16,000	20	6.06
Pump and Motor	13,500	15	6.82
	$76,704		$35.57

Annual per Acre Interest on Average Investment is 10%.

Total Annual Fixed Costs: $\frac{\$76,704}{(2) \times (132)}$ X 10% = $29.05/acre

Depreciation and Interest: $35.57 + 29.05 = 64.62/acre

Additional Sources of Information

Potato Production and Pest Management in North Dakota and Minnesota, NDSU Extension Bulletin Number 26 (revised, 1991).

Seed Potatoes, Red River Valley Potato Growers Association, P.O. Box 301, East Grand Forks, MN, 56721.

Irrigation Handbook, Extension Agricultural Engineering Dept, NDSU.

Potato Insect Control, NDSU Extension Bulletin Number E-881.

Disease Control Guidelines for Seed Potato Selection, Handling and Planting, NDSU Extension Bulletin Number PP-877.

Agricultural Weed Control Guide, NDSU Extension Circular W-253.

Commercial Vegetable - Weed, Insect, Disease Control Guide: Potatoes, University of Minnesota, AG-FO-1879-C, Revised 1991.

Crop Production Guide, NDSU Yearly Publication (Current Year)

Table 5. Summary of Estimated Costs and Returns per Acre (1992).

		Irrigated Russet Potatoes for Processing			
ITEM	UNIT	PRICE	QUANTITY	AMOUNT	YOUR FARM
		DOLLARS		DOLLARS	
PRODUCT					
U.S. No. 1 Russet	cwt	4.50	325.00	1462.50	________
TOTAL PRODUCT VALUE				1462.50	________
DIRECT CASH EXPENSES					
FERTILIZER					
Nitrogen, Urea (46,0,0)	lb	0.20	128.00	25.60	________
Nitrogen, 28% Liquid	lb	0.23	32.00	7.36	________
Phosphorus P_20_5	lb	0.22	75.00	16.50	________
Potassium K_20	lb	0.10	125.00	12.50	________
Micro Nutrients	$	4.00	1.00	4.00	________
Soil Testing	$	0.65	1.00	0.65	________
Leaf/Petiole Testing	$	3.00	1.00	3.00	________
FUNGICIDES					
Fungicide	$	5.00	7.00	35.00	________
HERBICIDES					
Herbicide	$	9.00	3.00	27.00	________
INSECTICIDES					
Insecticide	$	15.00	1.00	15.00	________
CROP INSURANCE					
All crop insurance	$	50.00	1.00	50.00	________
MISCELLANEOUS					
Vine Killer (Spuds)	$	15.00	1.00	15.00	________
Add'l Liability Ins.	$	3.00	1.00	3.00	________
Spud Promotion Tax	cwt	0.05	325.00	16.25	________
Reload, Grade & Misc.	$	14.00	1.00	14.00	________
Chemigation	$	0.50	4.00	2.00	________
CUSTOM WORK HIRED					
Aerial Application	acre	4.00	6.00	24.00	________
Custom Hauling	$	81.25	1.00	81.25	________
SEED/PLANTS					
Russet certified	cwt	8.00	20.00	160.00	________
Custom Spud Cutting	cwt	0.75	20.00	15.00	________
Seed Disinfectant	cwt	0.45	20.00	9.00	________
HIRED LABOR					
Occasional labor	hour	5.00	3.60	18.00	________
UNSKILLED LABOR USED					
Self-propelled Eq.	hour		1.92		
Additional Labor	hour		1.51		
Center Pivot, Electric	hour		0.39		
FULL-TIME LABOR					
Tractors	hour		5.88		
Self-propelled Eq.	hour		0.20		
DIESEL FUEL					
Tractors	gal.	0.95	22.00	20.90	________
Self-propelled Eq.	gal.	0.95	4.82	4.58	________
ELECTRICITY					
Center Pivot, Electric	kwh	0.07	377.00	26.39	________

Table 5. Continued

				Irrigated Russet Potatoes for Processing	
ITEM	UNIT	PRICE	QUANTITY	AMOUNT	YOUR FARM
		DOLLARS		DOLLARS	
REPAIR & MAINTENANCE					
Tractors	acre	14.65	1.00	14.65	________
Self-propelled Eq.	acre	2.23	1.00	2.23	________
Implements	acre	23.72	1.00	23.72	________
Center Pivot, Electric	acre	0.42	13.00	5.46	________
INTEREST ON OP. EXPENSES	acre	0.12	652.05	18.22	________
TOTAL DIRECT CASH EXPENSES				670.27	________
RETURNS ABOVE DIRECT CASH EXPENSES				792.23	________
OVERHEAD EXPENSES					
Tractors	acre	46.89	1.00	46.89	________
Self-propelled Eq.	acre	9.98	1.00	9.98	________
Implements	acre	88.48	1.00	88.48	________
Center Pivot, Electric	acre	64.62	1.00	64.62	________
* Land Rental Value	acre	1.00	50.00	50.00	________
Allocated Full-time Labor	hour	8.25	9.90	81.68	________
TOTAL ALLOCATED OVERHEAD				341.65	________
TOTAL SPECIFIED EXPENSES AND COSTS				1011.92	________
RETURNS ABOVE SPECIFIED EXPENSES AND COSTS				450.58	________

* Land rental value reflects the value of undeveloped dryland use. Once the property is developed by perfecting water permits and constructing irrigation works, rental values would be set by competitive pressure for irrigated cropland.

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