BREEDING FOR POTATO DISEASE RESISTANCE

by
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Diseases and Defects Cost Millions

Growers, processors and packers in the Northwest have built a thriving potato industry with an estimated annual value exceeding 500 million dollars. This industry is based on the variety Russet Burbank, a widely adapted, high-yielding variety with good storability and eating quality. Unfortunately, this variety is susceptible to a long list of potato diseases and defects. The estimated annual cost of these is staggering when value is placed on the resulting reduced yields, poor grade, low solids, processing trim loss, disease and insect control measures, and the need of long rotations or new land to maintain profitable production. Losses will range from minimal to catastrophic for any one grower, processor or packer in a given year but the threat of these diseases and defects necessitates expensive control measures every year to reduce risk. The average annual losses or costs resulting from some of these weaknesses of Russet Burbank have been estimated in various U.S.D.A. documents used in long-range planning (Table 1). Overcoming any of these weaknesses by genetic resistance would have great value, particularly to the Northwest potato industry.

New Commercial and Prospective Varieties also Lack Resistance

Much time and effort have been devoted to developing varieties better than Russet Burbank. Some important improvements have been made. Newer varieties in general have less malformation, net necrosis, hollow heart and growth cracking; however, they share many of the susceptibilities of Russet Burbank (Table 2). All are susceptible to the foliage and soil-borne diseases that cause the "early dying" that is so destructive in the Northwest.

In 1978 potato breeders in the Western States initiated formal regional trials to thoroughly evaluate promising new selections in each potato producing area in the West. These trials are intended to define the areas of adaptability of new lines and identify weaknesses which might limit their commercial production. Eight lines entered in the 1978 performance trials were evaluated in disease nurseries in Eastern Washington. They appeared to offer very little improvement over commercial varieties in disease resistance (Table 3). The only exception was the white, chipping line BR7093-24, which has some resistance to Verticillium wilt and leafroll, and line A69327-5 which has some resistance to Verticillium wilt. Most of the new lines are also much less susceptible than Russet Burbank to second growth, net necrosis, hollow heart and growth cracks. Unfortunately, some of these lines are inferior to Russet Burbank in their reaction to scab and Sencor and in their yield and processing quality. Additional testing will be required to determine whether any of them are preferable to Russet Burbank.

Resistance to Diseases and Defects is Available

In 1977 and 1978 we screened many hundreds of new lines from throughout the United States in eight disease nurseries and five performance trials. These trials designed to identify susceptibility or resistance to the diseases or defects important in Northwest potato production. True seed was also planted in these nurseries in 1978 to determine if resistance could be detected in seedlings. High levels of resistance to a wide range of diseases were found in seedlings and advanced lines, both of which were derived from crosses between commercial-type potato clones. It had been assumed that we would have to go to exotic wild species from South America to find resistance to several of these diseases.

Early Generation Mass Screening for Resistance and Horticultural Characteristics

Finding resistance to diseases and defects troubling the Northwest potato industry has been unexpectedly easy. However, combining this resistance with commercially acceptable horticultural characteristics will probably require much time and effort. We are developing a new potato breeding method which will expedite this step. It involves screening through large populations of early generation clones, first for disease resistance then for horticultural characteristics, maintaining throughout a minimum of pedigree records to reduce the time and effort involved. Disease nurseries are conducted where new untested lines and older lines thought to be resistant to a disease are severely exposed to that disease for at least two years to eliminate all except those lines that can consistently withstand such exposure. Within each nursery, resistant lines are mass cross-pollinated by use of a mechanical buzzer that collects a capsule of pollen from all lines combined which is then used to pollinate freshly-opened flowers on the same resistant lines. Cross-pollinated flowers are identified with fluorescent red ribbons so seedballs can be found and harvested in the fall.

Seed from each nursery is saved enmasse and seeded directly into the same field nursery the next year. Since the seed parents are resistant to the disease, many resulting seedlings remain healthy throughout the season. Before harvesting, disease resistant seedlings are marked with colored plastic stakes pushed under the soil at the base of the plant. The vines are beaten off before the tubers are dug with a flat bed digger. The colored stakes pass through the digger with the tubers from resistant seedlings, making them easily identified.

Irrigation frequency is reduced in each nursery twice during the summer to create water stress which emphasizes susceptibility to scab, second growth, tuber deformity, and growth cracking. Disease resistant hills of tubers relatively free of these external defects are bulked together into one lot of tubers from each nursery. This bulk lot of tubers are then passed enmasse through a series of "horticultural screens" to eliminate tubers that are weak in important characteristics such as solids, storability, bruise resistance, hollow heart, processability and number of eyes.

Industry representatives in the Northwest require that new varieties must compare favorably with Russet Burbank in yield, grade, and freedom from external and internal storability, processability and quality defects. The earlier in a breeding program that clones with weaknesses can be identified and eliminated, the better the chance of finding commercially acceptable clones. Many undesirable weaknesses can be eliminated early in the breeding program by the above procedure (Table 5) with a minimum of effort and expense, and disease resistance can be efficiently combined with desired characteristics.

Multiple Disease Resistance Being Found

In the process of screening for disease resistance, advanced clones found resistant to one disease are screened in the other disease nurseries to determine their reaction to all diseases being studies. In addition, individual tubers from first year seedlings found resistant in one disease nursery are cut into two to eight seedpieces and each seedpiece is placed in a different nursery for another year of mass screening for disease resistance, external defects and horticultural characteristics. We were very pleased to find in 1978 a strong tendency for resistance to Verticillium wilt, Sclerotinia wilt, early blight, powdery mildew, leafroll and Colorado potato beetle to be combined in clones (Table 6).

As a result of this good fortune, a number of clones with a remarkable range of disease resistance have been identified (Table 7). It will take a number of years to evaluate their production potential in comparison to Russet Burbank but in preliminary trials in 1978 some of these multiple disease resistant lines produced very high yields of No. 1 potatoes in late harvested trials. These lines appear to yield more because they remain alive and

vigorous late in the fall while Russet Burbank and other commercial varieties succumb to "early dying". The outlook is favorable for new varieties which will greatly reduce losses currently suffered by the potato industry from diseases and defects.

Use of Potato Vines for Feeding Animals

The presence of large, healthy vines late in the season could cause problems in harvesting. However, frost or the use of chemical defoliants would probably alleviate this problem. The availability of such vines at harvest offers some interesting possibilities. Work at the University of Wisconsin has shown that potato vines can be used to make a sileage that is excellent cattle feed. Table 8 is extracted from some of the Wisconsin results. Lines such as PSDT41 which maintain vigorous vine growth until frost can produce from 20 to 30 tons of sileage per acre. In feeding trials the palatability of this sileage to cattle was as good or better than alfalfa hay sileage and, in general, it was superior to alfalfa in percent digestible dry matter. The alkaloids in vines seemed to cause no problems. Vines are usually too moist to put directly into sileage but could be mixed with grain, straw or other dry material while being put into the silo. Wisconsin workers propose squeezing part of the juice from vines to reduce moisture content. This extracted juice can be heated to precipitate out protein which can be utilized in feed supplements and the remaining juice can be used as a liquid fertilizer. Studies will be conducted at Prosser in 1979 to determine the feasibility of utilizing the large, healthey vines from our disease resistant potato lines as cattle feed.

Table 1. Estimated annual losses or preventative costs resulting from potato diseases and defects in the 500 million dollar Northwest potato industry.

Disease or Defect	Estimated Losses or Costs
Tuber Deformities (Low grade, trim loss)	$74,219,000
Net Necrosis (Insecticides, trim loss)	46,740,000
Verticillium wilt (Early dying, yield loss)	31,992,000
Low Solids (Low quality, processing plant yield)	21,767,000
Leafroll (Certified seed, insecticides)	12,626,000
Early Blight (Fungicides, yield loss)	8,734,000
Powdery Mildew (Fungicide, yield loss)	6,528,000
Hollow Heart (Pack rejects, trim loss)	5,326,000
Sclerotinia wilt (Yield loss)	4,384,000
Growth Cracks (Low grade, trim loss)	3,458,000
Common & Deep-pitted Scab (Packing & trim loss)	1,112,000
Colorado Potato Beetle (Insecticides)	1,030,000

Table 2. Disease response of commercial potato varieties commonly grown in the Northwest when evaluated in Washington disease nurseries in 1978.

Variety	Average Disease Rating[1/]							
	LR	Ve	EB	PM	Scl	Sc	DPSc	CPB
Russet Burbank	1.0	2.2	1.8	1.0	1.6	4.5	4.0	1.0
Norgold	1.0	1.4	1.2	1.0	1.0	4.5	4.0	1.0
Kennebec	1.5	2.5	2.8	1.5	2.2	2.3	2.7	1.5
Nooksack	1.3	1.8	2.0	1.5	1.4	4.5	5.0	2.0
Butte	1.0	2.3	1.6	1.5	1.3	4.3	5.0	1.8
Pioneer	1.0	1.4	1.0	1.0	1.1	4.2	2.8	---

[1/] Disease response rated on a 1 to 5 scale with 1 = very susceptible and 5 = very resistant. Entries shown are an average of the 2 to 20 observations made on each disease. LR = Leafroll, Ve = Verticillium wilt, EB = Early Blight, PM = Powdery Mildew, Scl = Sclerotinia wilt, Sc = Common Scab, DPSc = Deep-pitted Scab, CPB = Colorado Potato Beetle.

Table 3. Disease response of potential new varieties from 1978 western regional trials when evaluated in Washington disease nurseries.

Line	Average Disease Rating[1/]							
	LR	Ve	EB	PM	Scl	Sc	DPSc	CPB
Russet Burbank	1.0	2.2	1.8	1.0	1.6	4.5	4.0	1.0
WnC 316-1	1.3	2.1	1.3	1.0	1.1	2.7	3.5	1.5
AC67560-1	1.0	2.6	1.1	1.0	1.3	4.2	4.5	1.5
A68678-1	1.0	1.8	1.8	1.0	1.0	4.8	5.0	1.5
A69327-5	1.5	3.3	2.4	1.0	2.8	3.7	2.5	2.0
A70365-6	1.0	1.7	1.7	1.0	2.1	4.2	4.7	2.0
B7024-81	1.5	1.9	1.4	1.0	2.3	3.1	1.0	2.3
BR7093-24	4.0	3.7	1.6	1.5	1.9	2.5	1.0	1.0
BC8370-24	1.0	2.1	1.7	1.0	1.0	3.4	3.0	1.7

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Table 4. Resistance to disease found in Washington disease nurseries in 1978.

Nursery	Number Resistant	
	Advanced Clones	Seedling Clones
Verticillium wilt	58	312
Sclerotinia wilt	37	---
Powdery Mildew	18	187
Early Blight	46	473
Leafroll	22	206
Deep-pitted Scab	39	18
Common Scab	49	43
Colorado Potato Beetle	38	---
Early Dying	36	---

Table 5. Mass screening methods being used during the first two generations from true seed to eliminate clones susceptible to diseases and defects.

Disease or Defect	Mass Screening Method
External Defects	Water stress
Leafroll and Net Necrosis	Leafroll nursery
Verticillium wilt	Verticillium nursery
Early Blight	Early Blight nursery
Powdery Mildew	Powdery Mildew nursery
Sclerotinia wilt	Early Dying nursery
Common and Deep-pitted Scab	Scab nursery
Colorado Potato Beetle	Colorado Potato Beetle nursery
Hollow Heart	Cut tubers open in all trials
Low solids	Screen through salt solutions
Sugar Accumulation	Fry plug from each tuber
Sprouting and Shriveling	Store at 50 to 60°F for a while

Table 6. Combined resistance in potato clones evaluated in 1978 Washington disease nurseries.

Clones Resistant to:	No. of Clones	Percentage Also Resistant to:					
		Ve	Scl	EB	PM	LR	CPB
Verticillium wilt	58	---	53	64	22	28	41
Sclerotinia wilt	37	84	---	78	35	35	38
Early Blight	46	83	67	---	30	26	50
Powdery Mildew	18	72	72	78	---	50	56
Leafroll	22	82	55	59	36	---	64
Colorado Potato Beetle	38	68	37	58	29	34	---

Table 7. Multiple disease resistant potato clones developed by early generation, mass screening methods.

Line	Average Disease Rating[1/]							
	LR	Ve	EB	PM	Scl	Sc	DPSc	CPB
Russet Burbank	1.0	2.2	1.8	1.0	1.6	4.5	4.0	1.0
Wn 618-21	4.0	4.7	3.6	3.3	4.0	4.0	5.0	3.5
Wn 701-56	4.0	2.3	3.0	3.0	---	2.0	4.5	4.0
Wn 705-15	4.5	4.3	3.6	2.5	4.5	2.0	3.0	3.8
Wn 705-57	2.0	4.1	4.1	4.0	4.7	3.0	4.0	2.3
Wn 705-64	3.8	4.4	4.1	3.5	4.7	1.6	2.0	3.7
Wn 705-113	5.0	4.8	4.0	4.5	5.0	1.3	1.0	3.0
Wn 705-114	4.0	4.5	4.5	5.0	5.0	3.3	3.0	4.0
Wn 706-21	1.0	4.0	3.5	3.0	4.3	4.5	5.0	3.0
Wn 706-26	4.0	4.2	2.7	3.0	3.5	2.7	1.0	3.0
Wn 720-50	3.7	5.0	5.0	5.0	---	3.0	---	5.0
Wn 726-3	3.0	4.5	4.5	5.0	5.0	2.0	1.0	4.5

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Table 8. Relative tuber and vine yields and the potential value of vines as animal food.

		Fresh Weight Yield T/A	Digestible Dry Matter %
Russet Burbank	Vines	14	72
	Tubers	20	
PSDT41	Vines	26	70
	Tubers	27	
Alfalfa	---	--	69