Crop Profile for Potatoes in North Dakota

Prepared December, 2000

General Production Information

North Dakota ranks 6th in the United States in potato production:

- Approximately 5 % of the nation s potatoes are grown in North Dakota
- In 1996 producers planted 134,000 acres of potatoes and harvested 131,000 acres with a yield of 220 cwt/acre. The value of the 1996 crop was estimated at $135 million.
- In 1997, producers planted 125,000 acres and harvested 105,000 of those acres with a yield of 205 cwt/acre.
- In 1998, producers planted 126,000 acres of potatoes and harvested 122,000 acres with a yield of 235 cwt/acre.
- North Dakota produced 32,079, 29450, 24041 acres of certified seed potatoes in 1995, 1996, 1997 respectively.

Production Region

The main potato producing region in North Dakota is the Red River Valley. The northeast, east central, central and north central portions of the state comprising the major potato producing region. Irrigation is a common practice on the lighter soils of North Dakota. The primary cultivar grown under irrigation is the Russet Burbank Approximately one quarter of North Dakota s potatoes are grown on irrigated soils. North Dakota is also a producer of seed potatoes.

Cultural Practices

Producers are usually finished planting potatoes by June 1. Irrigated potatoes are planted by mid May. It is generally considered best in nonirrigated production to precede potatoes with small grains or fallow. Sugarbeets and potatoes should not follow each other in a rotation because of the depletion of soil moisture. This would substantially reduce yields of both crops. Common practice is to precede potatoes with a grain crop and a grain crop the two years directly after the potato crop, entirely excluding fallow from the rotation. Common practice in the Red River Valley is to fall plow, followed by two or more field cultivations and frequently a harrowing in the spring. Producers harvest potatoes from September to the end of October.

Irrigated potatoes of North Dakota are generally grown on coarse textured soils low in organic matter. Typically, these soils are characterized as sandy loams or loamy sands, low in native fertility, and quite acidic. These acres typically have a higher yield compared to non-irrigated potatoes.

Insect Management

There are many key pests of potato, fortunately relatively few occur in North Dakota and the Red River Valley. The Colorado potato beetle is the most serious pest found in North Dakota. Other potato pests occur sporadically. The aster leafhopper is of concern for producers who raise potatoes intended for chipping. A seed potato crop can be deemed unsuitable for seed potatoes because of the viruses transmitted by aphids. Wireworms potentially could be a problem for potatoes on light soils. Other insect pests would cause problems if it were not for the control measures being taken against the key pests. The major pests are discussed below. Insecticides used for controlling these pests and the estimated number of treated acres in 1996 are summarized in Table 1 (Zollinger, et al. 1998). Table 2 summarizes recent data for insecticide use obtained from a USDA-NASS survey on agricultural chemical use in fall potatoes (USDA-ARS, 2000).

Colorado Potato Beetle (*Leptinotarsa decemlineata*)

The Colorado potato beetle (CPB) is a constant threat as a defoliator in potato fields. Both the adult and immature forms feed on the foliage of the potato. CPB overwinter as adults and emerge in the spring with the developing potatoes. Overwintered adults feed, then lay eggs for the first generation. First generation larvae feed from early June to mid-July. Larvae develop into adults around mid-July. In North Dakota and the Red River Valley there is a second generation of adults that usually emerge towards the end of August. Insecticide control measures target the small larvae. They are the most susceptible to the insecticides, reducing the number of small larvae before they become large larvae. The larger larvae cause the greatest amount of defoliation. Resistance to chemicals is of concern to the producers of North Dakota. There are documented cases of CPB being resistant to the pyrethroid (Asana and others) and carbamate (Furadan) insecticides in North Dakota. When used, these classes of insecticides should be limited to once per season to reduce the possibility of a resistant population. Cultural control practices for CPB control are to distance potato fields from fields of the previous year by crop rotation. Current biological control practices that are commercially viable are the use of genetic engineered plants that contain Bt (*Bacillus thuringiensis*).

Leaf Hoppers

Potato Leafhopper (*Empoasca fabae*)
Aster leafhopper (*Macrosteles fascifrons*)

There are two leafhoppers commonly associated with potato fields in North Dakota, the potato leaf hopper and the aster leafhopper. The leaf hoppers overwinter in southern United States and are carried to the northern states by upper level winds. Aster leafhopper also overwinters in the egg stage, producing a local population. They build up their populations in alfalfa or grain fields before the potatoes have emerged in the spring. The potato leafhoppers can cause significant yield loss by feeding on potato sap. Most years they arrive late enough not to be of concern; other years, such as 1990 and 1999, they arrived early and needed to be managed with insecticides. Unlike the potato leafhopper, only the aster leafhopper adults are found on the potato. The aster leafhopper does not reproduce on the potato. The aster leafhopper is a vector of the potato purple top which affects chipping potato and is why it is a species of concern for many producers. Biological control has not been a viable option to control these insects. Because these insects cause damage in different ways it is important to make the correct identification of the species.

Aphids

Green peach aphid (*Myzus persicae*)
Potato aphid (*Macrosiphum cuphurbiae*)
Buckthorn aphid (*Aphis nasturtii*)

Aphids are a major pest of seed potatoes. These aphids are the primary vectors of viruses which can lead to the rejection of the seed lot. For this reason, seed producers must keep aphid numbers much lower than what can be tolerated in table stock potatoes. Control measures are targeted specifically against aphids in an effort to keep virus spread to a minimum in seed production fields. Control is seldom necessary in normal commercial production, though even this may be changing in recent production years. The treatment threshold for aphids in seed stock is 10 aphids per 100 leaves; the threshold to prevent yield loss in table stock is 30 aphids per 100 leaves. The two most important viruses transmitted are the potato leaf roll virus (PLRV) and potato virus Y (PVY or mosaic). Although there are several species of aphids on potatoes, the green peach aphid is the most common and the most efficient vector for PLRV. The potato aphid and buckthorn aphid can transmit PLRV. Green peach aphid is an efficient PVY vector, but there are many other aphids that act as a vector for PVY.

Potato Flea Beetle (*Epitrix cucumeris*)

The potato flea beetle is often the first pest to attack the potatoes during spring. The overwintering adults can cause economic damage to the newly emerging potato plants. The damage is identifiable by small shot holes in the leaves. There are usually two generations of this beetle in North Dakota. Mid-season damage is uncommon because the plants are larger and are often treated for other insect pests. Fortunately, the tuber beetle, *Epitrix tuberis* a much more destructive pest, does not occur in North Dakota.

Other Damaging Insects

Grasshoppers, especially redlegged grasshopper, *Melanoplus femurrubrum*; black blister beetle, *Epicauta pennsylvanica*; and numerous other defoliators occur on potatoes and occasionally cause conspicuous injury. The economic consequence of these pests seldom justifies treatment. Potatoes are relatively tolerant of some defoliation especially if the attack is not sustained. Cabbage looper and other caterpillars are probably never of economic importance on potatoes.

The soil insects, wireworm and white grub, are occasional pests of potato in the region. Soil insecticides have provided some protection from damage when populations are small. Unfortunately, infestations may go undetected until tuber damage is found at harvest

Table 1. Registered insecticides and their usage in North Dakota to manage potato insect pests in North Dakota.

Insecticide	Tradename	Acres Treated[1]		Dosage in lbAI/ acre	Product per Acre	Insects Controlled[2]	Pre-harvest interval (days)
		x 1000	%				
permethrin	Ambush 2E Pounce 3.2EC	NR	NR	0.05 - 0.2 lb/ acre1	3.2 - 12.8 fl oz 2 - 8 fl oz	CPB, LH	7
Ensfenvalerate	Asana XL	25.9	19.3	0.03 - 0.05 lb/ acre1	5.8 - 9.6 fl oz	CPB, APH, LH, CL	7
Carbaryl	Sevin	NR	NR	1 lb/acre	rate varies by formulation used	CPB LH	-
Endosulfan 3EC	Phaser Thiodan	22.6	16.9	0.5 - 1 lb/acre1	0.66 - 1.33 qts	CPB, APH, LH	1
Carbofuran	Furadan 4F	144.1	107.5	0.5 - 1lb/acre1	1 - 2 pts	CPB, LH	14
Azinophos-methyl	Guthion 3F	17.6	13.1	0.375 lb/acre	1 pt	CPB	7

				0.5 - 0.75 lb/ acre1		LH	
Imidacloprid	Provado 1.6F	1.7	1.3	0.0475 lb/acre	3.75 fl oz	CPB, APH	
	Admire 2F			refer to label	0.9 - 1.3 fl oz/1,000 ft of row	CPB	
Phosmet	Imidan 50 WP	NR	NR	1lb/acre	2 lbs	CPB, LH	7
Methamidophos	Monitor	25.8	19.3	0.75 - 1lb/acre	1.5 - 2 pts	CPB	14
Methomyl	Lannate LV	NR	NR	0.5 - 1 .lb/acre	1.5 - 3 pts	CL, APH	6
Oxamyl	Vydate L	NR	NR	0.5 - 1 .lb/acre	2 - 4 pts	CPB, LH	7
methyl-parathion	Penncap-M	NR	NR	0.5 - 1.5 lb/acre	0.5 - 1.5 lb/acre	CPB	5
				0.5 -1 lb/acre		LH	
Phorate	Thimet 20G	14.2	10.6	11.3 oz/1,000 ft of row		CPB, APH, LH	90
Dimethoate	Digon 400, Bimetoate 400	14.6	10.9	0.5 lb/acre	1 pt	APH, LH	-
Disulfoton 15 G	Di-Syston	NR	NR	15 - 23 fl oz/1000 ft row1		CPB, APH, LH, WW, FB	75
pymetrozin	Fulfill	NR	NR	0.086 lb/acre	2.75 fl oz	APH	14
cyfluthrin	Baythroid	NR	NR	0.025 - 0.044 lb/ acre	1.6 - 2.8 fl oz	CPB, LH, CL	0
spinosad	SpinTor 2SC	NR	NR	0.047 - 0.094 lb/ acre	3 - 6 fl oz	CPB	7

[1] Zollinger, et al. 1998. NR = not reported.
[2] CPB=Colorado potato beetle, APH=Aphids, LH=Leaf hoppers, WW=wireworms, FB=flea beetles, CL=cabbage looper

Table 2. Registered insecticides and their usage during 1999 in North Dakota to manage potato insect pests.

Insecticide	**Tradename**	**Area Applied[1] %**	**Recommended Dosage *lb AI/acre***	**Rate per Application[1] *lb AI/acre***	**Rate per Crop Year[1] *lb AI/acre***	**Insects Controlled[2]**
Ensfenvalerate	Asana XL	19	0.03 - 0.05	0.01	0.01	LH
cyfluthrin	Baythroid	8	0.025 - 0.044	0.03	0.04	CPB, LH
Endosulfan 3EC	Phaser Thiodan	15	0.5 - 1	0.61	1.02	CPB, APH, LH
Azinophos-methyl	Guthion 3F	19	0.375 - 0.75	0.48	0.51	CPB, LH
Imidacloprid	Admire 2F	68	0.18 to 0.31	0.09	0.10	CPB, APH,
	Provado 1.6F		0.0475			
Methamidophos	Monitor	NR	0.75 - 1	NR	NR	CPB, APH
Phorate	Thimet 20G	8	11.3 oz/1,000 ft of row	2.83	2.83	CPB, APH, LH

Dimethoate	Digon 400, Bimetoate 400	24	0.5	0.27	0.62	APH, LH
spinosad	SpinTor 2SC	20	0.047 - 0.094	0.04	0.04	CPB

[1] USDA-NASS. 2000.

[2] CPB=Colorado potato beetle, APH=Aphids, LH=Leaf hoppers, WW=wireworms, FB=flea beetles, CL=cabbage looper

New Advancements in Insect Control

When managing Colorado potato beetle and the green peach aphid, insecticide resistance to currently available products is a major concern. New insecticidal discoveries are providing some attractive alternatives for use in managing these pests. The goal should be to preserve these new alternatives through industry coordinated resistance management programs.

One major group of insecticides being used and developed are the Neonicitinoids. This class of insecticidal compounds includes imidacloprid and thiamethoxam. Imidacloprid (Admire and Provado) has seen a significant increase in use in the region since its section 3 labeling in 1995 (Table 2). The insecticide has provided effective control of both these pests within the region. The Admire formulation is applied in-furrow or to seed pieces; the Provado formulation is applied as a foliar spray. Use of imidacloprid is restricted to a total of 0.31 pounds active ingredient per growing season, or the high label rate for soil application with Admire. However, this does not restrict the use of the Provado formulation when lower rates of Admire are utilized. Thiamethoxam (Platinum and Actara) has registration pending, possibly for the 2001 season. Platinum is a soil use formulation; Actara is a foliar formulation. Labeling for this insecticide will recommend not using the foliar formulation after the soil application is used, but will not restrict the use. With two effective compounds available from the same chemical class, greater consideration in the development of a comprehensive resistance management program among manufacturers should occur. Without a common strategy, these insects could face season long exposure to one or both of these insecticides which share their chemistry, a scenario that could enhance the risk of insecticide resistance developing.

Spinosad (SpinTor), a reduced risk pesticide, is being used to manage Colorado potato beetle (Table 2). The section 3 label was issued in 1999. Spinosad has been classified as a Naturalyte® insecticide product, being biologically derived from the fermentation of *Saccharopolyspora spinosa*, a naturally occurring soil organism. Spinosad has insecticidal activity against coleoptera, lepidoptera, and others. It is recommended for use against small larvae of the Colorado potato beetle. The label restricts use to two applications per generation, and not for use against consecutive generations. Spinosad does not have activity against the other major potato pests in the region.

Pymetrozine (Fulfill) is registered in potato for managing green peach and potato aphids. The active ingredient belongs to the insecticide class Pyridine azomethine, a class of compounds not previously used as pesticides and where no resistance or cross-resistance is known. Pymetrozine inhibits neural control of feeding behavior in aphids and is expected to aid in the reduction of virus transmission. The compound has no significant impact on other major potato insect pests and has demonstrated only low levels of toxicity to beneficial insects.

Another insecticide of interest is fipronil (Regent), which is being considered for registration on potato to aid in the management of wireworms and white grubs. Fipronil belongs to the chemical class Fiproles. It is registered for use on field corn to manage the soil insect pests mentioned. Currently, the only insecticides registered in the state for managing wireworms in potato are phorate, ethoprop, and diazinon, all organophosphate compounds. No insecticides are labeled specifically for managing white grubs in potato.

Disease Management

Diseases are present at every stage of the potato life span and are known to cause severe economic loss to potato growers. There are potato diseases that reduce seedling stands, cause leaf spots, cause wilts, cause storage rots and are carried by the seed tuber from one crop to the next. Any improper cultural practice used in growing the potato crop can result in disease. Management is probably the most important tool in controlling, avoiding, or reducing crop losses in North Dakota. Disease resistant varieties are the best way to reduce disease occurrence, but resistance does not equate to immunity to diseases. The best cultural and sanitation practices should be integrated into the growing system to reduce the spread of diseases. The different diseases are discussed below.

Fungal Diseases

Fungicides are used to control the fungal diseases in North Dakota. The two main types of fungicides are contact or systemic fungicides. Contact fungicides, commonly called protectant fungicides, work on the surface of the plant to protect against infection. In contrast, systemic fungicides are absorbed by the plant tissue and are active from inside the plant.

Protectant fungicides kill germinating fungus spores to prevent infection, but cannot protect against systematic infections, such as wilts and virus diseases. Protectant fungicide are used for seed piece treatment and to protect against foliar diseases, primarily early and late blight. They cannot prevent disease development once infection has occurred and must be present on the leaf before infection occurs. Common protectant fungicides include chlorothalonil (Bravo, Echo), copper hydroxide (Kocide, Champion), mancozeb (Dithane, Manzate, Penncozeb, Manex II) maneb (Maneb 80, Maneb Plus Zinc F4), and triphenyltin hydroxide (Super tin, Agri Tin). Most are broad spectrum fungicides.

Systemic fungicides work after the plant has been infected. Many systemic fungicides target certain fungi and have limited broad spectrum activity compared to protectant fungicides. Systemic fungicides commonly move to the edges of the leaves when applied. Most move upward if they are absorbed into the conducting tissues of the plant. Metalaxyl (Ridomil), a acylalanine fungicide, moves downward, to some extent. Other systemic fungicides are thiabendazole (TBZ, Mertect) and thiophanate methyl (Topsin M). Cymoxanil (Curzate) and azoxystrobin (Quadris) are effective systemic fungicides against late blight fungus. The benzimidazoles are primarily effective against protecting against infection of seed piece pathogens. Metalaxyl (Ridomil) is active against the lower fungi, namely *Pythium* and *Phytophthora* (which includes the late blight fungus), and has both protectant and curative properties. Fungi have developed resistance to certain fungicides rather quickly, so some fungicides come as a package pre-mix. The purpose of the package pre-mix is to delay the development of resistant fungi. Table 3 and 4 summarize the estimated amount of foliar fungicides used in 1996 and 1999 on North Dakota potato acres. Table 5 summarizes the estimated amount of seed treatment or soil applied fungicides used in 1996 on North Dakota potato acres.

Verticillium Wilt

There are several species of Verticillium fungus that occur in the soil. *Verticillium alboatrum* and *Verticillium dahliae* are the two species associated with "early dying" or Verticillium wilt of potatoes. The occurrence of either species is temperature related. *Verticillium alboatrum* is associated with cooler temperatures, and *V. dahliae* with warmer temperatures. These fungi survive in potato fields through infected potato debris that remains in the harvested field. Verticillium wilt may remain in the field for several field seasons as small sclerotia or dark mycelium. The loss that results from a wilt is reduced tuber size (quality and yield) and loss of quality because of tuber discoloration. Wilt may become more severe with the presence of the lesion nematode (*Pratylenchus penetrans*).

Short crop rotation systems may not be a useful management tool because of the survival system of the wilt fungus. However, if possible a rotation system where potatoes would not occur every other year should be helpful. Of more importance would be the physical removal of disease-infected potato stems after harvest. Several new varieties have a high degree of disease resistance. These varieties should be grown where possible, along with using the recommended sanitation practices. In heavy infestations with severe yield losses, soil fumigation may be required to reclaim the land.

Fusarium Wilt

Fusarium sambucinum is common in soil and in infected crop debris. The fungus survives as spores or mycelium in soil. Infection is favored by high soil temperatures and moisture conditions and infection occurs mainly through the roots. Fusarium wilt is similar to Verticillium wilt in diagnosis but Fusarium wilt will have a yellowish brown discoloration of the stem tissue and may be more fibrous. It appears that Fusarium wilt fungus has not infected North Dakota potato fields to the same degree as Verticillium wilt. There is no practical control at this time. Disease free seed and crop rotation are recommended, but are not solutions for this disease.

Early Blight

Early blight is caused by the fungus *Alternaria solani.* Symptoms develop in July or August on the lower foliage. Early blight is favored by warm weather, especially if it is alternating wet and dry. It is more serious on early maturing varieties. Immature tubers are readily infected, but mature tubers are infected only through wounds. Mature tubers may be infected through wounds or bruises made at harvest.

Crop rotation helps reduce levels of overwintering early blight fungus. Effective fungicides include azoxystrobin, mancozeb, maneb, chlorothalonil, and triphenyl tin hydroxide. Copper fungicides are less effective. Fungicides applications should begin when the first lesions are visible. These fungicides will not kill existing leaf spots but will protect against new infections from spores produced on early lesions. Complete coverage with fungicide applications is necessary for good control. To prevent tuber infection, allow tubers to mature prior to harvest. Vine killing before harvest will allow the tubers to mature and reduce the potential for tuber infection. Use harvest practices and equipment that minimize wounding and bruising.

Late Blight

Late blight is caused by the fungus *Phytophthora infestans.* The current *P. infestans* genotype present in the region is resistant to the fungicide, metalaxyl (Ridomil). Late blight is a serious problem in potato growing areas where cool, humid weather is common. Outbreaks in the warmer and drier areas of North Dakota tend to be sporadic, occurring only when weather conditions are favorable. Late blight is more common in irrigated areas, especially near the pivot. Late blight can infect leaves, stems and tubers. Soft rots may follow late blight infections resulting in destruction of the entire tuber.

Late blight survives the winter in infected tubers. Primary infection comes from spores produced on the infected sprouts of diseased seed pieces or tubers. Secondary infection comes from the spores produced by late blight on the crop. These spores can either infect tubers or leaves of other potato plants. The best management against late blight is to use blight-free seed and destroy cull piles and volunteer plants. Crop rotation is used to avoid or reduce carryover of the late blight fungus. If the weather has been cool and damp and more cool and damp weather is predicted, spraying for late blight should begin immediately. The management program relies heavily on the use of protectant fungicides such as cymoxanil (Curzate), dimethomorph (Acrobat), and propamocarb (Previcur). Fields should be inspected carefully for late blight. Another practice is to hill potato rows to prevent the spores from reaching the tubers. Kill vines at least two weeks before harvest so that the tuber skin is mature and any infected tubers will have disintegrated before digging.

Fusarium Dry Rot

Fusarium fungi can cause seed decay, wilt and dry rot decay in storage. Most varieties do not have resistance to dry rot. *Fusarium sambucinum* infects potatoes through wounds or injuries associated with harvesting and handling operations. Manage and control dry rot by assuring that the tuber skin is mature before harvesting. This is accomplished by vine killing. Avoid injuring or bruising tubers at harvest and promote a storage environment for suberization. Thiabendazole may be applied post-harvest as part of a management program for dry rot control. The dry rot fungus has developed resistance to thiabendazole in many parts of the United States and Canada; thiabendazole efficacy is reduced where resistance is present. To treat for seed decay dry rot before planting warm seed tubers for a week before planting or cutting seed pieces. Also treat with a fungicidal dust. Sanitizing equipment will reduce dry rot spread between seed lots.

Rhizoctonia Canker / Black Scurf

The Rhizoctonia fungus is found in the soil and on tubers wherever potatoes are grown. Rhizoctronia infection causes cankers on young plant stems prior to emergence, resulting in uneven stands or gaps in the potato rows. Avoid planting in cool wet soils, avoid irrigation until after emergence, and do not hill until plants have emerged. This disease is very important in irrigated potatoes where the very susceptible Russet Burbank is the primary variety grown for use in processing. Harvest within two to three weeks of vine killing to limit the amount of sclerotia formed on the tubers as sclerotia form on senescing plants.

Silver Scurf

Silver scurf, caused by *Helminthosporium solani*, is most noticeable on red-skinned potatoes. No rot develops and symptoms are relatively superficial. Infected areas become somewhat wrinkled in storage due to excessive water loss. This fungus survives in the soil and on tubers. Diseased seed pieces are the most common source of infection. Manage silver scurf by using disease-free seed and harvesting tubers as soon as they mature. A seed piece treatment with fludioxonil can reduce the amount of silver scurf going into storage. Preventing condensation by reducing the humidity and temperature in storage may reduce symptom development but not reduce the occurrence of the disease.

Common Scab

Common scab is caused by the fungus *Streptomces scabies* on rapidly developing tuber tissues. In addition to tuber infections, stems, rhizomes and roots may develop milder symptoms. It is favored on alkaline soils, which are common in the Red River Valley of North Dakota. Dry soil condition also favor scab development. Resistant varieties are the most effective means of control in the region. Manure should not be applied to fields where potatoes may be grown, as this may increase the severity of scab. Increase the length of rotation between potato crops to reduce scab. Use of sulfur to reduce soil alkalinity has been recommended in other potato regions but is not feasible in highly alkaline soils. No chemical seed or soil treatments have been effective in the Red River Valley. Partial control under irrigation is possible by maintaining adequate soil moisture.

Pythium Leak

Leak is one of two water rots that can cause serious storage rot problems during years when harvest conditions are unfavorable. The Pythium fungus, present in the soil, invades the tubers through wounds made during the digging operation. To manage leak do not dig potatoes in unusually warm temperatures and reduce tuber injuries. If leak develops, lower pile temperature, increase the air flow and dry down the diseased tubers with dryer forced air. Dry air is not conducive to wound healing or suberization, so the storage should be watched closely.

Pink Rot

Probably the most prevalent of the two water rots is pink rot caused by the soil_borne fungus *Phytophthora erythroseptica*. This disease can be found in the field before harvest and is characterized by rotted tuber tissues that turn pink after exposure to air for 20 to 30 minutes. Another important diagnostic trait for pink rot is that the rot will usually appear to start from the stem end of the tuber and will then progress through the tuber in a very uniform manner, often with a nearly straight line between the healthy and the diseased portions of the tuber. Pure pink rot is not a slimy soft rot, but infected tissues are easily, and often invaded by soft rot bacteria which will cause this symptom. In a tuber that is infected with the pink rot fungus alone, the rotted tissues will retain some structure and firmness but not nearly as much as the healthy portions of the tuber. The texture of the infected tuber tissue is much like that of a boiled potato and is referred to as a "cooked potato" texture. Another feature of pink rot is the characteristic smell of ammonia that is given off by pink rot infected tubers. This odor can frequently be detected in potato storage structures prior to the development of visual symptoms.

Pink rot and pythium leak can both be managed efficiently using applications of metalaxyl (Ridomil) during the growing season. One well timed application, when the largest tubers are the size of a nickel to a quarter, is generally sufficient. However, water rot susceptible varieties may require a second application. Irrigation managers should avoid excess watering late in the growing season.

Table 3. Registered foliar fungicides and their usage in North Dakota to manage potato diseases.

Fungicide	Tradename	Application Method[1]	Rate/A[2]	Disease Control[3]		Acres Treated[4]		Application Timing
				Late Blight	Early Blight	x 1000	%	
Foliar Sprays								
Azoxystrobin	Quadris, 22.9%	Spray or fungigation	6.2-15.4 fl oz	E	E	NR	NR	NR
Chlorothalonil	Bravo 500, Echo 500	Spray or fungigation	1.0-2.13 pt	G	G	696.1	519.5	7 day PHI
	Evade, 40.4%	Spray or fungigation	1.13-2.13 pt	G	G			
	Bravo 720 or Echo 720, or Terranil 6L, 54%	Spray or fungigation	0.75-1.5 pt	G	G			
	Bravo Ultrex DG, 82.5%	Spray or fungigation	0.7-1.4 lb	G	G			
	Bravo Zn, 40.4%	Spray or fungigation	1.0-2.13 pt	G	G			

	Terranil 90 DF, WSP, 90%	Spray or fungigation	0.25-0.5 packets	G	G			
Copper	Basicop WP, 53%	Spray	3-6 lbs	F-G	F	7.4	5.5	NR
	Champ DP, 57.6%	Spray or fungigation	0.66-2.66 lb	F-G	F			
	Champ Formula 2Flowable, 37.5%	Spray or fungigation	0.66-2.66 pt	F-G	F			
	Kocide 2000, 53.8%	Spray or fungigation	0.75-3.0 lb	F-G	F			
	Kocide 4.5 LF, 37.5%	Spray or fungigation	0.66-2.66 pt	F-G	F			
Copper Sulfate	BlueViking Star Glow Powder or Triangle Brand Copper Sulfate Instant Powder	Spray	10 lb	-	-	NR	NR	NR
Cymoxanil	Curzate 60 DF	Spray or fungigation	3 1/3 oz	E	No	NR	NR	14 day PHI
Dimethomorph + Mancozeb	Acrobat MZ	Spray or fungigation	2.25 lb	E	No	NR	NR	14 day PHI
Iprodione	Rovral, 50% or Rovral 4 Flowable, 41.6%	Ground spray or fungigation	1-2 lb, early blight 1-2 pt, early blight 2 lb, white mold 2 pt, white mold	(P)	G	NR	NR	14 day PHI
Mancozeb	Dithane DFRainshield NT, 75%	Spray or fungigation	0.5-2 lb	G	G	15.9	11.9	14 day PHI
	Dithane F-45, 37%	Spray or fungigation	0.8-1.6 qt	G	G			
	Dithane M-45, 80%	Spray or fungigation	1-2 lb	G	G			
	Dithane WPS, 80%	Spray or fungigation	1-2 lb	G	G			
	Manex II, 37%	Spray or fungigation	0.8-1.6 qt	G	G			
	Manzate 75 DF, 75%	Spray or fungigation	1-2 lb	G	G			
	Penncozeb, 80%	Spray or fungigation	1-2 lb	G	G			
	Penncozeb DF, 75%	Spray or fungigation	1-2 lb	G	G			

Maneb	Maneb 80, 80%	Spray or fungigation	1.5-2 lb	G	G	NR	NR	14 day PHI
	Maneb 75DF, 75%	Spray or fungigation	1.5-2 lb	G	G			
	Manex, 37%	Spray or fungigation	0.8-1.6 qt	G	G			
Maneb + Triphenyltin Hydroxide (TPTH)	Pro-Tex, 32.63%:4.72%	Spray or fungigation	0.75-1.5 qt	G	G	6.3	4.7	21 day PHI
	Blite-Out Plus, 32.63%:4.72%	Spray	0.75-1.5 qt	G	G			
Metalaxyl + Chlorothalonil	Ridomil Gold/ Bravo 76 WP,4.5%:72%	Spray or fungigation	2 lb	F-E	G	16.7	12.4	14 day PHI
	Ridomil Gold/ Bravo Liquid Twin Pak	Spray or fungigation	5 acre Paks					
	Ridomil/Bravo 81W, 9%:72%	Spray or fungigation	2 lb					
Metalaxyl + Copper Hydroxide	Ridomil Gold/ Copper 65 WP, 5%:60%	Spray or fungigation	2.0 lb + 0.5 lb ai of maneb, mancozeb, metiram or chlorothalonil	F-E	F	NR	NR	14 day PHI
	Ridomil Copper 70W, 10%:60%	Spray or fungigation						
Metalaxyl + Mancozeb	Ridomil Gold MZ	Spray or fungigation	2.5 lb	F - E	G	NR	NR	14 day PHI
Metiram	Polyram 80 DF	Spray or fungigation	1.5 - 2 lb	G	G	NR	NR	14 day PHI
Propamocarb	Previcur	Spray or fungigation	1.2 pt	E	E	NR	NR	14 day PHI
Propamocarb + chlorothalonil	Tattoo C	Spray or fungigation	2.3 pt	E	E	1.9	1.4	14 day PHI
Triphenyltin hydroxide (TPTH)	Super Tin 80WP, AgPak, Agri Tin	Spray or fumigation	2.5 -3.75 fl oz	G	E	6.2	4.6	7 day PHI

[1] Spray = ground or aerial, Fungigation = application through sprinker irrigation system.
[2] Dosage = Amount of formulated product to apply.
[3] P = Poor; F = Fair; G = Good; E = Excellent; () = Not registered for disease; No = No control.
[4] Zollinger et al. 1998. NR = not reported.

Table 4. Registered fungicides and their usage during 1999 in North Dakota to manage potato diseases.

Fungicide	Tradename	Area Applied[1] %	Recommended Dosage *lb AI/acre*	Rate per Application[1] *lb AI/acre*	Rate per Crop Year[1] *lb AI/acre*	Diseases Controlled
azoxystrobin	Quadris	49	0.1	0.1	0.32	Late blight, Early blight
chlorothalonil	Bravo and others	82	0.5 to 1.1	0.9	5.65	Late blight, Early blight
cymoxanil	Curzate 60 DF	34	0.124	0.1	0.21	Late blight, Early blight
mancozeb	Dithane, Manex, Penncozeb	57	0.4 to 1.6	1.34	4.19	Late blight, Early blight
mefanoxam	Ridomil Gold EC, Ultra Flourish	20	0.18 to 0.2	0.16	0.19	Pythium leak and pink rot
triphenyltin hydroxide (TPTH)	Super Tin 80WP, AgPak, Agri Tin	24	0.125 to 0.19	0.14	0.4	Late blight, Early blight

[1]USDA-NASS. 2000.

Table 5. Registered seed/soil treatment pesticides and their usage in North Dakota to manage potato diseases

Fungicide	Tradename	Application	Dosage[1]	Disease control[2]		Acres Treated[3]	
				Fungi[4]	Bacteria[5]	x 1000	%
Seed Treatment							
Fludioxonil	Maxim 0.5%	Dust	8.0 oz/cwt	E	No	NR	NR
Fludioxonil + mancozeb	Maxim MZ, 0.5%:9.6%	Dust	0.5 lb/cwt	E	No	NR	NR
Mancozeb	PSP 6%	Dust	1 lb/cwt	E	No	33.2	24.8
	P.S.T. Plus Bark 6%	Dust	1 lb/cwt	E	No		
Maneb	7 1/2%	Dust	1 lb/cwt	E	No	NR	NR
Maneb + Streptomycin	Dustret A or LD 8%:0.01%	Dust	1 lb/cwt	E	No	NR	NR
Thiabendazole	Mertect 340-F, 42% Flowable	Post harvest spray	0.42 fl oz/gal - one gallon treats 2,000 lb.	E	No	3.5	2.6
	Sim-Tec Plus, TBZ 0.5%	Dust	1 lb/cwt	E	No		
Thiophanate methyl	Dustret T, 2 1/2%	Dust	1 lb/cwt	E	No	0.5	0.4
	Tops-2.5D, 2 1/2%	Dust	1 lb/cwt	E	No		
	Tops 5, 5%	Dust	0.5 lb/cwt	E	No		

Thiophanate methyl + mancozeb + cyomoxanil	Evolve, 2.5%:6.0%:1.0%	Dust	0.75 lb/cwt	E	No	NR	NR
Thiophanate methyl + mancozeb + imidacloprid	Tops MZ-Gaucho, 2.5%:6.0%:1.25%	Dust	0.75-1.0 lb/ cwt	E	No	NR	NR
Soil Application							
PCNB	Blocker	Broadcast	180-250 lb	G used for *Rhizoctonia* control		NR	NR
	PCNB 10% Granules	In-Furrow granules	100 lb/12,400 linear ft of a 36 inch row				
Mefenoxam	Ridomil Gold EC, 48%	6-8 inch band, in furrow or impregnated on dry fertilizer	0.42 fl oz/1000 ft of row	E for post harvest control of pythium leak and pink rot (*P. erythroseptica*)		NR	NR
	Ultra Flourish, 25.1%	6-8 inch band, in furrow or impregnated on dry fertilizer	0.84 fl oz/100 ft of row				

[1] Dosage = Amount of formulated product to apply.
[2] P = Poor; F = Fair; G = Good; E = Excellent; () = Not registered for disease; No = No control.
[3] Zollinger et al. 1998. NR = not reported.
[4] *Fusarium*, *Rhizoctonia solani* and *Helminthosporium solani*. These fungi cause dry rot, Rhizoctonia stem canker and silver scurf.
[5] Includes Erwinia, cause of soft rot decay, and Corynebacterium, cause of ring rot.

Bacterial Diseases

Ring Rot

Ring rot is caused by the bacterium *Clavibacter michiganensis* ssp *sepedonicus* (=*Corynebacterium sepedonicum*). Potentially, it is one of the most serious diseases of potatoes because of the ease and rapidity with which it spreads during a single growing season, and the total devastation that it can cause. The bacterium lives from season to season in infected tubers and bacterial slime. Bacteria are readily transmitted from disease tubers to healthy seed pieces during the cutting of seed tubers. The most important method of controlling ring rot is to plant disease-free tubers. Certified seed has a zero tolerance for ring rot, which means if only one plant or tuber is found infected with ring rot the whole field or seed lot is not eligible for certification.

Blackleg and Soft Rot

Blackleg and soft rot are caused by related subspecies of the bacterium *Erwinia carotovora.* These two diseases are found wherever potatoes are grown. Each subspecies of *E. carotovora* is capable of causing both diseases and heavy economic losses under the proper environmental conditions. Because of its seed-borne nature, management or control of blackleg should be directed toward the use of disease free "clean" seed. However, under irrigation mid to late-season infection may come from other sources of bacteria for which little control exists. The management of soft-rot is similar to blackleg. Reduce soft-rot by minimizing injury and bruises to the tubers. It is important to remember that soft rot develops in potato tubers most frequently under conditions of oxygen depletion in the tuber tissue. These anaerobic conditions are generally induced by carbon dioxide accumulation or by a moisture film.

Virus, Viroid, Phytoplasma and Other Diseases

All common viruses in potato are tuber-borne, occurring alone or in multiple infections and are a source of significant losses in production. The viruses occurring in potato growing areas of North Dakota may be broadly classified into two groups based on symptoms in most potato cultivars: a) those for which most strains normally cause symptoms and include potato virus Y, potato virus A and potato leafroll virus; B) those that are usually latent and include potato viruses S and X. Expression of typical symptoms is dependent on suitable environmental conditions and viruses infecting the plant. Symptoms may not be expressed at all if average temperatures are much above normal. It is also important to recognize that other non-viral diseases as well as insect pests may be responsible for symptoms that modify or mimic symptoms caused by viruses.

Potato Leafroll Virus (PLRV)

Potato leafroll virus is capable of causing severe yield losses if heavily infected seed is planted. In North Dakota, PLRV has probably not been a significant disease when foundation or certified seed is used. The virus is carried from season to season in infected tubers. It is transmitted from infected to healthy plants by aphids. Use of healthy nucleus or seedstocks, control of aphid vectors with appropriate insecticides and rigid certification standards have been highly effective for controlling this virus disease in North Dakota for seed production. Therefore, the use of healthy, disease tested seedstocks by growers of processing or fresh market potatoes has been a primary factor in reducing incidence of this disease.

Potato Virus Y (PVY)

This virus occurs throughout the world wherever potatoes are grown and can cause significant yield losses either alone or in combination with other viruses. There are several strains of this virus that have been identified based on symptoms produced in certain indicator species. This virus has been periodically found in the Red River Valley of North Dakota and the isolate appeared to cause mild symptoms or only latent infections in some potato cultivars. It has become a major threat to North Dakota s certified seed potato industry.

Control of this disease may be more difficult than some other virus disease of potato because the virus is mechanically or sap transmissible, it is tuberborne and at least 30 species of aphids including the green peach aphid are capable of spreading PVY. Frequent applications of a light mineral oil emulsified in water to potato plants also helps reduce aphid transmission of PVY to potatoes. Breeding for resistance in potatoes has been one of the most effective long term methods of controlling PVY. Using certified seed stock also reduces the spread of PVY.

Potato Virus A (PVA)

This virus, which is related to potato virus Y, is reported to be wide spread in most potato growing areas of the world, but no comprehensive surveys have been made in North Dakota. Control measures are the same as potato virus Y.

Potato Virus X (PVX) and Potato Virus S (PVS)

Excepting primary infections in some cultivars, potato virus X (PVX) is usually latent in potatoes. Potato virus S (PVS) in potato is milder than PVX and is almost always latent in all varieties under all environments. Transmission of both viruses occurs mechanically via contact between healthy and infected foliage in the field or sprouts in tuber storage. They can be readily spread in seed-piece cutting operations and when there is vine contact with virus-contaminated equipment in field work. Controlling these viruses involve using certified seedstocks and sanitary cultural practices.

Other Viruses

Other viruses that may be occasionally observed in potatoes in North Dakota include calico, potato yellow dwarf and, possibly potato virus M. These virus diseases are not currently of economic significance in North Dakota.

Potato Spindle Tuber

This disease in potato is caused by a relatively recently recognized class of plant pathogens known as viroid. Spindle tuber is readily sap or mechanically transmitted via foliage contact, by knives and by abrasion of vines by field machinery or by human or animal contact. Spindle tuber has been kept in check primarily by thorough inspection and assays of nucleus stocks and by high certification standards.

Purple Top

Purple top, sometimes called aster yellows, bunchy-top, haywire disorder or purple top wilt is infrequently but periodically a problem for potato growers. Significant amounts of purple top occurred in some potato production areas of North Dakota in 1981, and processors reported excessive chip discoloration in some varieties the following processing year. The disease is caused by a pathogen called aster yellows mycoplasma-like organism (or phytoplasma) that is spread by the aster leafhopper (*Macrosteles fascifrons*). The sporadic and unpredictable mobility of large numbers of aster leafhopper into potatoes makes control difficult, and currently available means of determining if the insects are infective with the aster yellows phytoplasma are slow and cumbersome. Since purple top outbreaks are sporadic and infrequent in potatoes, better predictability of their occurrence may be useful to growers as well as processors.

Nematodes

Nematodes may adversely affect the growth of potatoes through their feeding, through their movement into and through plant tissues, by interacting with other microorganisms that are pathogenic to potatoes, and by acting as vectors and reservoirs for plant viruses. Several different nematodes have the potential to adversely affect potatoes grown in the Upper Midwest although their effects on potato production in North Dakota are not well documented.

Pinkeye

Pinkeye disease is usually classified as a minor disease. It is regarded as a nuisance disease, but can be serious in some fields. The descriptive term "pink" occurs in the name or symptoms of more than one potato disease. These are often lumped together as pink rot. There are three pink diseases: leak, pink rot and pink eye. All three affect tuber quality more than yield and are more of a problem in storage than in the field. They cause a wet decay and are weather dependent, being favored by moisture. All are caused by soil borne organisms. Little, if any, control exists. Management recommendations for these are to reduce moisture levels.

Abiotic Diseases

Several diseases are associated with the growing and storage conditions of potato tubers. The development of cavities in the pith area of tubers is known as hollow heart. Hollow heart is associated with periods of rapid tuber growth. Potassium deficiency and stress that causes cell injury may contribute to the development of symptoms. Precautions against hollow heart include close plant spacing and large seed pieces that will ensure a good stand with an adequate number of stems per hill. Low temperature injury and freezing or frost injury is caused by having the tubers exposed to temperatures near the freezing point for extended periods of time. To avoid this injury harvest before cold weather sets in and try to keep the crop well hilled. Tarp truck loads between field and storage. Monitor storage conditions and do not store potatoes against an outside wall without proper ventilation. Greening is the result of tubers being exposed to light in the field or in storage. Green tissues often are bitter due to the development of solanine which is considered poisonous to humans. To avoid greening, store tubers in the dark and limit the light exposure to tubers in transport and in the field.

Weed Management

Weeds can directly limit crop yields by shading crop plants and by competing with them for resources such as space, water, and nutrients. Dense weed infestations restrict the growth of potato plants which results in undersized tubers. Weeds can also affect crop quality by direct injury (for example, by piercing tubers with sharp rhizomes). Water stress due to weed competition can result in tuber physiological disorders and in lowered dry matter content. Besides affecting the plant, heavy weed infestations can interfere with proper operation of harvesting equipment.

Weeds are generally classified as annual or perennial and as broadleaf or grass species. Effective control of annual weeds in potatoes requires timely cultivation, the use of herbicides, or a combination of cultivation and herbicides. Crop rotation is a useful tool in a weed management program. A diverse crop rotation discourages domination by any one set of weed species and provides the opportunity to control troublesome species during various portions of the rotation. If perennial weeds, such as quackgrass, Canada thistle, or hedge bindweed are present, they should be controlled with herbicides prior to planting. Also, weeds should be prevented from producing seed to help reduce further infestations. Tillage and herbicides are the primary means of controlling weeds in potato. Cultivation, 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 cultivation and two harrowing operations are common in North Dakota. 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 the tuber from sunburn (tuber greening), late season frosts, excessive rainfall or irrigation and reduces the amount of soil to be moved at harvest.

Herbicides can save considerable labor when growing potatoes. Under some conditions they are more effective than cultivation, but special care is required when using them. When herbicide applications are effectively integrated with timely cultivation, the two can complement one another and overcome some of the disadvantages of using either alone. Herbicides are designed for situations to take care of certain weed problems. Common herbicides used in North Dakota are metolachlor, EPTC, linuron, rimsulfuron, sethoxydim, pendamethalin, metribuzin, trifluralin, and glyphosate. It is not uncommon to tank mix herbicides to get better control of a weed problem in a field and to reduce application costs. These applications are discussed in the following paragraphs with the chemical name in parentheses. Tables 6 and 7 summarize herbicide usage in North Dakota during 1996 and 1999, respectively.

1. Dual/II/Magnum (metolachlor at 2-3 lb of ai/acre) control annual grasses and most broadleaf weeds. It may be applied preplant and incorporated, postplant and incorporated, or preemergence (on soil surface before crop and weeds emerge). Dual will give poor control of wild mustards and common ragweed. Combinations include Dual plus Sencor, Lexone, or Lorox for increased broadleaf control. Dual has a 40 day post-harvest interval in potato.

2. Prowl, Pendimax, and others (pendimethalin at 1-1.5 lb of ai/acre) control grasses and certain broadleaf weeds. Light incorporations will increase weed control. It can be tank mixed with Lexone, Sencor, Lorox, or Eptam. Prowl gives poor control of common ragweed, velvetleaf, and Pennsylvania smart weed. Do not follow with sugarbeets.

3. Treflan and others (trifluralin at 0.5-1 lb of ai/acre) control grasses and some broadleaf weeds. Treflan gives poor control of wild mustard. It works best to incorporate after planting, but before emergence or immediately following drag-off. It can be tank mixed with Eptam. Soil residue may injure susceptible crops the following year.

4. Eptam (EPTC at 3-6.125 lb of ai/acre) gives control of grasses and some broadleaf weeds. It can be applied before planting and incorporated into the soil, or applied and incorporated in the fall before freeze-up. It has weak control on wild mustard. Eptam cannot be applied within 45 days of harvest. Eptam may be tank mixed with metribuzin at specified rates.

5. Sencor (metribuzin at 0.25-1 lb of ai/acre) when applied before or after weeds emerge, but before potatoes emerge, controls germinating and emerged broadleaf weeds plus some grasses. It can also be applied to white-skinned varieties after both potatoes and weeds have emerged for control of broad leaf weeds. Also, for broader spectrum of weed control, Sencor can be tank mixed with Dual or Prowl. Do not follow with sugarbeets.

6. Lorox and others (linuron at 0.75-2 lb of ai/acre) control most annual grasses and broadleaf weeds. It is applied prior to potato and annual weed emergence or to emerged broadleaves and certain grasses. The higher rates are for fine textured soils. For increased control of annual grasses Lorox can be tank mixed with Eptam, Dual, or Prowl.

7. Poast (sethoxydim at 0.1-0.3 lb of ai/acre) controls annual grasses and quackgrass. Poast is applied with an oil additive for greater control after emergence. Poast does not control sedges or broadleaf weeds. Unsatisfactory control may result if applied to grasses growing under stress or if applied within one hour before a rain. Do not apply or mix with any other pesticide, additive or fertilizer unless specifically recommended, or do not apply within 30 days of harvest.

8. Roundup and others (glyphosate at 0.19-0.75 lb of ai/acre) control emerged grass and broadleaf weeds. It is applied before planting or anytime prior to potato emergence. It can also be applied in the fall. Roundup will not control yellow nutsedge.

9. Matrix (rimsulfuron at 0.25- 0.375 oz ai/acre) controls annual grasses and broadleaf weeds. It also suppresses quackgrass and Canada thistle, but offers poor control of common lambsquarters and eastern black nightshade. Matrix can be applied prior to potato and weed emergence or a postemergence application can be made before potatoes are 14 inches tall and annual weeds are less than 1 inch tall.. Matrix requires 0.75 to 1 inch of water no later than 5 days after application. It may be tank mixed with Dual, Eptam, Prowl, or Lexone.

Table 6. Registered herbicides and their usage in North Dakota to manage weeds in Potatoes.

Herbicide	Tradename	Acres Treated[1] x 1000	Acres Treated[1] %	Dosage in Lb AI/Acre	Product per Acre	Weeds controlled	Application Timing
Glyphosate	Roundup Ultra/RT others	12.7	9.5	0.19 to 0.75	0.5 to 2 pt of a 3 lb ae/gal conc.	Emerged grass and broadleaf weeds, and volunteer crops.	Preplant or anytime prior to crop emergence
	Roundup UltraMax				0.4 to 1.6 pt of a 3.7lb ae/ gal conc.		
	Roundup Custom, others				0.38 to 1.5 pt of a 4 lb ae/ gal conc.		
	Roundup UltraDry				4.7 to 18.5 oz of a 65% SG.		
EPTC	Eptam	1.7	1.2	3 to 6.125	3.5 to 7 pt 15 to 30 lb 20G	Grass and some broadleaf weeds.	PPI, Dragoff, or Directed Spray at layby.
				4.5 to 6	5.25 to 7 pt 22.5 to 30 lb 20G		Fall incorporated after October 15 until freeze-up.
trifluralin	Treflan and others	8.3	6.2	0.5 to 1	1 to 2 pt 0.8 to 1.7 lb 60DF		PPI
pendimethalin	Prowl Pendimax	20.6	15.4	1 to 1.5	1.2 to 3.6 pt 1.67 to 2.5 lb DG		PPI, PRE or EPOST Potato: Before 6 inches tall.
metolachlor	Dual II Dual II Magnum	9.4	7.0	2 to 3 1 to 2	2 to 3 pt 8 to 12 lb 25G 1 to 2 pt		PPI or PRE
linuron	Lorox and others	0.5	0.4	0.75 to 2	1.5 to 4 lb DF 1.5 to 4 pt L	Most annual grasses and broadleaf weeds.	Potato: PRE Grasses: Up to 2 inches tall Broadleaf weeds: Up to 6 inches tall.
metribuzin	Sencor	15.6	11.6	0.5 to 1	0.67 to 1.33 lb DF	Annual broadleaf weeds and some grasses.	PRE to Crop
				0.25 to 0.5	0.33 to 0.67 lb DF	Annual broadleaf weeds and some grasses.	POST Weeds: Up to 1 inch tall.

rimsulfuron	Matrix	18.1	13.5	0.375 oz	1.5 oz DF	Annual grass and broadleaf weeds and suppression of quackgrass and Canada thistle.	PRE to crop and weeds: After hilling or drag-off but before potato emerge.
				0.25 to 0.375 oz	1 to 1.5 oz DF	Poor common lambsquarters control	POST Potato: Up to 14 inches tall. Annual weeds: Less than 1 inch tall.
rimsulfuron + metribuzin	Matrix + Sencor	NR	NR	0.25 to 0.375 oz + 0.188 to 0.25	1 to 1.5 oz DF + 0.25 to 0.33 lb DF	Annual grass and broadleaf weeds including common lambsquarters, ALS resistant kochia, and wild buckwheat and suppression of quackgrass and Canada thistle.	PRE to crop and weeds: After hilling or drag-off but before potato emerge.
							POST Potato: Up to 14 inches tall. Annual weeds:Less than 1 inch tall.
sethoxydim	Poast	20.5	15.3	0.1 to 0.3	0.5 to 1.5 pt	Annual grasses.	POST Weeds: 2 to 4 inches.
clethodim (Registration Pending)	Select/Prism	NR	NR	1.5 to 2.5 oz	6 to 10 fl oz/ 12.8 to 21.3 fl oz	Annual grasses and quackgrass.	POST Grass: 2 to 6 inches tall.
Potato Vine Desiccation							
endothall	Desicate II	0.8	0.6	0.5 to 1	2 to 4 pt	Desiccant.	At least 14 to 21 days prior to harvest.
diquat	Diquat	47.7	35.6	0.25 to 0.5	1 to 2 pt		At least 7 days prior to harvest.
glufosinate	Rely	NR	NR	0.375	48 fl oz		At least 9 days prior to harvest.
paraquat	Gramaxone	4.0	3.0	0.47	1.5 pt		
Sulfuric acid		NR	NR		20 gal		At least 5 days prior to harvest.

[1] Zollinger et al. 1998. NR = not reported.

Table 7. Registered herbicides and their usage during 1999 in North Dakota to manage weeds in potato.

Herbicide	Tradename	Area Applied[1] %	Recommended Dosage lb AI/acre	Rate per Application[1] lb AI/acre	Rate per Crop Year[1] lb AI/acre	Weeds Controlled
metalochlor	Dual and Magnum	21	1 to 3	1.61	1.61	Grass and some broadleaf
metribuzin	Sencor	42	0.25 to 1	0.52	0.57	Annual broadleaf and some grasses
pendimethalin	Prowl and Pendimax	11	1 to 1.5	1.07	1.07	Grass and some broadleaf
rimsulfuron	Matrix	25	0.25 to 0.375	0.02	0.02	Grass and some broadleaf
sethoxydim	Poast	6	0.1 to 0.3	0.23	0.23	Annual grasses
diquat	diquat	41	0.25 to 0.5	0.35	0.4	Desiccant

[1] USDA-NASS. 2000.

Contacts

Steve Lessard, Chairman
Red River Valley Potato Growers Association
P. O. Box 301
East Grand Forks, Minnesota 56721

Duane Preston
Extension Potato Specialist
North Dakota State University Extension Service

Phillip Glogoza
Extension Entomologist
Department of Entomology
North Dakota State University

Denise Olson
Assistant Professor of Entomology
Department of Entomology
North Dakota State University

Art Lamey
Extension Plant Pathologist
Department of Plant Pathology
North Dakota State University

Neil Gudmestad
Professor of Plant Pathology
Department of Plant Pathology
North Dakota State University

Gary Secor
Professor of Plant Pathology
Department of Plant Pathology
North Dakota State University

Richard Zollinger
Extension Weed Specialist
Department of Plant Sciences
North Dakota State University

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