GENETIC RESISTANCE TO EARLY DYING *

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ABSTRACT

The USDA-ARS potato germplasm enhancement program at Prosser, Wa., has identified and characterized a number of potato clones sufficiently resistant to early dying (ED) diseases that they can be produced in the northwestern United States without use of pesticide sprays or soil fumigants ordinarily used to control these diseases. This multiple resistance to Verticillium and Sclerotinia wilts, early blight, powdery mildew, and other early dying diseases allows these clones to continue increasing in yield and quality after Russet Burbank and most other Northwest cultivars have died from senescence and diseases. Resistance is usually associated with large, vigorous plants with primary and secondary branching and lower than normal petiole nitrates. It is sometimes associated with late tubers setting and bulking. However, results of sequential harvests of performance trials during August, September, and October show ED resistance can be combined with early tuber maturity. Resistant genotypes usually produce more tubers and higher yields than susceptible types and often have unusually large numbers of tubers and extraordinary yields, especially if they are allowed to grow a full season. These resistant genotypes contain lower propagule numbers of V. dahliae in plant tissues than susceptibles and suffer minimal, if any, damage.

INTRODUCTION

<u>Disease, pest, and stress resistant potato cultivars are being developed</u>

There is increasing need for improved cultivars that can be produced more economically, with less risks involved and less use of pesticides.

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* Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the USDA and does not imply its approval to the exclusion of other products that may also be suitable. This article reports the results of research only.

Acknowledgement: Many of the resistant potato clones reported herein are the result of crosses made at Aberdeen, Idaho, in a program conducted by J. J. Pavek and D. L. Corsini. Initial selections were made at various locations in the northwestern United States by participants in the Western Regional Coordinating Committee for Potato Variety Development (WRCC-27).

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The USDA-ARS potato breeding program at Prosser concentrates on development and identification of disease, pest, and stress resistant potatoes that will minimize production costs and risks, and reduce needs for pesticides that pollute the environment or concern consumers (10, 12, 13, 14, 16, 17, 18, 19). A prime goal of this germplasm enhancement program is effective genetic resistance to the early dying (ED) diseases which cause multi-million dollar losses each season to growers in the northwestern states. These growers as a group spend many more millions on pesticide applications, trying to reduce the serious deleterious effects of these diseases.

Worldwide collection of resistant germplasm collected and intercrossed

We have accumulated a worldwide collection of breeding lines and cultivars with effective resistance to ED diseases troubling the potato industry in the Northwest. These have not only been intensively evaluated for resistance to ED diseases such as Verticillium and Sclerotinia wilts, early blight, and powdery mildew, but also other important disease and stress related factors such as PLRV and PVY viruses, Columbia root-knot nematode, and water stress effects. They have also been evaluated for yield and quality characteristics needed by the potato industry. Promising, high yielding resistant lines adapted to production in the Columbia Basin have been intercrossed to combine resistances and increase levels of resistance. They have also been crossed with cultivars popular in the West and breeding lines with minimal disease resistance but superior horticultural characteristics.

Resistant progenies tested under severe exposure in disease nurseries

Known resistant cultivars (1, 2, 3, 5, 6, 8, 20, 21, 22, 23, 24, 25), resistant parental germplasm, and progeny of crosses made at Prosser, Wa., Aberdeen, Id., and other locations have been tested and retested in nurseries designed to provide severe disease and stress pressures that identify useful resistant parents and clones for subsequent evaluation and use in crossing. For several years these selections have been evaluated for productivity and quality characteristics with and without use of pesticides. In 1990 and 1991, additional studies were conducted to characterize, quantify, and evaluate the resistance of the best clones. Results were reported at the 1992 Washington State Potato Conference and are described herein.

MATERIALS AND METHODS

Studying expression and value of early dying resistance

Over a 5-yr period, 1987-1991, the yield, grade, and tuber quality of numerous standard cultivars and several hundred ED resistant clones have been compared when grown with and without pesticides (soil fumigation, aldicarb, etc.) i.e. with and without damaging disease exposures. Exposure to early dying diseases in crops grown without pesticides was enhanced by planting in fields heavily infested with Verticillium dahliae Kleb. (12, 17, 18, 19). Verticillium wilt, early blight, powdery mildew, and Sclerotinia wilt were encouraged in these disease nurseries. One or more of these diseases, which comprise the ED disease complex, became severe on commercial cultivar checks during each harvest season.

Trial location and cultural practices

These studies were conducted at the Research Station in Prosser on sandy loam soils under sprinkler irrigation. Soil testing was done and fertilizer elements NPKZn were applied to total 200:67:67:10 lbs/A. These were applied in the spring before land preparation or during planting. The land was planted to Sudan grass the previous year and contained minimal carry over of nitrogen. From 1987 to 1989, a 4 to 7 day irrigation schedule was followed, depending on weather. This created stressful growing conditions, which enhanced ED diseases and identified stress sensitive clones similar to Russet Burbank. In 1990 and 1991 selected disease and stress resistant clones were compared with cultivars important to the Northwest under irrigation practices similar to those used by commercial growers. This included every other day sprinkler irrigation to replace water losses of the previous two days, as determined by the evaporative pan method.

Collecting information on disease expression and horticultural performance

Disease symptoms were subjectively rated on each line at biweekly intervals, starting in early August, and growth characteristics were evaluated on mature plants. The number of stems which emerged in each plant harvested in August were counted and diameter of the plants estimated. The number of primary branches and amount of secondary branching was determined on a randomly chosen stem from each plant. Twenty leaf petioles were collected from each plot and combined to be analyzed for nitrate nitrogen. Each growth parameter was compared with disease response by correlation analysis. Using the following formulas which we developed, two other measures of plant "vigor" and "size" were computed for comparison with disease response.

Vigor = (stems/plant x primary branches/stem)+[% 2nd branching

(stems/plant x primary branches/stem)]

Size = plant diameter x vigor

Periodically during the harvest season plant juices from stems of each line were plated out on PDX agar media (7, 9) to determine the number of colony forming units (cfu's) of Verticillium dahliae. In August a small section of stem 1 ft (25 cm) above the base of the plant was collected from five plants/plot, combined, and juice extracted for propagule counts. In September and October the apical 2 in (5 cm) of 10 stems/plot were collected and combined for juice extraction/propagule counts.

The 9 replications of 10 hills of each line planted in randomized blocks in each trial were sequentially harvested, three replications every 3 wks during August through October (11, 15). Total yield, marketable yield, number of tubers, and specific gravity were determined and tuber samples were examined for internal and external defects, bruise susceptibility, storability, and cooking characteristics.

Results of field trials with and without pesticides applied were compared to illustrate the value of ED resistance under severe disease exposure (data not shown). The data on 21 resistant lines plus Russet Burbank (Table 1) included in this report were extracted from results of a 1991, replicated, ED disease nursery involving over a hundred entries. They illustrate the type of results observed during the past five years and with dozens of other lines, which are not included for sake of brevity. Plots harvested in October were on a side of the field influenced by shade from nearby trees which in some cases caused yields to be lower than in the September harvest.

RESULTS AND DISCUSSION

Early dying resistance increases yields in later harvests

Data collected from biweekly monitoring of ED symptoms and sequential harvests showed that the ED resistant lines shown in Figure 1 produced yields similar to Russet Burbank when harvested, before or at the time (mid-September) susceptible cultivars were senescing and dying. However, plants of ED resistant lines remained healthier (Figure 2), continued to bulk, and in some cases continued to grow after susceptible lines had declined (Table 2). Consequently, they generally produced larger yields than Russet Burbank in later harvests. Resistant lines with their delayed senescing or dying had fewer Verticillium propagules in stem juices (Fig. 3, Table 2).

Plant characteristics associated with ED resistance

Numerous statistically significant associations with ED resistance were identified by computing all-combination correlation analyses between the growth, yield, and disease response characteristics measured in these studies on 32 lines in the 1991 ED disease trial (Table 2). Resistance to both Verticillium wilt and early blight was highly correlated with plant diameter, size, vigor, and primary and secondary branching (Figs. 4, 5). Resistance to Verticillium wilt also showed statistically significant correlations with number of tubers, yields in September and October harvests, petiole nitrates, Verticillium propagules in the juice of stems collected in August, and early blight resistance (Table 2). Verticillium wilt resistance was not significantly associated with number of stems/plant, yield in August harvests, Verticillium propagules in apical growing points of stems in September and October, and Verticillium propagules in soil around the plants shortly before harvest. Early blight resistance was not significantly associated with stems/plants, any yield parameters, or petiole nitrates. The results of these studies indicate that Verticillium wilt has a significant deleterious effect on yields of susceptible cultivars but early blight generally does not.

ED resistance not always associated with lateness but can cause problems at harvest

Though ED resistance is often characterized as "late maturity," it is not necessarily associated with late tuber setting, bulking, and maturity as evidenced by August and September yields shown in Figure 1.

Late natural senescence often confers resistance to Verticillium and Sclerotinia wilts, early blight, and powdery mildew, since these diseases usually occur only on senescing plants (12, 17, 18). High levels of ED resistance were associated with large, vigorous, immature plants difficult to kill and handle during harvest (4, 12, 17, 18). If these plants are left growing until harvest, the skin of tubers from such plants often does not properly "mature" or "set" so may not be retained well during harvesting.

Several early dying resistant clones being evaluated for release

Several of these ED resistant lines have potential for release as cultivars or breeding parents. These are being increased in commercial seed areas and their resistance and horticultural attributes evaluated in regional and grower trials. These resistant lines: 1) reduce grower costs and losses, 2) increase productivity, and 3) increase profits for growers, packers, and processors.

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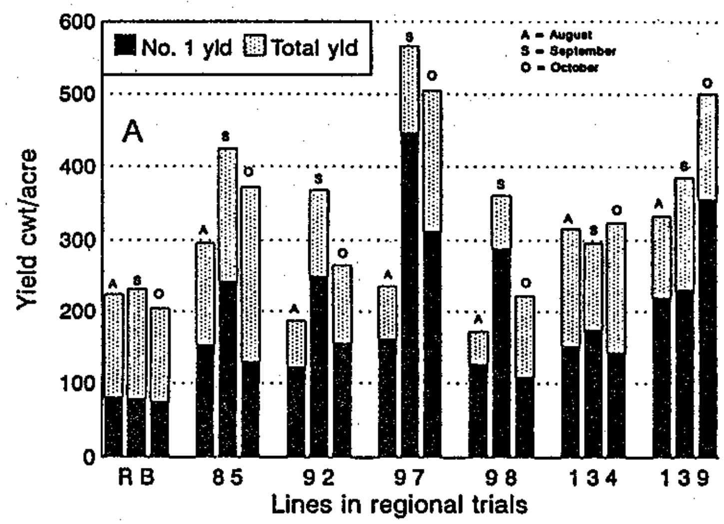
Early Dying Disease Trial

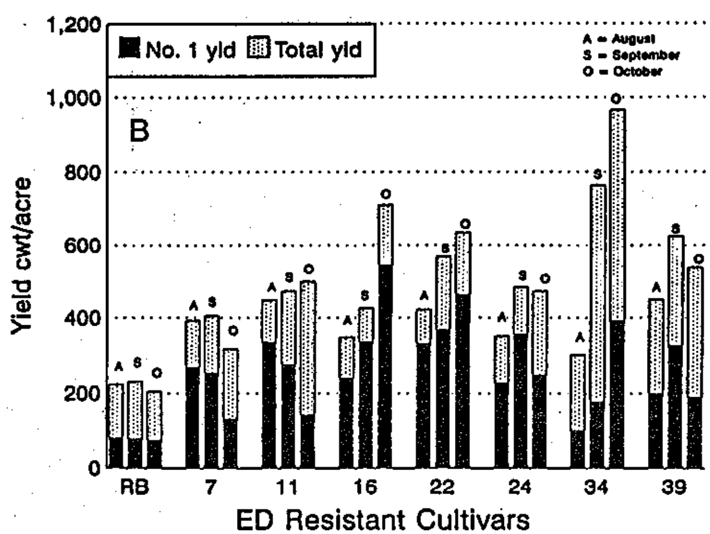
Fig. 1.
Average total and U.S. No. 1 yield of Russet Burbank (RB) and multi-resistant clones when grown in an early dying (ED) disease nursery in 1991. Each bar represents an average of 3 replications of 10 hills harvested sequentially in either August (A), September (S), or October (O). Identity of clones is shown in Table 1.

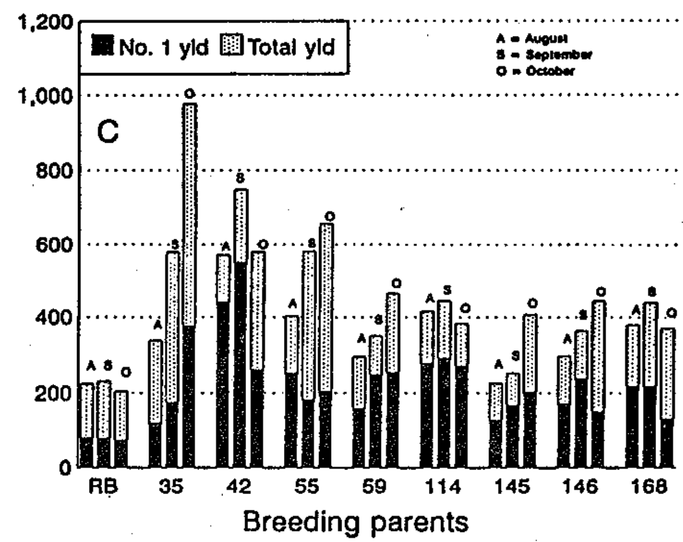
A. ED resistant lines in regional trials.

B. ED resistant cultivars.

C. ED resistant breeding parents.

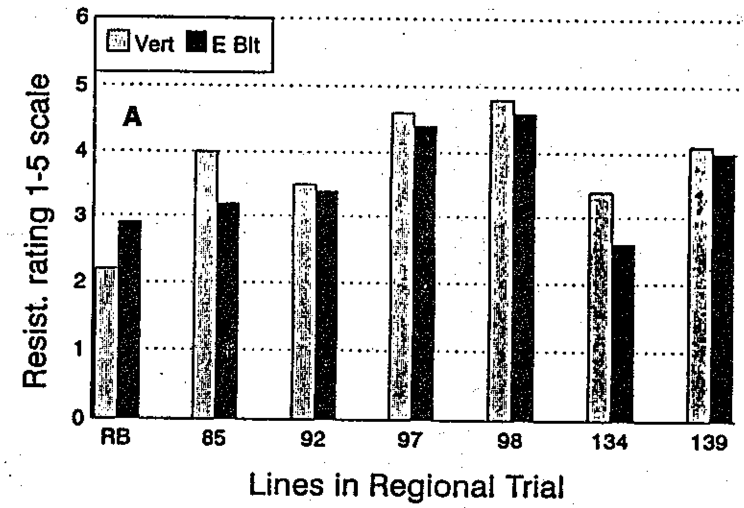


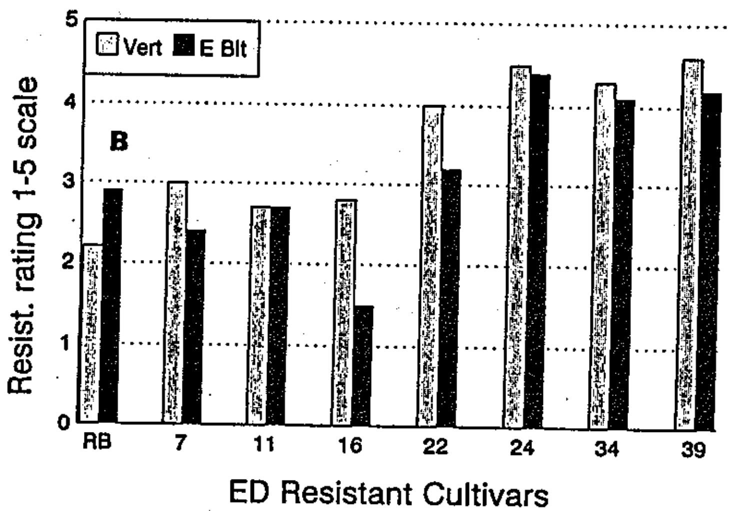




Early Dying Disease Trial

Fig. 2.
Overall average ED resistance ratings of Russet Burbank (RB) and clones listed in Table 1 and shown in Fig. 1. Resistance to Verticillium wilt (Vert) and early blight (E Blt) rated shortly before each sequential harvest using 1-5 scale with 1 = dead and 5 = no symptoms.





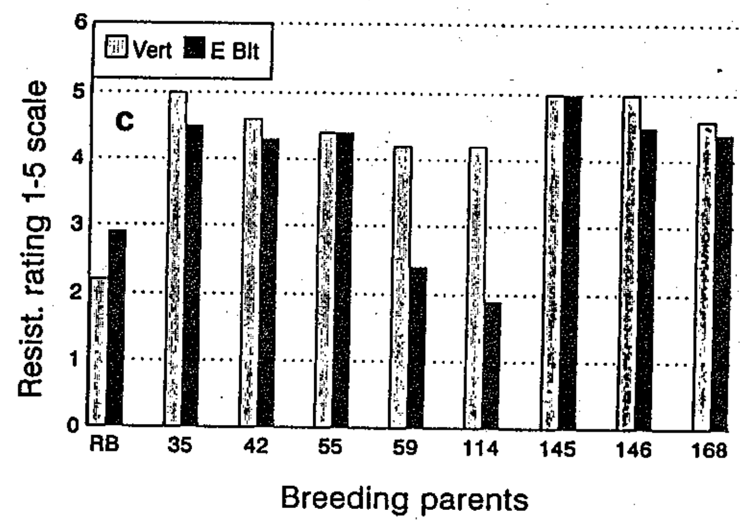


Figure 3. Average number of propagules of Verticillium dahliae in stems of plants grown in 1991 ED disease nursery. Clone identification in Table 1.

A. In tissue 30 cm (1 ft) above the base of stems in late August.

B. In apical portion of stems during September and October.

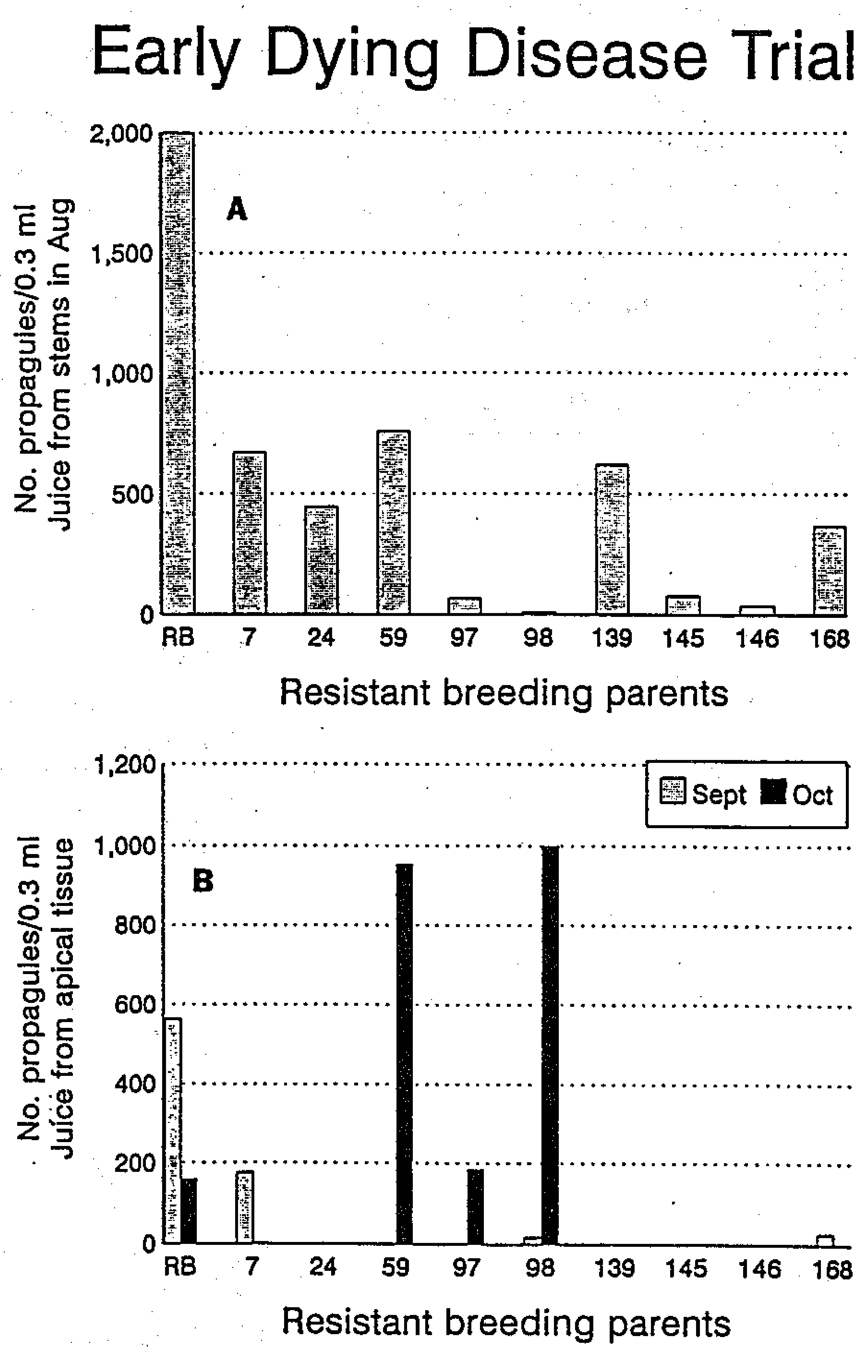


Figure 4. Primary and secondary branching in Russet Burbank (RB) and multi-resistant clones.

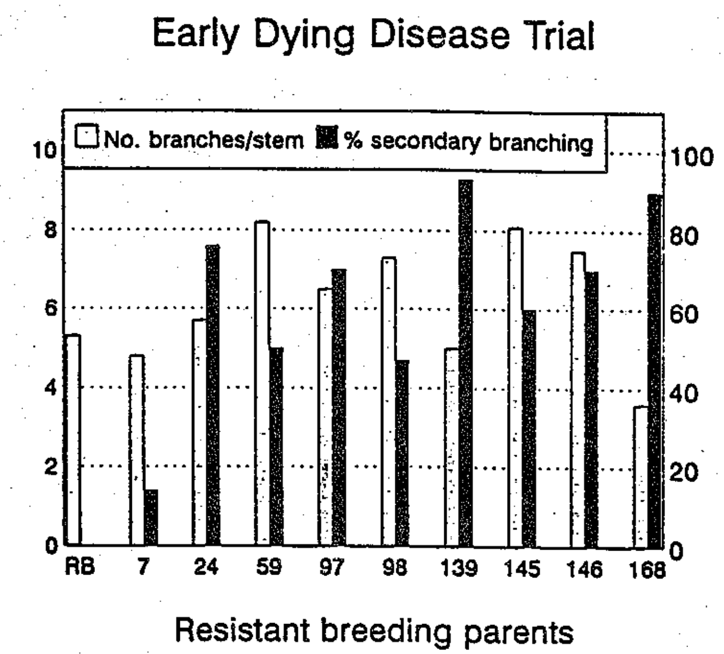


Figure 5. Plant size and vigor of Russet Burbank (RB) and multi-resistant clones. These measures of growth were computed with formulas shown in Materials and Methods.

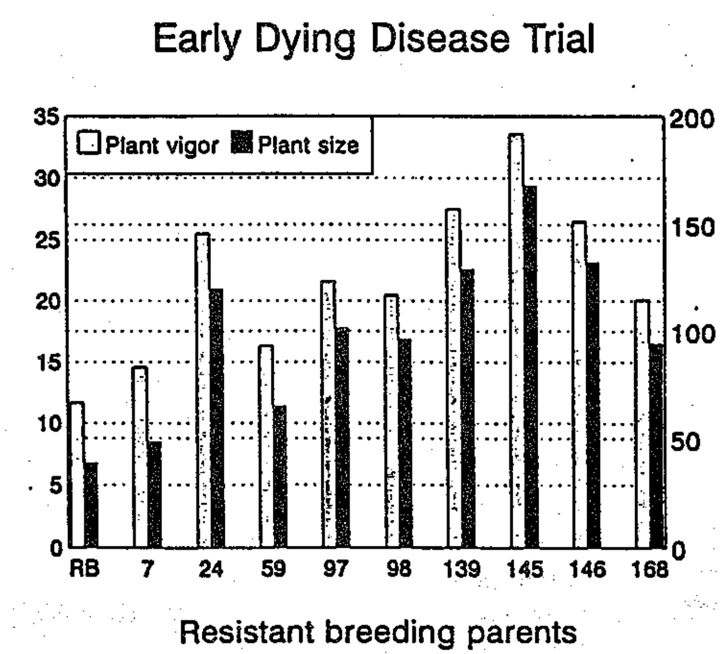


Table 1. Identity and description of 21 multiple-resistant potato cultivars, potential cultivars, and breeding parents, compared with Russet Burbank in graphs attached to this report. Each number in the table is an average of 27 replications placed in three trials and harvested sequentially in August, September, and October.

No.	Identity	Plant size[1]	Tuber type[2]	Tubers/ plant	Tuber size[3]	Specific gravity	Hollow heart[4]	Vascular necrosis[4]
						1.0--		
1	R Burbank	3.2	lg rus	5.2	.29	65	4	20
7	Century	3.3	lg lt rus	5.7	.37	67	5	26
11	Shasta	4.0	lg wh	5.1	.51	64	43	9
16	Gemchip	2.6	rnd wh	7.1	.33	68	3	18
22	Elba	3.7	rnd wh	8.1	.39	74	7	45
24	Serrana	4.1	bl wh	5.8	.44	71	14	16
34	Pilica	5.0	rnd wh	17.5	.25	97	0	12
35	V2	4.8	rnd wh	13.5	.29	74	6	26
39	Pirola	4.6	rnd wh	10.8	.27	82	4	11
42	79V100-40	4.0	bl wh	11.2	.29	74	5	25
55	79Ds500A-11	4.5	obl wh	10.5	.30	83	5	27
59	87Tr2275-9	3.3	obl rus	6.3	.37	79	43	7
85	A077224-3	3.7	obl hv rus	6.5	.34	70	17	6
92	A080432-1	2.8	lg rus	5.2	.34	76	12	11
97	A81286-1	3.9	lg lt rus	5.9	.47	74	12	21
98	A81473-2	3.8	lg rus	4.2	.42	71	19	3
114	A8315-1	3.2	rnd red	6.6	.32	71	4	17
134	A08478-1	2.5	lg rus	5.4	.31	71	6	5
139	A084275-3	3.9	obl hv rus	7.4	.27	87	17	10
145	AWn85542-1	4.8	obl wh	8.0	.27	69	23	24
146	AWn85542-9	4.9	bl buf	6.6	.30	83	43	8
168	Unk-5	4.0	rnd wh	9.3	.25	78	12	21

[1]Plant size rated on 1 to 5 scale with 1 - very small determinant, 5 - very large indeterminant. These ratings approximate the average plant diameter.

[2]Legend: lg - long, obl - oblong, bl - blocky, rnd - round
rus - russet, wh - white, buf - buff-colored, lt - light, hv - heavy

[3]Average weight of tubers in pounds/tuber

[4]Ten of the largest tubers in each rep sliced longitudinally and percent hollow heart and vascular necrosis recorded.

Table 2. Correlation "r" values for relationships between resistances to Verticillium wilt and early blight, and the yields, numbers of tubers, petiole nitrates, plant size parameters, and disease propagules in plant juices and the soil rhizosphere in an early dying disease nursery.

<u>Correlations between Resistance to Verticillium wilt and</u>:

August yields	+0.139^{ns}	Stems/plant	+0.211^{ns}	Propagules (stems, Aug)	+0.513**
September yields	+0.501**	Plant diameters	+0.816**	Propagules (apices, Sept)	+0.329^{ns}
October yields	+0.598**	Primary branches/stem	+0.512**	Propagules (apices, Oct)	+0.309^{ns}
Tubers/plant	+0.463**	Percent 2nd branching	+0.686**	Propagules (soil rhizosphere)	+0.166^{ns}
Petiole nitrates	-0.482**	Vigor of plant[1]	+0.702**	Early blight resistance	+0.691**
		Size of plant[1]	+0.752**		

<u>Correlations between Resistance to Early Blight and</u>:

August yields	-0.294^{ns}	Stems/plant	+0.265^{ns}
September yields	+0.191^{ns}	Plant diameters	+0.740**
October yields	+0.238^{ns}	Primary branches/stem	+0.443*
Tubers/plant	+0.324^{ns}	Percent 2nd branching	+0.608**
Petiole nitrates	-0.343^{ns}	Vigor of plant[1]	+0.768**
		Size of plant[1]	+0.801**

[1]Computed with formulas shown in Materials and Methods.

*,** - Statistically significant at 5% or 1% level, respectively.
ns - not statistically significant "r" value.