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The Effects of Soil Acidity on Phosphorus Uptake by Vegetable Crops in Western Oregon[1]

T. L. Jackson, W. A. Sheets,[2]
N. S. Mansour, H. J. Mack and J. Parsons

Predicting response from application of lime is one of the more complicated problems encountered in soil fertility extension and research work. There are good reasons for this.

In most soil fertility questions we are dealing with one or two fairly easily understood treatment effects and interactions. For example, when we measure a response from application of potassium, we apply potassium fertilizer on a potassium deficient soil, the yield is increased and potassium uptake in the plant is increased. This increased uptake of potassium may decrease the magnesium content in the plant, this could be enough to accentuate an incipient magnesium deficiency. These effects are relatively uncomplicated and easy to explain.

When we apply lime that results in a change in soil pH we have a whole series of effects that can occur. Changing the soil pH increases the availability of nitrogen, phosphorus, and sulfur released from soil organic matter through activities of the micro-organisms and increases the nitrogen fixation by legumes. The change in soil pH increases the availability of inorganic phosphorus present in the soil and decreases the solubility of most of the heavy metal micro-nutrients.

We have wide differences in the response of different species to application of lime. There are wide difference in tollerance to manganese and aluminum toxicity between different species and even between varieties within a species. Also, there is a big difference in the way plants respond to increased availability of phosphorus or decreased availability of heavy metal micro-nutrients.

In fertilizer experiments we can band fertilizer or have the fertilizer plowed down so that the plant roots will be taking up moisture and nutrients from the zone of fertilizer application and we can measure an effective fertilizer response. In contrast, when we evaluate response from application of lime the lime must be mixed throughout the surface plow layer of soil and the lime must react and neutralize the soil acidity throughout as large a portion of the rooting area as possible for maximum beneficial effect to take place.

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2/ Professor of Soils, Oregon State University, Assistant Horticulturist, N. Willamette Experiment Station, Extention Horticulture Specialist and Professor of Horticulture, Oregon State University and County Agent, respectively.

Another complication is the time required to evaluate effects from application of lime. In a fertilizer experiment, if the material is applied properly, you can measure treatment effects within one week in some situations and one to two months is almost always adequate to measure treatment effects. However, because of the time required for lime to react with soil acids, it is better for the lime to be applied and mixed throughout the soil a year before the cropping experiment starts. Since the effects of lime are evident for many years, a complete evaluation of liming effects requires measuring yield and chemical analyses of plant samples for several years.

In previous meetings we have discussed the effect of lime and phosphorus on legume production in western Oregon. OSU Technical Bulletin Number 83 summarizes two experiments that were carried out over a period of five years evaluating the response of legume species to lime and phosphorus treatments. At least three different kinds of responses were observed in these experiments. We have the example of subterranean clover where the application of either lime without phosphorus, or phosphorus without lime, (other nutrients such as potassium, boron and sulphur were applied in adequate amounts) approached the maximum yield. This is a classic example of the application of lime increasing the uptake of phosphorus by a plant, or stated another way, the effects of soil acidity being overcome by application of phosphorus. The other extreme in response was observed in alfalfa where we did get some response from application of phosphorus in the absence of lime, but the maximum yield achieved was about 1/3 of that achieved with the optimum rate of lime. In this situation there was very little response from phosphorus after the high rate of lime had been applied. A third pattern of response can be observed with crimson clover or red clover where there was a response from application of lime without phosphorus or phosphorus without lime, but the combined application of lime and phosphorus increased the yield about 20% above the yield with one of the treatments absent.

In the experiment on the Red Soil Experiment Station, where there was a marked response from application of phosphorus, the major effect of lime was to increase the total amount of phosphorus removed by the plant. In all cases, the application of phosphorus increased the phosphorus concentration found in the legume plants. New Zealand white clover was the only species that showed a marked effect of the lime application increasing the phosphorus concentrations found in the plants.

Lime Experiment - N. Willamette Experiment Station 1973

An experiment was established at the North Willamette Experiment Station in 1973 to determine the effect of soil-applied lime on nutrition and yield of certain vegetable crops. The lime treatments had been established in April, 1969, with applications of 0, 4, and 8 tons per acre. Three replications were established for all lime treatments with four replications on the lime check plot. Soil analyses for these treatments in March, 1973, are reported in Table 1.

Table 1. Effect of lime treatments on chemical analyses of soil samples.

Rate of Lime T/A	meq/100g pH	Ca	Mg	SMP*
0	5.8	5.7	1.3	6.2
4	6.3	9.3	1.3	6.6
8	6.6	12.5	1.2	6.8

*SMPpH readings of 6.2, 6.6 and 6.8 would indicate a lime application of 3.2, 1.1 and 0 Tons lime/A to reach pH 6.4 in a 6 inch layer of soil.

Table beets, spinach, rutabagas, turnips, and radishes were planted on April 25. Seventy pounds of nitrogen per acre as ammonium nitrate were applied to all crops except spinach where the nitrogen rate was increased to 140 pounds per acre, 100 pounds P_2O_5 per acre and 50 pounds S per acre were supplied as super-phosphate. All fertilizer treatments were broadcast and incorporated before planting. Sprinkler irrigation was applied as needed. Individual plots were 20 feet long with the center 12 feet being harvested for data.

Samples of the largest leaves were taken for chemical analyses when roots of radishes, beets, rutabagas, and turnips were 0.75 inches in diameter. The most recently matured spinach leaves were sampled 6 weeks after emergence. Harvest dates for yield were as follows: radishes, May 30; spinach, June 12; Turnips, July 26; rutabagas, July 30; and beets, August 17.

Lime treatments increased yields of spinach and beets, with most of the yield increase from the first 4 tons of lime per acre (Table 2).

Table 2. Effect of lime on mean yields of vegetable crops.

Treatment*	Table Beets		Spinach		Rutabaga	
	Lbs roots and tops	lbs roots only	No. of plants	Wght. grams	No. of roots	Lbs roots and tops
L_0	15.2	9.7	28	197	48	8.0
L_4	20.1	13.6	28	804	51	8.8
L_8	19.6	12.8	28	820	56	9.3

	Turnip		Radish	
	No. of roots	lbs roots	No. of roots	No. of mktable lbs
L_0	65	9.0	128	2.7
L_4	64	8.5	126	2.2
L_8	61	11.41	133	2.4

Manganese levels were 204 and 328 ppm for spinach and beets respectively on the zero lime plots. This is below the toxic levels of manganese reported for these crops where typical toxicity symptoms are present; however, these levels are apparently high enough to be associated with reduced yield. Applicaiton of 4 tons of lime per acre reduced the manganese content below 80 ppm on both crops (Table 3). Lime application also reduced the zinc content of beet and spinach leaves but the reduction was not enough to approach zinc deficiency.

Table 3. Chemical analyses of leaf samples with different rates of lime.

Crop	Treatment	Percent				PPM	
		Ca	Mg	P	K	Zn	Mn
Table	L_0	2.04	1.24	0.51	6.91	71	328
Beets	L_4	1.77	0.93	0.63	7.08	57	78
	L_8	2.19	0.95	0.65	6.75	45	71
Spinach	L_0	1.95	1.17	0.46	6.30	164	204
	L_4	1.82	1.08	0.67	7.80	137	70
	L_8	2.08	0.94	0.68	7.62	113	63
Rutabaga	L_0	2.18	0.28	0.53	5.11	34	70
	L_4	2.45	0.25	0.52	5.78	31	42
	L_8	2.28	0.22	0.58	4.70	32	42
Turnips	L_0	2.18	0.30	0.61	4.28	37	81
	L_4	2.51	0.29	0.62	4.43	32	53
	L_8	2.43	0.26	0.67	4.45	34	47
Radish	L_0	3.09	0.40	0.41	3.14	35	117
	L_4	3.39	0.34	0.42	3.40	33	72
	L_8	3.46	0.30	0.41	2.93	32	78

The response from application of lime was variable on the other crops. It apparently was not associated with high levels of manganese since the radish was the only one of these three crops with manganese levels above 100 ppm in leaf samples.

The effects of lime application on leaf phosphorus and calcium were different with spinach and beets, the two crops showing possible manganese toxicity, than with the other crops. On both beets and spinach, lime reduced the manganese content and increased the phosphorus content. This is expected and is often associated with reduction of manganese toxicity. There was very little effect of lime on phosphorus content of turnips, rutabagas and radishes; this would be expected where manganese levels were not high enough to cause toxicity or to be associated with reduced yields and where phosphorus levels in the soil are relatively high.

The reduction of calcium content in spinach and beets with the first 4 tons of lime applied may be explained as a dilution effect from increased yield of plant material. This explanation is supported by the increase in calcium content from the 8 ton lime application. Such effects are frequently observed when the first increment of a fertilizer treatment is associated with large increases in yield.

The effect of lime on calcium content of rutabaga, turnip, and radish leaves did not show any indication of dilution. The first increment of lime increased leaf calcium for these three crops but had only slight effect on phosphorus content.

Soil acidity in the Willamette Valley is an increasing problem with cropping and use of acid-forming nitrogen fertilizer.

It is important to recognize the wide difference in response from lime expected from different crops. These differences are associated with:

1. Marked differences in tolerance to manganese and the effect of lime application on reduction in manganese uptake.

2. Possible increased phosphorus uptake; this could be associated with manganese toxicity, which reduces phosphorus uptake, or increases microbial activity after liming which increases phosphorus released from the soil. This increased microbial activity could also increase availability of soil nitrogen.

3. Application of lime will usually decrease zinc uptake and could cause deficiency on those crops growing on soils that are relatively low in zinc and susceptible to zinc deficiency.