WHAT SOIL VARIABILITY MEANS TO THE POTATO INDUSTRY[1]

R. Kunkel, Horticulturist
Washington State University

"Multiply and replenish the earth and subdue it."

This was the first law that Adam and Eve were commanded to fulfill after being driven from the garden paradise where fruit grew abundantly -- free from the plague of weeds, drought, and insects, and where Adam and Eve whiled away the golden hours -- ignorant of hunger and disease. To Adam this new commandment was a law of survival that he must follow if he hoped to exist in the new wilderness. And today, hundreds of years and billions of people later, we are still subject to this law of survival. As the world population continues to increase, more importance is placed on the productivity of our finite amount of land. To achieve this maximum productivity, man must discover and subdue the factors which control production and preservation of food. The researcher's goal is to discover and present the truth about these controlling factors for the beneficial use of mankind.

However, people often misunderstand or misapply discovered facts, losing confidence in research in the process. Some people are even presumptuous and slow to change. But I learned years ago never to consider a problem eternally solved and to be constantly looking for experimental exceptions and alternative explanations. Until a researcher not only determines what happened, but also why it happened, a problem isn't fully solved. Had it not been for this philosophy of constant inquiry and the prodding of colleagues and industry members to try new things, fifty tons of potatoes per acre would have been an impossible dream. But even now, some growers occasionally, and we routinely in experimental work, harvest 35 to 40 tons per acre.

Washington has a tremendous potato production potential because of the long growing season, ample irrigation water and soils adapted to mechanical harvesting of potatoes. Many of the acres now planted to potatoes produce far less than their maximum potential because of soil spots which were improperly fertilized, water infiltration problems, and disease infected soil. It will not be possible to continue to move to new land on which to produce potatoes. The correction of problems which exist on some older acres could give greater returns per dollar invested than the shift to new land.

It costs little more to produce a large yield than a small one. The cost of land preparation, seed, disease and insect control and irrigation is the same regardless of the crop size.

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Nearly every potato field has areas of early die-back. Yield is affected, but secondary problems of blackspot and decay may arise which cause a selling loss of greater concern than yield reduction. The seriousness of the problem depends upon the extent of the area involved. Small areas may be of no consequence unless they add up to a sizeable proportion of the whole.

Low production areas within a field have been blamed on land leveling, but in the Ellensburg area where almost no land leveling was done, small areas were potassium deficient with one potato variety, but not with another. Soil heterogeneity from causes other than mechanical land leveling are involved. Between the Columbia Basin and Pullman, soil erosion is evident as the soil color varies from the top of the hills to the bottom of the ravines. Soil erosion best explains the spotty conditions of the non-leveled lands in the New Jersey soil sampling studies.

In the Columbia Basin, wind erosion may be a dominant factor as indicted by the exposed seed tubers. This effect, however, doesn't show on cut and fill maps.

Potassium deficiency was suspected at one end of our fumigation experiment. The following year, four-row strips throughout the field received potassium applications. Its effect was evident early and persisted until harvest. In addition, the effect was not only large in the suspected potassium deficient area, but extended the length of the field.

Plants in some parts of a field often die weeks before those in the rest of the field. On the Washington State University Othello Experimental Unit, a number of such spots occurred in a uniformly fertilized potato field.

The following year in the same area, different rates of potassium were used with nitrogen and phosphorus. The plots extended the length of the field. Early in the season, the field appeared quite uniform except for the plants in the check row which were light green and dwarfed. Color differences in the foliage in the treated rows were apparent; the darkest foliage indicated potassium deficiency.

As the season progressed, the deficiency symptoms grew more obvious and were labeled with the date of first appearance. The results of soil and tissue samples taken indicated that the lower the soil potassium, the lower the tissue potassium and the sooner the plants died.

Later in the season, the deficiency symptoms became more pronounced, and in extreme cases the plants died.

Close examination revealed that plants in some rows were dead, in others partially dead, and in still others quite green. The dying rate was related to the amount of fertilizer potassium. In the check row, the plants remained small, no deficiency symptoms developed and no tubers were produced.

The kind and amount of fertilizer influenced longevity, yield, harvest date, and blackspot.

Plant longevity often differs within the same field. At times nitrogen and phosphorus are equally as important as potassium. Fertilizer phosphorus in excess of plant needs accumulates in the soil. Fertilizer potassium, however, is applied in quantities far less than the amount removed in a large potato crop. Consequently, potassium deficiency symptoms are becoming more prevelant throughout the Basin each year. The amount of phosphorus and potassium in the soil can be assessed by soil analysis.

Nitrogen is usually the key element. When phosphorus and potassium are plentiful but nitrogen is limiting, there is essentially no growth. In the Basin, these three nutrients are frequently dependent on each other. With high nitrogen rates, high phosphorus and potassium rates are also required. When 400 pounds per acre of nitrogen and phosphorus were applied without potassium, extreme potassium deficiency symptoms were present in 88 days in a low potassium soil.

Soil nutrient variations greatly effect grade and yield, and the same fertilizer may give yield differences in excess of 75 cwt. per acre. No. 1 potatoes produced by the same fertilizer may differ by as much as 100 cwt. per acre depending upon the location in the field (Fig. 1).

Non-uniform field growing conditions also affect specific gravity. Differences among tubers of the same variety in different parts of the same field are often greater than differences among varieties. Such soil variations make it difficult to ascertain whether one variety or treatment is better than another.

Table 1. Effect of Position in the Field on Specific Gravity

Variety	1	2	3	4	5	Mean
1	1.086	1.080	1.080	1.083	1.088	1.083
2	96	85	95	92	91	92
3	85	93	80	93	90	88
4	93	96	84	91	91	91
5	89	86	88	89	88	88
Mean	90	88	85	90	90	

Tubers from plants which have died prematurely because of poor mineral nutrition, water or disease are more prone to blackspot than tubers from normal plants. A price adjustment in the markets of as little as 5¢ per cwt/car means a grower loss of $25/car, and frequently the loss is much greater. To avoid such losses, all parts of a field should be kept growing until harvest time.

Soil areas with early plant death also present irrigation problems. If irrigation is continued to adequately water the green plants, the dead ones become too wet and the tubers develop enlarged lenticels and eventually decay. Field decay, however, is not as bad as that which is undetectable at grading time, but is discovered on the market. If the water is turned off to prevent decay, the live vines dehydrate the tubers and increase blackspot susceptibility, especially if potassium is deficient.

Dow conducted an experiment in an area only 34 X 150 feet. One end of the area was wet and the other dry. As the distance from the wet end toward the dry increased, the yield and No. 1 grade potatoes decreased almost linearly (Fig. 2).

Specific gravity and blackspot increased with the distance from the wet end toward the dry end. Blackspot in the tubers from the dry end of the experiment was one of economic importance, yet the two ends of the plot were only 150 feet apart (Fig. 3).

Soil variability due to nutritional causes and moisture differences is an annoyance to the potato industry and the research man. Where two asterisks occur for blocks, it means that specific gravity and blackspot differed in various parts of the same experiment at odds exceeding 99:1. The two asterisks for the blocks by fertilizer interactions for yield, specific gravity, and blackspot indicate that the same fertilizer had different effects in various parts of the same experiment at odds exceeding 99:1 (Table 2).

Table 2. Values of "F"

	Yield	% No. 1	Sp. Gr.	B.S.I.	Chip Color
Blocks	N.S.	N.S.	* *	* *	N.S.
Blocks X Feet	* *	N.S.	**	* *	N.S.

Therefore, no general statements can be made as to fertilizer effect on these three factors in this experiment. The factors which cause differential responses of the same treatment in different parts of the experiment are most likely variations in water infiltration to the soil and in soil fertility level.

When I came to Washington, I consulted a number of colleagues about the growing conditions of the Columbia Basin. At that time Dr. Moodie strongly recommended that a soil sample be taken from every plot in an experiment. We sampled the top foot of soil and also the second where feasible. The many soil samples taken and analyzed showed extreme soil variability. These analyses also made it possible to calculate a standard deviation with which to establish confidence limits for the results of the soil analyses.

The standard deviation, abbreviated St. D., is a measure of variability. A mean plus and minus its standard deviation denotes the expected range in values which will occur four-sixths of the time if the area is resampled. A mean plus and minus its standard deviation includes four-sixths of the population. One sixth would be expected to be lower than the mean minus its standard deviation. The mean plus and minus its standard deviation therefore denotes the range in values which could be expected two-thirds of the time from chance, because of sampling error, if the areas were resampled a second time similar to the first method.

How to use the standard deviation is of more interest to farmers and fieldmen than its origin or computation.

Suppose that a five acre field were divided into 450 little rectangles 12 X 40 feet and that twelve soil cores were taken from each of the rectangles and analyzed separately for potassium. The average value for potassium would now represent the average of 5,400 (or 450 X 12) soil cores. Since a large number of soil analyses were made separately, it is possible to calculate the standard deviation.

Suppose the mean potassium index were 300 and the standard deviation 100, written 300 ± 100. Three hundred minus 100 leaves 200, and 300+ 100 gives 400. Thus two-thirds of the sample obtained from the field would be expected to have values between 200 and 400 for one potassium index. To date no field is sampled to such a degree, nor is it economically feasible, but unless an accurate estimate of the fertility status is achieved, the fertilizer results could be inadequate.

The advantage of dividing the five acres into rectangles and testing each separately, over taking an equal number of cores randomly over the same area, is that the location of different potassium level areas can be identified, and secondly, that the total area of each potassium level can be calculated. Furthermore, each part of the field is equally represented in the sample.

The results of a number of intensive soil sampling studies made in the Columbia Basin are shown in terms of the means and their standard deviations.

Table 3 A. Soil Test Data for Experimental Plots (1957-1964) - Soil P

Depth of Sample	Size of Area - (Acres)	Mean P	St. D.	Number of Plots	Extremes Found
0 - 12"	.73	28.9	7.0	40	55.0 - 19.8
12 - 24	.73	8.9	5.2	40	22.4 - 3.6
0 - 12	.73	28.2	11.6	40	70+ - 11.4
12 - 24	.73	16.5	6.6	40	28.4 - 4.0
0 - 12	.73	19.7	7.7	40	35.2 - 5.6
12 - 24	.73	7.9	4.5	40	23.0 - 4.0
0 - 12	.73	47.6	9.7	40	70+ - 30.0
0 - 12	.73	13.3	12.1	40	70+ - 4.8
12 - 24	.73	4.6	1.0	20	6.2 - 3.2
0 - 12	.71	45.4	6.4	112	59.8 - 30.2
0 - 12	.71	25.2	2.9	56	32.2 - 17.4
0 - 12	.64	25.7	6.8	56	41.6 - 12.6
12 - 24	.64	10.2	5.1	25	17.8 - 3.2
0 - 12	.23	7.5	1.9	45	13.0 - 5.2
0 - 12	.83	4.1	2.3	164	11.0 - 1.0
0 - 12	.71	14.89	4.2	56	29.0 - 8.0
0 - 12	.27	13.0	3.5	48	22.3 - 7.6
0 - 12	1.96	24.6	12.7	189	62.0 - 8.0
0 - 12	1.04	38.3	9.5	100	62.0 - 21.3
0 - 12	1.12	17.6	3.3	108	24.0 - 11.4
0 - 12	.91	32.1	4.8	80	44.0 - 21.2
0 - 12	.89	9.78	4.9	78	20.8 - 3.8
0 - 12	1.12	17.1	7.0	36	30.9 - 4.2
0 - 12	1.61	13.1	5.4	64	23.3 - 5.2
0 - 12	1.12	23.8	9.4	108	58.4 - 8.4
0 - 12	.67	19.0	5.6	256	37.2 - 7.4
0 - 12	1.61	38.71	16.4	128	62+ - 8.4

Table 3 B. Soil Test Data For Experimental Plots (1957-1964) - Soil K

Depth of Sample	Size of Area- (Acres)	Mean K	St. D.	Number of Plots	Extremes Found
0 - 12"	.73	518	173	40	900 - 210
12 - 24	.73	259	218	40	780 - 80
0 - 12	.73	425	111.9	40	690 - 90
12 - 24	.73	413	198	40	670 - 130
0 - 12	.73	388	129.5	40	650 - 140
12 - 24	.73	109.5	129	40	540 - 50
0 - 12	.73	646	177.1	40	970 - 360
0 - 12	.73	338	123.4	40	580 - 180
12 - 24	.73	189	119.4	20	410 - 70
0 - 12	.71	544	54.5	112	670 - 400
0 - 12	.71	500	67.1	56	650 - 400
0 - 12	.64	311	109.7	56	520 - 130
12 - 24	.64	301	165.6	25	570 - 70
0 - 12	.23	94	16.6	45	130 - 70
0 - 12	.83	226	205.6	164	670 - 60
0 - 12	.71	288	38.3	56	323 - 183
0 - 12	.27	361	85.5	48	516 - 156
0 - 12	1.96	180	74.1	189	400 - 90
0 - 12	1.04	358	96.1	100	615 - 164
0 - 12	1.12	487	66.9	108	678 - 248
0 - 12	.91	436	68	80	600 - 300
0 - 12	.89	265	72.9	78	563 - 150
0 - 12	1.12	468	212.1	36	850 - 125
0 - 12	1.61	320	147	64	741 - 114
0 - 12	1.12	383	143.3	108	660 - 150
0 - 12	.67	266.3	11.3	256	610 - 110
0 - 12	1.61	317.7	108.7	128	630 - 170

Although phosphorus has accumulated to fairly high levels in many fields, there are areas in almost every field where additional phosphorus would increase the yield. However, these areas are often scattered and of different sizes. Most of the phosphorus seems to be in the plow layer or the top foot of soil, and a soil sample should be taken to that depth.

The potassium level in different parts of a field was found to be as variable as that of phosphorus in both the top and the second foot of soil. The amount of potassium in the second foot can be considerable and may explain why soil and tissue correlations are usually so low. Potato roots normally extend well into the second foot and absorb nutrients from that root zone.

The pattern of soil phosphorus distribution varies in different fields. In some fields there are fairly large areas which should be treated separately whenever possible. The same is true for potassium.

Some field soils are so heterogeneous that it is impossible to take a soil sample which adequately describes the fertility status of the land. The likelihood of getting a sample which tests low is just as possible as getting one which tests high. If the sample obtained tests high and a large percentage of the soil is actually low, early dieback and all the related problems will result in these areas.

In some fields where fertility levels are distributed erratically, it is difficult to observe where one ends and another begins.

To make an adequate, economical fertilizer recommendation requires a knowledge of the size of soil spots and their distribution (Fig. 4). Under-fertilization can cause a greater loss to the grower because of reduced yield, grade loss, increased decay and blackspot than the cost of the excess fertilizer applied to areas where a yield increase would not occur.

Land leveling is a major cause of soil variance. Land leveling maps are available which show the cuts and fills. Soil appearance is a poor indicator of soil variability without the aid of a land leveling map or a soil sampling tube. The light colored areas may have been filled to various depths with subsoil. Wind erosion also affects the variance, but the extent and location of loss or deposition, though not definitely known, can be extensive.

Furrow erosion may be an even greater factor in producing soil variability than land leveling. Many growers broadcast their fertilizer to reduce the fertilizer tonnage which must be handled at planting time. Fertilizer phosphorus and potassium are especially likely to erode to the depressions, a condition which need not be great to bring about a marked increase in the concentration of either element in the depression.

Another factor which may contribute greatly to fertility variation among soil samples is the practice of banding fertilizer. It is common in the fall to find remains of early spring applied fertilizer bands. Potato digging and tillage operations disperse the bands, but the phosphorus and potassium concentrations in the immediate vicinity of the bands would remain relatively high compared to those in adjacent soil. Although soil samples taken from fertilizer band areas might be accurate, the results could be misleading because the field wasn't represented.

Fields are often totally or partially infected with soil diseases. In these cases the fertilization may have been accurate, but its full benefit not obtained. The use of soil fumigation has demonstrated that this problem exists in the Columbia Basin.

The purpose of this talk is to emphasize the problems of inadequate fertilization and the complexity of soil sampling for chemical analysis upon which to base a fertilizer recommendation.

Fig. 1--The same fertilizers often produce vastly different yields in various parts of the same field because of the soils' diverse inherent fertility levels.

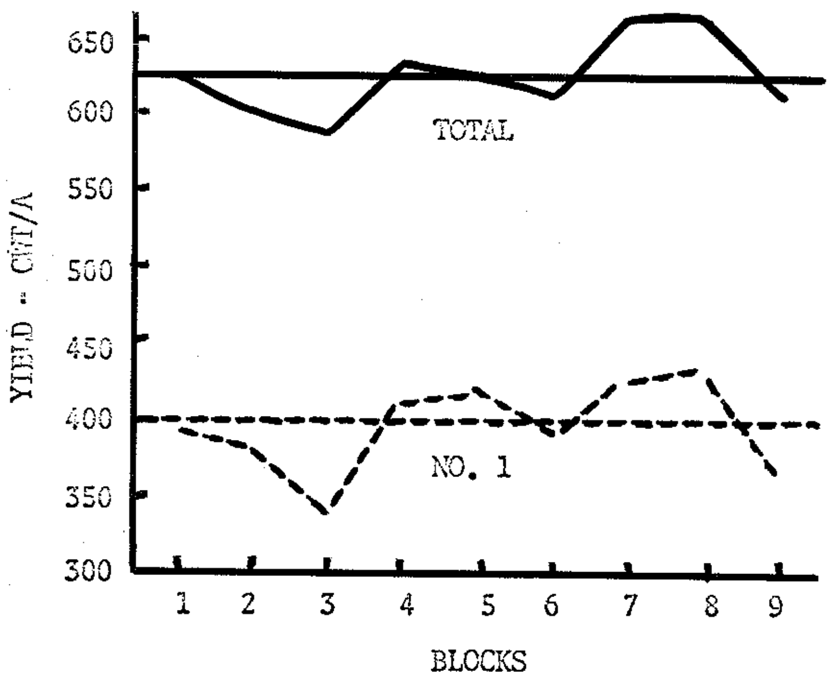

Fig. 2.--Potato yield and grade often vary greatly in relatively small areas within a field due to soil moisture differences.

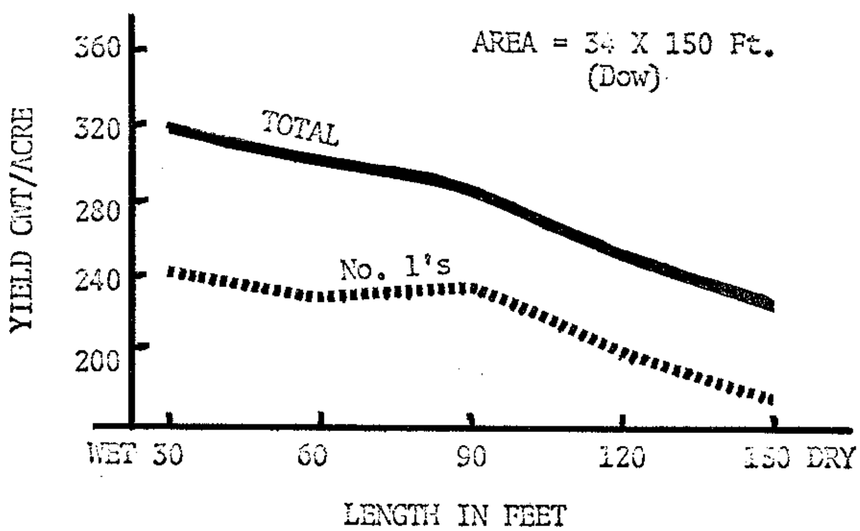

Fig. 3.--Blackspot and specific gravity vary greatly within relatively small areas within a field because of soil moisture differences.

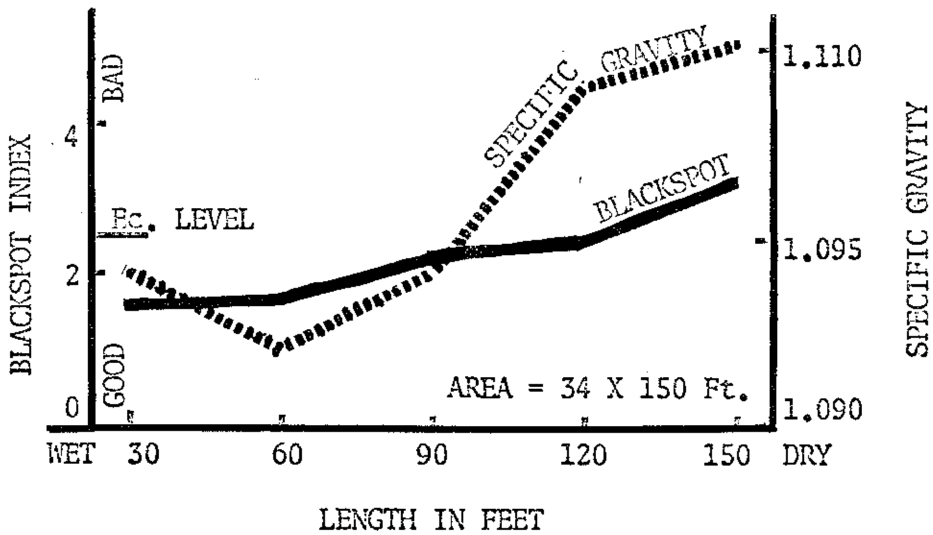

Fig. 4.--Soil variability is a major problem in obtaining a soil sample on which to base a fertilizer recommendation.