SAMPLING SOILS FOR POTATOES

by

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Introduction

Uneven dying of potato vines in a field frequently occurs in relatively small areas. When the areas are small and scattered, the extent of the problem often goes unappraised; however, the combined economic effect could equal the value of many potatoes even if only a total of 10% of an area is affected.

The cause of uneven plant dying can often be associated with unequal soil fertility. In most cases, it can be a shortage of nitrogen, phosphorus and/or potassium, but other factors may be responsible. When plants in a field are of unequal size or some live longer than others, not only is yield reduced, but the tubers could become blackspot susceptible due to a lack of potassium. A lack of oxygen due to over-irrigation of the small and dead plants will produce enlarged lenticels on the tubers causing the tubers to be unsightly, and tuber decay may occur in the field as well as in storage.

Soil Variability by Soil Tests

The small, nutrient deficient areas can be located by observing previous crops or by measuring off small areas, intensely sampling each plot and analyzing the soil from each plot, as we have done in many of our studies. Some of the data from such studies are presented in Table 1. From an inspection of the means and the range in soil tests found for both P and K, fertilizing according to the mean would be unsatisfactory even for areas that in most of the examples are less than one acre in size. Locating the deficient spots is expensive, and it is impractical to treat them separately. In this presentation, the quantities of P and K in the second foot of soil have not been considered because so few potato roots grow deeper than 12 inches into the soil.

Another method of presenting the data is shown in Figure 1. The percentage of a 0.73 acre area was classed according to the present "Fertilizer Guide" as very low, low, medium, and high. Actually, such soil nutrient level designations are meaningless in the Columbia Basin unless the anticipated yield of potatoes is also stated. Large tuber yields require more nutrients than small yields. The size of the yield is largely determined by how long the potato plants live and function.

Soil Variability by Tuber Yield

In two studies, tuber yield was used as the measure of soil heterogeneity. In 1963, 1.1 acres of land were planted to Russet Burbank potatoes and a number of fertilizer treatments ranging from nil to 400 lb/acre of $N\text{-}P_2O_5\text{-}K_2O$ were applied. Each treatment was replicated 11 times. The yield data are in Table 2.

The land had never grown potatoes; therefore, soil-borne diseases were not a factor in controlling yield. An inspection of the data will show that as the amount of fertilizer applied increased, the average yield of tubers increased. As the amount of fertilizer applied increased, the coefficients of variation (CV) decreased indicating a more uniform response in yield. Note that the CV's for the replications vary from 13% to 29% indicating extreme variability in yield among the replications. Note the ranges in tuber yield among the replications resulting from the same fertilizer application. Finally, note that increasing the fertilizer decreased the CV's.

In a second experiment of 8 randomized blocks, the same treatments were put on their respective plots for two consecutive years. The land had never grown potatoes; therefore, soil-borne potato diseases were not a factor in production.

The effects of the lowest and highest fertilizer treatments on total yield and soil variability are shown in Table 3. In 1967 the higher fertilizer rate out yielded the lower rate by 168 cwt/acre. The yield among the 8 replications receiving the same low fertilizer rate ranged from 359 to 548 cwt/acre with a CV of 15%. The yield among the 8 replications receiving the higher fertilizer rate ranged from 554 to 673 cwt/acre with a CV of 7%.

In the second year, 1968, the average yield for 8 replications receiving the lower fertilizer rate was only 18 cwt/acre larger than in 1967, but the CV dropped from 15% to 12% indicating that the range in tuber production was less than in the first year. This is an indication that the soil variability was decreasing. In 1968 the higher fertilizer rate produced 104 cwt/acre more potatoes than in 1967. Factors other than fertilizer may have influenced the extra yield. But, the fact is, that without adequate reserves of P and K, there was essentially no increase in yield in the second year. Furthermore, the CV's were about the same both years.

What Constitutes an Adequate Soil Sample?
A Soil Sampling Study was Conducted on the WSU Othello Experiment Station

The results of this study will be used to illustrate, in still another way, the importance of obtaining a reliable soil sample.

The experimental area chosen was about 4.5 acres in size. It represents an area large enough to maintain its identity for a number of years if both ends of the field are permanently staked. (For example, take a circle 1/2 mile in diameter. It would require about 6 rows per acre or 24 rows per 4 acres equaling a strip 2,640 ft long and about 68 ft wide.) The area was also large enough to include considerable soil variability that would make the results more generally applicable. The degree of land leveling is indicated in Table 4.

The area was divided into 24 quadrates 32 ft wide and 255 ft long (about 1/5 acre each), and a total of 96 samples were taken for soil testing, Fig. 2 and 3. Four independently random samples (each consisting of 20 soil cores) were taken per quadrate 0-12 inches deep with a soil sampling tube. Of the 20 cores per sample, 10 cores were randomly taken; and for each of the 10 taken, a paired core was also taken 1/2 the distance to the next row, or 17 inches away (there being 34 inches between rows). The soil samples were taken in the springs of 1975, 1976, and 1977.

All P and K had been broadcast and only N was banded in the years preceding the study. In the fall of 1976, a 130 lb/acre rate of P and a 500 lb/acre rate of K were broadcast over the area, some of which is reflected in an increased soil test for P and K in 1977. The data for the soil tests covering the 3 year period are presented in Table 5.

A mean represents the midpoint of a population if the population is from a normal distribution, Fig. 4. If adequate sampling is done, half the population will be less than and half will be more than the mean. Consequently, if the dispersion is large, fertilizing according to the mean would be folly because to some degree half the acreage would be under-fertilized and half would be over-fertilized. A mean to which has been added and subtracted ($\pm$) the standard deviation includes 68% of the sampled population or area and 32% of the area lies outside the parameter (16% would be on one extreme and 16% would be on the other), Fig. 4. The values for P (Table 5) have been used in this example. If the range between the lowest and the highest soil test values is large, narrow soil test classifications are meaningless because they cannot be accurately identified in the field or treated separately for economic reasons. A mean and the standard deviation of the sample population can be accurately defined if enough random samples are taken, but as such are of little value in prescribing how much fertilizer to apply. However, a mean and its standard deviation can be defined with remarkable precision and is useful for determining the change in soil fertility status. The accuracy of the mean is the standard deviation of the sample population divided by the square root of the number of observations within that sample population. For example, if a mean is composed of 4 samples, the standard deviation is reduced by 2. However, if there are 16 observations in the mean, the size of the standard deviation is reduced by 4, and if there are 100 samples, the standard deviation is reduced by 10.

Note the examples:

Mean Phosphorus test for 1977 is 71.9 and the standard deviation is 15.7

$15.7/\sqrt{1} = 15.70\ (S_{\bar{x}})$	$71.9 \pm 15.70 = 56.20$ to 87.60
$15.7/\sqrt{4} = 7.85$ "	$71.9 \pm 7.85 = 64.05$ to 79.75
$15.7/\sqrt{16} = 3.92$ "	$71.9 \pm 3.92 = 67.98$ to 75.82
$15.7/\sqrt{100} = 1.57$ "	$71.9 \pm 1.57 = 70.33$ to 73.47

$S_{\bar{x}}$ is the standard deviation of the mean

By using a mean and its standard deviation, it is possible to calculate the number of samples required to establish a mean within a desired range of accuracy and with a probability that if the sampling is repeated, the mean will come within the limits set up, such as 19 out of 20 times. The data in Table 5 were derived from such calculations.

The data in Table 5 indicate that to establish a mean for P with an accuracy of $\pm$ 10% at a 5% level of significance would require 340 soil cores (17 samples of 20 cores each) from 0-12 inches deep per 4.5 acres. The approximately 150 lb of soil can be composited, mixed, and two samples drawn for chemical analyses.

The mean of the composited samples is as representative of the fertility status of the soil as if 17 samples of 20 cores each had been randomly taken in the 4.5 acres and each of the 17 samples were analyzed separately and the results of the 17 analyses were averaged. However, the costs would be very different. To analyze 17 samples would cost $136 (17 x $8 = $136) for a standard analysis of organic matter, pH, P, K, Ca, and Mg. If the sampling technique were used, the cost of analyzing two samples would be only $16 per 4.5 acres. It is the use of such a sampling technique based on the intensity of sampling required to establish a mean ($\pm$ 10% with a p .95) that should enable the grower to determine if his fertilizer program is benefiting his land. This would then allow him to adjust his fertilizer program accordingly.

From the data to be presented, it should be clear that soil sampling as a short term management tool has certain limitations. For long term management, monitoring sites can be established to enable the grower to estimate if his fertilizer program is maintaining, increasing or decreasing the fertility level of his soil.

Since neither P nor K are leached from the soil, as the levels in the soil must be high for maximum production, because of the immobile nature of these elements and because large excesses in the soil are less detrimental than small deficits, it seems reasonable to us that the sooner the levels of P and K in the soil can be built up to where the soil would support a 1200 cwt potato crop, the better. Emphasis could then be put on efficient use of N which can be "spoon fed" and monitored. Nitrogen is leachable and exerts the greatest effect on production.

The amount of leaching of P and K is unimportant. But, the loss of P and K resulting from soil erosion by wind or water is important, both economically and environmentally.

This is especially true if the levels of these elements have become high in the soil. These losses can be reduced and even eliminated if a program of minimum- or no-tillage is practiced wherein plant residues are left on the soil surface.

Farmer Adaptation

The land in a large cirlce may vary considerably in texture and nutrient content. If the topsoil has been removed by graders, wind or water, a very infertile sub-soil remains. Such large areas can be detected from land leveling maps, from the change in appearance of the surface soil, or previous cropping histories. Strips of land, about 50 potato rows wide and representing the extreme soil types in a circle, could be permanently staked at each end of the field and divided in the middle, Fig. 5. Each quadrant area of approximately 4 acres could then be used as a monitoring site for soil analyses, tissue sampling, and production trends. The soil analyses and tissue samples could also be correlated with production.

On the basis of the sampling study performed on the Othello Station, 340 soil cores randomly taken 0-12 inches deep from throughout the 4 acre area should produce mean values with an accuracy of $\pm$ 10% of the mean with reasonable consistency. The amount of soil from 340 cores will weigh about 150 lb. It must be homogenized if the results of the soil analyses are to be meaningful. Duplicate samples could be taken as a check on the degree of homogenization. In total, there would be 8 samples analyzed for a cost of $64 ($8 x 8 samples) per 130 acres. This is about $.50 per acre once the circle has been permanently staked. The analyses would include organic matter, pH, P, K, Ca, and Mg. Tests for N and salts would cost extra. In this example, 12.3% of the area would be intensely sampled for a cost of $64 for chemical analyses plus the cost of permanently staking the area and collecting the soil samples, Fig. 5.

Another proposal has been the use of the grid system in which, say 130 acres, are arbitrarily divided into areas 100 x 100 ft (about 0.23 acres) in size and the intercepts intensely sampled. This system of sampling has the advantage of locating relatively large areas that could be fertilized separately. However, the soil test values obtained at the intercepts may not be representative of the 0.23 acres because of the extreme soil variability that occurs in relatively small areas; furthermore, it is time consuming and expensive. For example: If an 130 acre circle were divided into 100 ft square quadrates and all intercepts were located and sampled, about 566 soil samples would require analyses (43,560 x 130 / 10,000 = 566) at a cost of $4,528 (566 samples x $8) if the standard soil analysis for organic matter, pH, P, K, Ca, and Mg were needed, Fig. 6. To this would have to be added the cost of obtaining the samples, marking the field, and time lost waiting for the test results. On a per acre basis, the cost of the chemical analysis might not be prohibitive ($4,528/130 acres = $34.83 acre).

Bulk rates for chemical soil analyses are available, if the only soil test criteria needed are levels of P and K (which in our opinion is inadequate from the standpoint of long term agriculture). The expense of marking off the field, collecting the samples, etc. would be the same. At current prices, the breakdown would be:

		Cost
Samples @ $1.20 ea.	50	$ 60.00
Samples @ $ .75 ea.	516	387.00
Total samples per 100 ft grid	566	$447.00
Cost of laying out grid		? ?
Cost of collecting samples		? ?
Time lost waiting for analyses		? ?

How Much Fertilizer?

The amount of P and K in the soil is relatively unimportant as long as there are sufficient amounts present to meet the needs of the plant. The amount needed is a function of the tuber yield; and, tuber yield is a function of the length of the growing season, Fig. 7. The amount of nutrients removed from the soil, by a potato crop of a given size, can be computed from the data in Table 6.

Over and under nitrogen fertilization has the greatest influence on yield and quality of tubers for any specific date of harvest. If too little was added at the start, N can be added without decreasing tuber quality providing the supplemental N is added before plant growth is retarded by a lack of nitrogen. If too much nitrogen has been added, an extra two or three weeks of growth can produce surprising increases in yield.

On new land, a 1-1-1 ratio fertilizer has supplied sufficient P and K to enable N to produce very high yields. But with time, there has been a buildup of P in the soil and K has begun to become depleted. Such trends would become obvious from the use of monitoring sites.

Table 1. Variability of P and K Soil Test Data Found Within Experimental Plots (1957 - 1965)

Depth of Sample	Size of Area in Acres	Number of Plots	Mean P	Extremes Found	Mean K	Extremes Found
0 - 12"	.73	40	29	55 - 20	518	900 - 210
"	.73	40	28	70+ - 11	425	690 - 90
"	.73	40	20	35 - 6	388	650 - 140
"	.73	40	48	70+ - 30	646	970 - 360
"	.73	40	13	70+ - 5	338	580 - 180
"	.71	112	45	60 - 30	544	670 - 400
"	.71	56	25	32 - 17	500	650 - 400
"	.64	56	26	42 - 13	311	520 - 130
"	.23	45	8	13 - 5	94	130 - 70
"	.83	164	4	11 - 1	226	670 - 60
"	.71	56	15	29 - 8	288	323 - 183
"	.27	48	13	22 - 8	361	516 - 156
"	1.96	189	25	62 - 8	180	400 - 90
"	1.04	100	38	62 - 21	358	615 - 164
"	1.12	108	18	24 - 11	487	678 - 248
"	.91	80	32	44 - 21	436	600 - 300
"	.89	78	10	21 - 4	265	563 - 150
"	1.12	36	17	31 - 4	468	850 - 125
"	1.61	64	13	23 - 5	320	741 - 114
"	1.12	108	24	58 - 8	383	660 - 150
"	.67	256	19	37 - 7	266	610 - 110
"	1.61	128	39	62+ - 8	318	630 - 170

Table 2. Soil Heterogeneity as Measured by Variations in Total Yield of Russet Burbank in Cwt/Acre (Extremes are underlined)

Block	$N_1P_2K_2$	$N_2P_3K_3$	$N_3P_3K_3$	$N_3P_4K_4$	$N_4P_4K_4$	Mean	CV
1	<u>254</u>	446	523	600	569	478	29
2	346	<u>392</u>	623	546	677	517	28
3	338	507	615	538	700	540	25
4	369	454	638	638	600	540	23
5	384	392	569	654	654	531	25
6	<u>461</u>	<u>592</u>	615	569	654	578	13
7	<u>254</u>	415	<u>400</u>	554	<u>469</u>	418	26
8	415	484	461	561	592	503	14
9	277	561	477	<u>461</u>	577	471	25
10	338	484	<u>684</u>	<u>692</u>	<u>738</u>	587	29
11	361	408	623	608	600	520	24
Mean	345	467	566	584	621		
CV	19	14	16	11	12		

lb/acre

N	P_2O_5	K_2O
$N_1 = 100$	$P_2 = 133$	$K_2 = 133$
$N_2 = 200$	$P_3 = 267$	$K_3 = 267$
$N_3 = 300$	$P_4 = 400$	$K_4 = 400$
$N_4 = 400$		

Size of experimental area - 1.099 acres

Experimental design - Randomized Complete Block

Width of experiment - 64 rows, 34 inches between rows - 181.33 ft

Length of harvested plot - 20 ft

Length of experimental area - 264 ft

Alleys between plots - 4 ft wide

Table 3. Soil Variability as Measured in Cwt/Acre Potato Yields with the Same Treatments on the Same Plots in 1967 & 1968 (Extremes are underlined)

	$N_1P_1K_1$		$N_4P_4K_4$	
Block	1967	1968	1967	1968
1	393	399	652	792
2	423	486	652	649
3	493	518	673	754
4	527	528	664	749
5	548	542	554	781
6	469	469	594	762
7	417	446	600	675
8	359	391	591	646
Mean	454	472	622	726
CV	15	12	7	8

lb/acre

N	P_2O_5	K_2O
$N_1 = 100$	$P_1 = 100$	$K_1 = 100$
$N_4 = 400$	$P_4 = 400$	$K_4 = 400$

Table 4. Cuts and Fills in about 4.5 Acres to the Nearest Inch (100 ft grid)[1,2]

C 0	C16	C22	C19	C13	C 8
C 6	C10	C22	C24	C18	C14
C 1	C 5	C20	C24	C16	C 1
C 5	C11	C17	C17	C 7	F 2
C 4	C10	C11	C 5	C 5	F13
C 5	C 5	C 8	C 1	C 2	F11

[1] Approximate area included in the experiment according to the land grading plan.

[2] C = cut, F = fill.

Table 5.

Number of 10 Pairs of Core Samples Required to Establish a Width of 95% Confidence Intervals at 20% of the Mean on a 4.5 Acre Field Sampled in the Spring for Three Consecutive Years.

	NO_3		P		K		pH		Salts	
Year	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1975	8.8	5.4	33.3	6.5	196	26.5	7.6	0.2	0.4	0.1
1976	7.7	1.4	31.2	4.7	179	23.3	7.6	0.2	0.5	0.1
1977*	37.9	11.7	71.9	15.7	306	55.4	7.4	0.2	2.0	0.6

Coefficient of Variation in Percent

1975	62	19	14	3	17
1976	18	15	13	2	14
1977	31	22	18	3	32

Number of 10 Pairs of Core Samples to Establish a 95% Confidence Interval at 20 Percent of the Mean.

1975	153	17	10	3	15
1976	15	12	9	3	10
1977	40	21	15	3	41
Mean	69	17	11	3	22

*The higher soil test levels in 1977 resulted from a fall application of fertilizer.

Table 6. Average Pounds of Selected Mineral Nutrients Removed from the Soil per Hundred Weight of Potato Tubers.

Element	Lbs/100 cwt
Nitrogen	30.0
Phosphorus	7.0
Potassium	44.00
Calcium	0.8
Magnesium	2.5
Sulfur	2.4
Zinc	0.02
Copper	0.016
Manganese	0.015
Iron	0.047
Boron	0.007

Fig. 1.--Soil variability is a major problem in obtaining a soil sample on which to base a fertilizer recommendation.

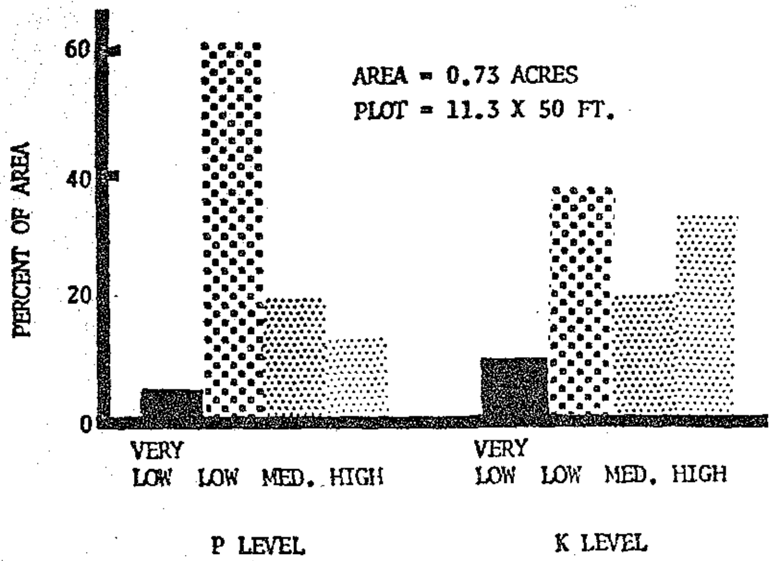


Fig. 2. Soil Sampling Layout of 4.5 Acres on the Othello Experiment Station.

4.5 Acres - 24 Plots

1 1/5 Acre	13 4 Samples
2	14
3	15
4	16
5	17
6	18
7	19
8	20
9	21
10	22
11	23
12	24

Fig. 3. Intensity of Soil Sampling Within Each Plot.

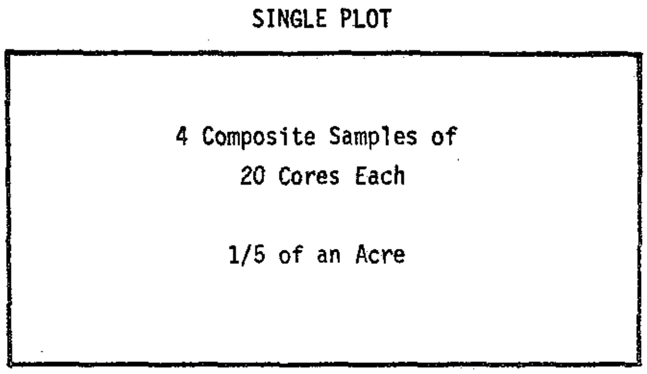


Fig. 4. Distribution Curve for Phosphorus Illustrating Effect of Standard Deviation as the Measure of a Dispersion.

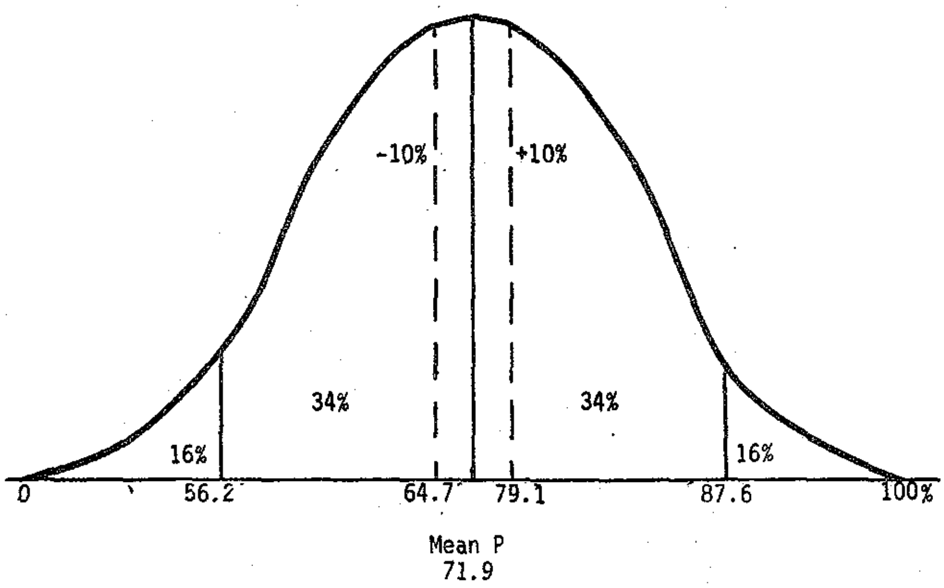
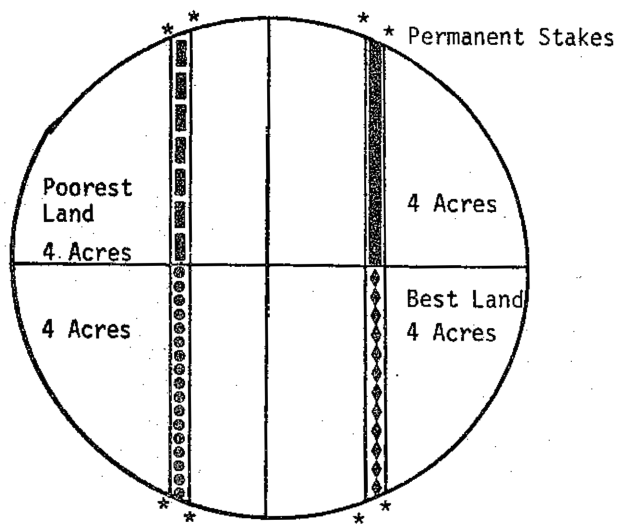


Fig. 5. An Example of a Circle Laid Out with Permanent Monitoring Sites.



340 cores taken per 4 acres and composited.
2 samples drawn from composite.

2 samples/4 acres x $8/sample = $16/4 acres

Fig. 6. A Circle Laid Out for Soil Sampling with a Grid on 100 ft Quadrates.

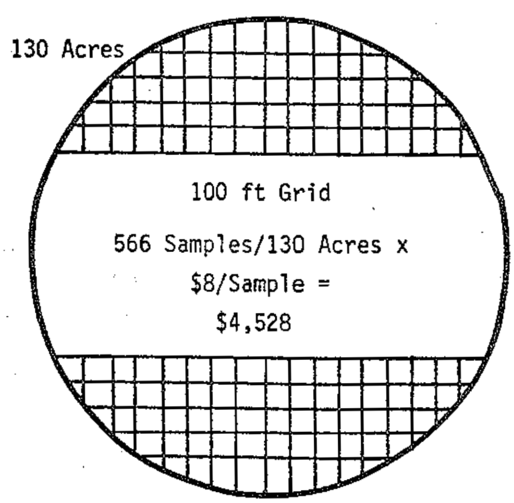
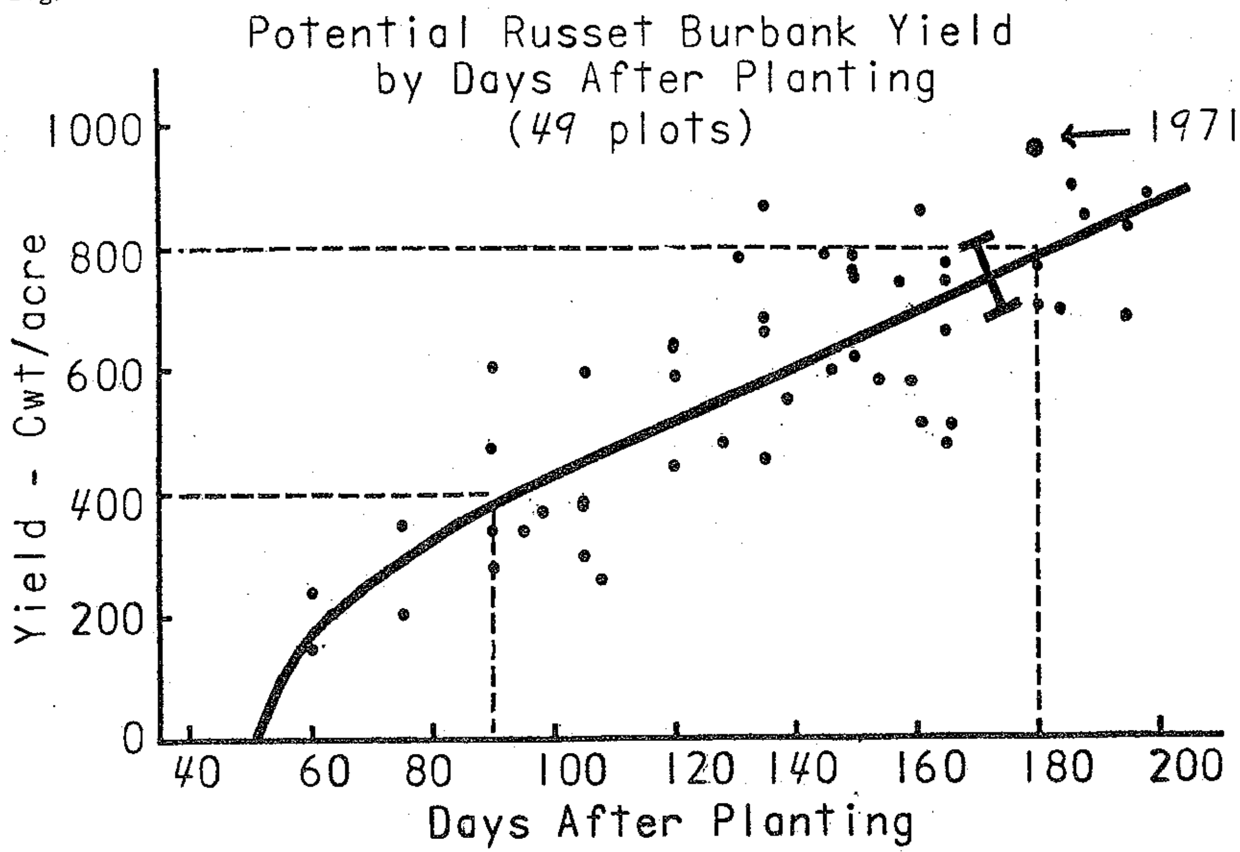


Fig. 7


Potential Russet Burbank Yield
by Days After Planting
(49 plots)
1971
Yield - Cwt/acre
0
200
400
600
800
1000
40
60
80
100
120
140
160
180
200
Days After Planting