POTATO PRODUCTION WITH MINIMAL PESTICIDE USE

by
Mark W. Martin
USDA-Agricultural Research Service
IAREC, Prosser, Wa. 99350-9687

ABSTRACT

Potato lines have been identified that produce high yields of good grade tubers under severe virus disease exposure without use of aphicides such as aldicarb (Temik) or methamidophos (Monitor). These multi-resistant lines also produce satisfactorily without soil fumigation or fungicides, even on soils where scab, Verticillium wilt, Sclerotinia wilt, early blight, and powdery mildew cause serious losses with most cultivars. The productivity of resistant lines is the same whether grown with or without these pesticides and usually exceeds Russet Burbank, especially under disease exposure. Fumigation will probably be needed where nematodes are prevalent and pyrethroid sprays will probably be required for control of Colorado potato beetles, along with an acaricide for mite control. However, these pesticides are of less concern environmentally than those used for aphid control. If bans are imposed on toxic aphicides that currently play such an important role in potato production, these resistant genotypes would be very valuable in maintaining the half billion dollar potato industry in the Northwest.

INTRODUCTION

Cultivars used for Northwest potato production are disease susceptible

Potato production in the Northwest involves a limited number of cultivars, with Russet Burbank dominating. These cultivars are susceptible to most of the viral, fungal, and bacterial diseases that damage potatoes. Profitable potato production is possible only with use of insecticides and fungicides.

Disease control pesticides are under fire

Unfortunately, though exhaustive studies on these pesticides have shown them to be safe at recommended rates and for registered uses, their use is causing increasing concern to environmentalists and consumers. (Note papers by Don Miller and Al Pettibone in these proceedings.) Some of the most important chemicals used for control of aphid vectors of viruses and control of fungal diseases are in danger of being banned. There is a critical need for alternate means of disease and pest control.

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Resistant cultivars are the best answer

Resistant cultivars are the best solution to the worsening problem (6,7). They reduce costs and losses by producers and increase productivity and profits to growers, packers, and processors. They largely eliminate the need for insecticides and, thus, reduce environmental contamination.

Resistance is available in domestic potatoes

After 13 years of searching and breeding for resistance to diseases, pests, and stresses economically important to the potato industry in the western United States, valuable levels of resistance to these production deterrents have been identified in commercial type, domestic potatoes adapted to production in this area (1-11). These levels are adequate to allow profitable production with minimal pesticide use. Reported herein are results that define levels of available resistance to viruses and early dying pathogens that necessitate use of toxic pesticides. Several resistant cultivars and breeding lines with promising horticultural characteristics are described.

MATERIALS AND METHODS

Trial location and cultural practices

These studies were conducted in 1989, at Prosser, Wa., on sandy loam soils under sprinkler irrigation. Before final land preparation in the spring, NPK Zn was broadcast applied at 200:67:67:10 lbs/A and incorporated. The land had been planted to either Sudan grass or corn the previous year and had minimal carryover nitrogen. Soil tests generally showed adequate residual P and K for potato production. Seed potatoes were planted 10 inches apart in rows 34 inches apart in late April and early May. After plant emergence the plots were irrigated daily throughout the growing season with small quantities of water to replace evapotranspiration as determined by an evaporation pan. Plant growth was very good throughout the season with no water stress being evident.

A combination of the herbicides pendimethalin (Prowl), EPTC (Eptam), and metribuzin (Sencor) at 1:2:0.5 lb ai/A was incorporated at plant emergence. This provided excellent weed control throughout the growing season but caused metribuzin damage on sensitive lines, like the Shepody cultivar.

In general, four replications of 10 hills of each line were planted in each trial. However, where sufficient seed was available of the more promising lines, 20 hills per replication were planted and in a few cases lack of seed allowed planting of only 4 hills per replication. All were converted to hundred weight per acre for comparison. Plant counts were made and the data adjusted for the few missing plants.

Disease exposure

Six trials were grown in four fields that were isolated from each other. In the first trial (NO Y/LR), pesticides were applied in a manner commonly used by commercial potato producers.

Shortly before plant emergence aldicarb was banded on both sides of each row at 3 lb ai/A. Starting in late July, the trial was sprayed by airplane three times with insecticides. The first two sprays were with methamidophos (Monitor) and the last with a synthetic pyrethroid (Ambush) and an acaricide (Comite). This trial was grown on a field that had not previously produced potatoes so it was relatively free of soilborne diseases. However, it was downwind from nearby fields of potatoes and fields where potatoes had been previously produced. Apparently wind and blowing dust had carried some disease organisms because some Verticillium wilt and scab was evident at harvest in this supposedly disease-free field.

Two trials (CS LR and CHR LR) were planted in a field that had been cropped to potatoes twice in the last four years. No aldicarb or methamidophos was applied. In the CS LR trial, every third row was planted to seed known to be infected with potato leafroll virus (PLRV). Green peach aphids appeared and began to proliferate by mid-summer. They provided a severe, uniform exposure to PLRV in both trials over at least a 2-month period before harvest. Exposure to Verticillium wilt was moderately severe in the CS LR trial and severe in the CHR LR trial. Two sprays of Ambush were applied to control Colorado potato beetles, one in July and the second in August.

Another two trials (CS Y and CHR Y) were planted in a field that had been cropped to potatoes three times in the last six years. Each plant in the CS Y trial was rub inoculated early in the season with buffered plant juice containing potato virus Y (PVY). Green peach aphids along with the mechanical inoculations provided a moderately severe exposure to PVY in both trials over a 2-month period before harvest. These latter two trials had moderately severe exposure to Verticillium wilt and early blight. Some powdery mildew also appeared late in the growing season. Again, sprays of Ambush in July and August were required for control of Colorado potato beetles.

A sixth trial (Vert) was grown in a field where potatoes have been grown for 36 consecutive years and Verticillium wilt exposure is consistently severe. Aldicarb was applied at emergence to reduce virus spread. This field was furrow irrigated. Yields were so poor that no yield data were collected.

Harvesting and data collecting

The four replications in each trial were harvested sequentially over a two month period from early August to late September, one replication being harvested every 20 days. The data shown are the averages of these four harvest dates (replications). Shortly before each harvest the plants of each line were rated for resistance to leafroll, mosaic, Verticillium wilt, and other early dying diseases using a 1-5 scale, with 1 being very severe and 5 being symptomless. The early dying complex of diseases included Verticillium wilt, early blight, some powdery mildew, and probably other unrecognized casual pathogens. These all combined with natural senescence to cause "early dying" (ED). An average of the four disease readings over a two month period was used as a resistance index for each line.

The tubers from each plot were sorted using standards employed by processors in our area. Specific gravities were measured and the tubers evaluated for internal defects. The tubers were examined for vascular necrosis (leafroll net necrosis?) after 2-3 mos storage at 40-45°F. Tuber samples from each plot were impacted with a motor-driven "thumper" and evaluated for blackspot and shatter bruising. These tuber samples are being evaluated for french fry color and storability.

Germplasm tested

Several dozen cultivars and lines with varying levels of resistance to PLRV, PVY, and ED were included in these trials. The performances of a few of the best are compared with that of Russet Burbank in a table and graphs to illustrate the exciting potential of this germplasm. The cultivars Abnaki (1), Elba (11), Pirola (9), and Shasta are examples of resistant cultivars available for use as breeding parents. The first three are very productive cultivars that produce round, white tubers suitable only for fresh market use. Shasta is the name given to a line A7822-3 developed by the USDA-ARS breeding program at Aberdeen, Id., from a pedigree involving the species Solanum andigena. It produces high yields of long, white tubers that can be processed into french fries.

The performance of five promising breeding lines, when grown with and without pesticides, is also illustrated. These selections from Aberdeen crosses, have horticultural characteristics adapted to the needs of the western potato industry along with varying levels of disease resistance.

RESULTS

Resistant lines produce well with or without pesticides

Some multi-resistant cultivars and breeding lines (Table 1) showed excellent yielding capacity when grown with applications of pesticides commonly used by commercial growers (NO Y/LR in Figs. 1-4). Their productivity, compared with that of Russet Burbank, was even more impressive when grown with minimal pesticide applications under severe exposures to aphid-borne viruses and soil-borne early dying diseases (CS Y and CS LR in Figs. 1-4). The dramatic effects of resistance to PLRV and PVY was particularly well illustrated when virus infected seed of Russet Burbank and these resistant lines was planted and crops were harvested from resulting chronically-infected plants (CHR Y and CHR LR in Figs. 1-4). Resistant lines produced high yields of marketable tubers even under this most severe of tests, while Russet Burbank yielded few useful tubers.

Effects of current season infections

The effects of virus diseases on yields were minor in the year infections occurred, even on Russet Burbank (CS Y and CS LR in Figs. 1-4). Vector buildup and virus spread did not occur until late in the season when bulking was largely completed. Thus, though symptoms, especially of leafroll, became quite severe, yields were not much affected (Table 1, Figs. 1-4).

Current season infections with PVY generally caused more yield reduction than infections with PLRV even though the symptoms appeared less severe. The most important loss suffered by Russet Burbank from CS LR infections was a reduction in internal quality caused by the net necrosis reaction (Table 1). Net necrosis data from the CS LR trial indicate that all these resistant lines express this defect much less than Russet Burbank. the resistant lines were all much more resistant than Russet Burbank in expression of foliar leafroll symptoms, though none were free of this disease.

Even partial resistance has important effects

Resistance to PLRV, PVY, and early dying was seldom complete in this germplasm (Table 1). However, even partial resistance produced dramatic effects when lines were grown under severe disease exposure (Figs. 1-4). The round white cultivars, Abnaki, Elba, and Pirola, and the long white cultivar, Shasta, were especially capable of producing high yields of marketable tubers, even when infected tubers were used as seed to plant the crop (Figs. 1, 3).

Though they showed somewhat less resistance than the white skinned cultivars (Table 1), the oblong russet lines selected for illustration in this report demonstrated a valuable ability to produce high yields of marketable tubers with minimal pesticide use, even when infected seed was used to plant the crop. Noteworthy was line 32 (AO84275-3) which has performed well in disease nursery trials for three years now, showing strong resistance to PVY, PLRV, and ED.

Most lines more resistant to ED than Russet Burbank

With the exception of Abnaki, these lines were all less susceptible to early dying than Russet Burbank (Table 1). This resistance allowed more complete expression of the benefits of virus disease resistance. Verticillium wilt exposure was more severe than expected in the NO Y/LR trial. The most severe wilt was present in the CHR Y and CHR LR trials, probably because the added stress of virus diseases caused earlier senescence. Stress and senescence are closely related to each other and to incidence of ED diseases like Verticillium wilt.

Disease exposure in trials

As planned, there was minimal exposure to virus diseases in the trial where pesticides were applied (Table 1). In the CS Y trial, it would have been better if the spread of PVY had been earlier and more severe. In the CS LR trial, the severity and rapid spread of PLRV provided an excellent test.

Quality characteristics of resistant germplasm

With the exception of line 21 (AC 77226-10), all these resistant lines had specific gravities equal to or better than Russet Burbank. In almost every case, however, virus infection, whether current season or chronic, caused a reduction in specific gravity.

This may create french fry quality problems if virus infected tubers were used in the processing industry. We did not observe any serious internal blemishes, bruising, or storage problems in these multi-resistant lines or cultivars (data not shown). Some had rather large amounts of stem end browning or vascular necrosis (Table 1).

DISCUSSION

Reduced pesticide use feasible

These results show there are multi-resistant potato cultivars currently available which are able to produce a full crop of high grade tubers with minimal use of pesticides. There are also available in breeding programs well adapted advanced selections that produce well under severe disease exposure. With such resistant lines, it is unnecessary to use aphicides normally required to produce potatoes in the western United States. Resistant lines also produce well without soil fumigants or fungicides. In trials not reported here, some of these multi-resistant lines have been shown to be less susceptible to Colorado potato beetles and Columbia root-knot nematodes than currently grown commercial cultivars. However, use of pesticides would be required to control these two pests along with two-spotted mites and wireworms where populations of any of these four are high enough to cause severe damage.

Partial resistance is important

In considering resistances of these lines individually we found even a small to moderate decrease in susceptibility or increase in resistance can have a large, economically important effect on yield or tuber size. One reason Russet Burbank has been a successful cultivar in the Northwest is because it has a worthwhile level of resistance to Verticillium wilt, even though it is usually considered a susceptible cultivar. The 1-3 wk longer growing season provided by this low level of resistance results in higher total and marketable yields, a higher proportion of desirable larger size tubers, and higher solids, compared with cultivars that are more susceptible. Even a few days of extra growth helps during the latter part of the growing season when tuber bulking is most rapid. Increased resistance to Verticillium wilt is often genetically linked with resistance to other foliar diseases also associated with senescence, such as early blight, Sclerotinia wilt, and powdery mildew. This multi-faceted "early dying" resistance even further enhances productivity.

Inherent earliness also an important factor

Interrelated with the length of time plants are alive and are producing and transporting photosynthates is the inherent "earliness" of each line. Some set tubers earlier, bulk them more rapidly, and/or accumulate acceptable levels of tuber solids more rapidly than others. Less ED resistance is needed in such "early" cultivars. In this study, Abnaki is a good example of an early cultivar that produces a large yield of marketable tubers even though it is very susceptible to ED diseases.

ED resistance in early cultivars can actually lead to undesirable oversize tubers late in the season, especially in lines that set low number of tubers. Later setting and bulking lines that produce larger number of tubers are the most benefited by ED resistance.

Too much ED resistance undesirable

Some multi-resistant types, like Elba and Pirola, probably have too much ED resistance. They have large, green plants at harvest which are very difficult to vine kill with chemicals and can interfere with harvesting. Plants of such cultivars would proably have to be removed with mechanical vine beaters. If methods could be developed to collect such plants at harvest time, they would make good silage for cattle feed. However, tubers under such plants usually have poorly set skins and often develop roughness and internal and quality problems because of their attachment to actively growing plants. We have concluded that too much ED resistance is undesirable.

Net necrosis important but hard to measure

The pesticides used in the "disease-free" (NO Y/LR) trial adequately contolled leafroll and mosaic viruses (Table 1). Mild, late season symptoms of these two viruses appeared on a few lines. We assumed these appeared too late to reduce yields or quality. However in several lines, including Russet Burbank, there was an unexpectedly large amount of vascular necrosis (Table 1). There was also more vascular necrosis than expected in some of the other trials. We normally attribute such vascular necrosis at least partially to current season infection by PLRV. It was difficult to separate true, leafroll-induced net necrosis from other expressions and causes of stem end browning or vascular necrosis. There were all gradations, ranging from superficial brown spots on the stem end, through scattered brown or black spots in the vascular ring deeper in the flesh, to the classic net necrosis symptoms involving a network of brown necrotic veins extending down through the stem end of the tuber. Since the resistant lines in this report had very little vascular necrosis in the CS LR trial where net necrosis would be expected and where Russet Burbank was severely affected, we assume most of the vascular necrosis in other trials was due to other unidentified stress factors. These complicating factors make it difficult to accurately measure the amount of PLRV net necrosis in each line.

Resistance to PVY mosaic

Russet Burbank is considered suceptible to PVY but it has a surprisingly high level of resistance or tolerance when compared with very susceptible cultivars (Table 1). This resistance is probably another contributor to the success of this cultivar. Current season infections caused only a mild mosaic in Russet Burbank, but chronic infections caused a more severe mosaic and stunting. The very susceptible cultivar Lemhi and several other very susceptible lines that were planted in these trials, expressed severe plant defoliation when they became infected with PVY. Lemhi had an average Y rating of 2.0 in CS Y, 1.7 in CHR Y, and 2.0 in CS LR. This compares with Russet Burbank's Y rating of 4.7, 3.0, and 4.2 in the same three trials.

All the lines in this report, with the exception of Shasta, have PVY resistance equal to or better than Russet Burbank. With these levels of resistance, minimal or no reductions in yield and grade result from current season infection with PVY (Figs. 1, 2). Highly resistant cultivars like Abnaki, Elba, and Pirola, are able to produce high yields of good grade tubers with acceptable quality even on chronically infected plants from PVY infected seed (Fig. 1). For reasons hard to understand, the cultivar Shasta also excels in this regard, even though it has only low to moderate levels of resistance. In contrast, several of the oblong russet lines in this report expressed only mild to moderate PVY symptoms in chronically infected plants but suffered definite reductions in yield (Table 1, Fig. 2). Even so, yield reductions in these lines were much less than in Russet Burbank.

Ability to produce under disease exposure best selection criteria

After several years of screening and evaluating many thousands of lines in disease nurseries, it has become obvious that it is not possible to predict how lines will perform without use of pesticides by observing only their disease response. There are just too many complex interrelationships between the various diseases involved, the many ways that resistance can be expressed, the many sizes and types of plants, the long period over which harvests can occur, the various components of "earliness," productivity and quality, and the interactions with soil fertility, irrigation practices, and weather. The ultimate and most meaningful test of lines is to, first, evaluate productivity and quality under growing conditions and pesticide practices closely approximating those used by commercial growers. Secondly, concurrently evaluate them under similar cultural conditions, but with minimal or no pesticides applied. Yields and quality under these two conditions are then compared. The potato industry will primarily be interested in whether a line will produce a crop with reduced or no pesticides, and the amount of yield or quality that might be sacrificed.

Sequential harvesting better determines potential

By arranging trials in such a way that replications of each line could be mechanically harvested sequentially, with one or more replications being harvested each two weeks from early August until early October, we were able to more accurately evaluate each line for the dynamics of its disease response and production characteristics. Early, mid-season, and late maturing genotypes were identified and preliminary data were obtained to guide growers in choosing a harvest date for peak performance of each line. The cultivars Abnaki and Shasta produced high yields early, and Pirola and Elba were found to be late maturing. The other lines reported herein would generally be considered mid-season in maturity.

Commercial potential of this resistant germplasm

The highest levels of resistance reported herein are, unfortunately, available in round white cultivars which were developed for fresh marketing in the eastern United States and Europe. Though our results show these cultivars are well adapted to production in the northwestern United States, they would have little use to western processing and packing industries.

They produced high yields and a high percentage of marketable tubers with few internal blemishes or bruising problems, and fair to good levels of solids. However, results of frying tests out of cold storages indicate they will not make acceptable chips or french fries. So it appears that the main use of Abnaki, Elba, and Pirola will be as valuable disease resistant germplasm for breeding programs trying to develop cultivars better adapted to the West and that can be produced without pesticides.

The long white cultivar Shasta has shown less resistance than the three round white cultivars just discussed, but produced well under intense disease exposure with minimal pesticide applications. It has had few internal blemishes or bruising problems, and fair to good solids. Shasta has shown some potential in the french fry industry. Its storability has not been adequately tested.

Several dozen oblong russet lines have been identified and evaluated that have valuable levels of resistance combined with adaptation to the needs of the potato industry. Data on five of the best are reported herein. Many of our most promising lines are derived from crosses made by Dr. J. J. Pavek at Aberdeen, Id., and subsequently screened through various selection programs in the western United States. These oblong russet lines do not have as much resistance as the round white cultivars discussed in this report, but they perform well with minimal pesticides. They will hopefully be acceptable and useful to growers, processors, and packers in the West. These and several similar lines are being increased in seed production areas so their potential can be more thoroughly evaluated in growers fields and regional trials.

Of special interest is line 32 (AO84275-3) which has performed well in disease nursery trials the past three years. It has had few internal or external blemishes or bruising problems, and has shown good solids and cooking qualities. Weaknesses of this line are a tendency to produce flattened tubers that stick to their stolons in early harvests. This line sets an unusually large number of tubers. This results in numerous undersized tubers in early harvests but very high yield capacity when allowed to grow a full season before harvest.

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Table 1. Disease responses and specific gravity of Russet Burbank and some multi-resistant cultivars and breeding lines which produce well with minimal pesticide applications.

		Disease Resistance[2]				Sp.Gr.
Cultivar	Trial[1]	Vert	Y	LR	V.Nec.	(1.0--)
R. Burbank	NO Y/LR	2.3	4.8	4.7	3.5	82
(RB)[3]	CS Y	1.0	4.7	2.0	1.0	71
	CHR Y	1.0	3.0	1.5	2.2	70
	CS LR	2.8	4.2	1.5	1.5	72
	CHR LR	1.0	3.0	1.0	5.0	74
	Vert	2.0	4.6	4.4	---	64
Abnaki	NO Y/LR	1.5	5.0	5.0	4.5	81
(Ab)	CS Y	1.2	5.0	4.3	2.9	75
	CHR Y	1.0	4.9	5.0	5.0	74
	CS LR	2.0	3.6	3.4	4.0	76
	CHR LR	1.7	4.4	4.6	4.3	75
Elba	NO Y/LR	4.5	4.9	4.9	3.3	86
(El)	CS Y	4.4	3.7	3.8	3.7	77
	CHR Y	3.3	4.7	3.6	3.4	77
	CS LR	4.4	3.3	3.0	5.0	76
	CHR LR	5.0	4.8	2.3	4.3	72
	Vert	4.2	4.5	3.7	---	81
Pirola	NO Y/LR	4.3	4.6	5.0	3.5	84
(Pi)	CS Y	4.2	4.8	4.7	4.0	83
	CHR Y	4.3	5.0	4.4	3.4	83
	CS LR	5.0	4.1	4.2	5.0	82
	CHR LR	4.7	4.8	4.5	4.3	91
	Vert	4.5	4.4	5.0	---	83
Shasta	NO Y/LR	4.7	4.1	5.0	4.0	79
(Sa)	CS Y	1.8	4.0	3.7	2.0	76
	CHR Y	1.3	2.2	2.2	3.0	75
	CS LR	2.8	3.0	3.3	4.0	91
	CHR LR	2.7	2.3	2.4	2.5	69

Table 1. Cont.

Cultivar	Trial	Disease Resistance Vert	Y	LR	V.Nec.	Sp.Gr. (1.0--)
A68113-4	NO Y/LR	3.0	5.0	4.7	2.8	94
(20)	CS LR	4.3	3.8	2.5	4.5	77
	CHR LR	3.7	2.3	2.3	4.0	78
	Vert	3.0	2.8	3.2	---	80
AC77226-10	NO Y/LR	2.0	4.6	5.0	3.5	77
(21)	CS Y	1.9	4.0	3.8	2.7	66
	CHR Y	1.3	5.0	3.7	2.5	68
A79216-1	NO Y/LR	4.0	4.1	4.4	4.2	102
(22)	CS Y	2.9	2.7	3.3	4.0	78
	CHR Y	1.7	4.3	2.3	3.9	81
	Vert	1.8	3.3	5.0	---	--
A080432-1	NO Y/LR	3.3	4.9	4.6	4.2	94
(23)	CS Y	3.3	3.9	3.3	2.8	74
	CHR Y	2.3	4.9	2.4	4.4	80
A084275-3	NO Y/LR	4.0	4.6	4.9	2.9	92
(32)	CS Y	4.7	4.3	4.5	3.0	81
	CHR Y	2.7	4.0	3.3	2.9	87
	CS LR	5.0	4.0	3.8	5.0	90
	CHR LR	2.7	1.3	2.6	4.0	82
	Vert	3.0	4.5	5.0	---	86

[1] Six trials conducted: NO Y/LR = standard pesticide applications, so minimal exposure to PVY and PLRV, less Verticillium wilt than in other trials; CS Y = current season exposure to PVY provided; CHR Y = PVY infected tubers planted so crop produced on chronically infected plants; CS LR = current season exposure to PLRV provided, no aphicides; CHR LR = PLRV infected tubers planted so crop produced on chronically infected plants, no aphicides; Vert = planted in field where Verticillium wilt consistently severe, aphicides applied.

[2] Average resistance rating of each line to Verticillium wilt (Vert), PVY mosaic (Y), and leafroll virus (LR). Rated four times on 1-5 scale with 1 = very susceptible and 5 = very resistant. Average resistance of tubers to vascular necrosis (leafroll net necrosis?) determined after 2-4 months storage at temperatures of 40-44°F.

[3] Abbreviations used in graphs.

Figure 1. Productivity of Russet Burbank and four multi-resistant cultivars when they receive standard pesticide applications with minimal disease exposure (NO Y) or receive minimal pesticide applications with severe current season (C SY) or chronic exposure (CHR Y) to PVY.

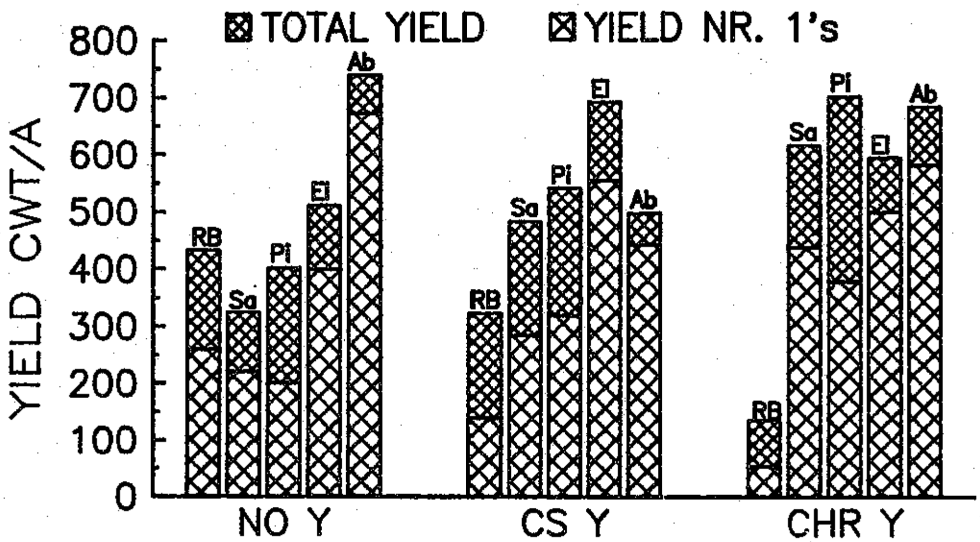

Figure 2. Productivity of Russet Burbank and four multi-resistant, oblong russet breeding lines when they receive standard pesticide applications with minimal disease exposure (NO Y) or receive minimal pesticide applications with severe current season (C SY) or chronic exposure (CHR Y) to PVY.

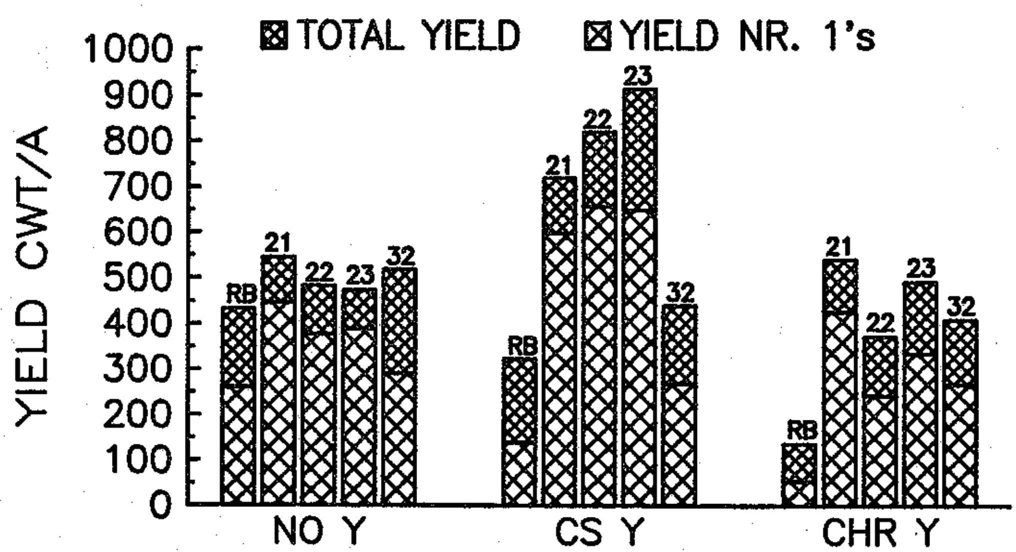

Figure 3. Productivity of Russet Burbank and four multi-resistant cultivars when they receive standard pesticide applications with minimal disease exposure (NO LR) or receive minimal pesticide applications with severe current season (CS LR) or chronic exposure (CHR LR) to PLRV.

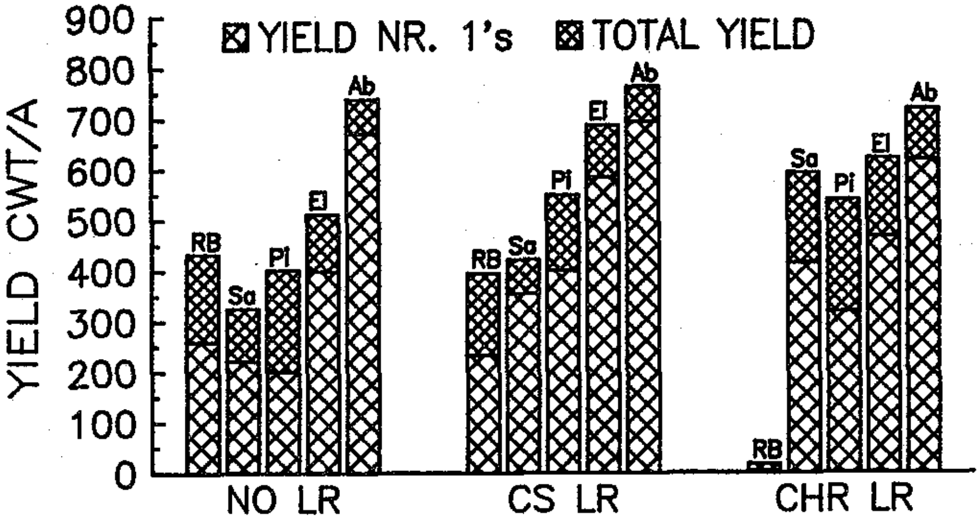

Figure 4. Productivity of Russet Burbank and two multi-resistant oblong russet breeding lines when they receive standard pesticide applications with minimal disease exposure (NO LR) or receive minimal pesticide applications with severe current season (CS LR) or chronic exposure (CHR LR) to PLRV.