EFFECTS OF LIME AND NITROGEN FERTILIZATION

ON SOLIDS CONTENT IN GARLIC CLOVES

by

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Garlic cloves with low solids* have been a problem in Willamette Valley garlic fields during the last three seasons. Affected cloves have a loose, leafy structure and white color when compared with the good garlic cloves that have a more dense appearance, a tan color and obvious presence of garlic solids when the cloves are cut through the middle.

Vaughn (1972) examined a number of these fields in 1970 and could not identify either fungus or bacterial diseases that might cause the problem. Observations by Chambers (1972) and other growers in the area during 1971 and 1972 probably eliminates the possibility of attributing the malady to application of herbicides or pesticides to the garlic crop or to the previous crop in the rotation. Additional observations and analyses of the problem by Chambers (1972) indicated a strong possibility of a relationship between the problem and soil acidity or soil fertility.

Soil samples taken from bad areas in fields during 1972 indicated soil acidity as a possible problem. Analyses of plant samples from these fields indicated that higher levels of manganese might be associated with affected plants. It was also noted that this problem was much worse on the California Early variety than on the California Late variety.

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*Material remaining after dehydration is defined as "solids" by the garlic industry.

After reviewing the previous observations, an experiment was established on the Wayne Chambers farm adjacent to a 10-acre California Early variety garlic field that was not harvested in 1972 because of the large percentage of bulbs with low solids.

MATERIALS AND METHODS

The experiment was located on a cloquato soil series which is a recent alluvial soil with relatively high clay content. Processing crops are normally produced on this soil series.

The soil analyses with the methods used (1971) by the Oregon State University Soil Testing Laboratory showed a soil pH of 5.2, 70 ppm of P, 1.23-15.0 - 4.5 meq per 100 g of soil for K-Ca and Mg, respectively, and an SMP lime requirement of 10 tons of lime per ha (4.5 T/A) to change the pH from 5.2 to 6.4.

The experiment was established in a split-split-split plot design with 0 or 11.2 tons of lime per ha (5 T/A) and 112 or 336 Kg N per ha (100 or 300 lb/A) as main plots. Six different combinations of P and K were included with each N rate as follows: 1. P_0K_0, 2. P_0K_1, 3. P_1K_0, 4. P_1K_1, 5. P_2K_1, 6. P_2K_2 (P_1 and P_2 = 50 and 100 kg P/ha or 100 and 200 lbs P_2O_5/A; K_1 and K_2 = 90 and 180 Kg K/ha or 100 and 200 lbs K_2O/A). These 6 phosphorus-potassium treatments were repeated with an intermediate rate of 5.6 tons of lime per ha (2.5 T/A) and 112 Kg N rate. Zero N treatments were included with the zero and 11.2 ton per ha lime treatments.

The California Early variety was planted on the treatments previously outlined. In addition, the California Late variety was planted with 112 kg N per ha on the 0, 5.6 and 11.2 tons per ha lime rates and 336 kg N per ha on the 0 and 11.2 ton lime rates; all plots of this variety received a February application of 50 kg of P and 90 kg K per ha.

The lime plus a constant application of 224 kg per ha of 10-7-7 (N-P-K) fertilizer was applied and disced into the surface before planting. Garlic cloves were planted September ____ in two-row beds with 1.25 meter spacing and the top of the bed about 0.7 meters wide and 25 cm high to provide drainage.

The N, P, and K variables were broadcast down the center of each bed as ammonium nitrate, monocalcium phosphorus, and potassium chloride on February 28. The 112 kg N treatments and half of the 336 kg N treatments were applied on this date with the remaining 168 kg of N applied April 7. Table number 1 shows effects of lime treatments on changes in soil analyses values by July 1, 1973. Table number 2 outlines the lime and fertilizer treatments applied.

One set of plant samples were taken from all treatments receiving 112 kg of N on April 5 with a second set of plant samples May 2. In each case the second and third most recently developed leaves were collected. On April 5 spring growth had recently started, by May 2 the bulbs were starting to enlarge. All plant samples were dried in a forced draft oven at 65°C for 72 hours and then ground in a stainless steel willey mill through a 20 mesh screen. The samples were wet ashed with nitric then perchloric acid digestion. Potassium, calcium, magnesium, zinc, and manganese were determined with atomic absorption using settings outlined by Perkin Elmers' standardized directions. Phosphorus was measured with the vanadomolybdophosphoric acid colorimetric method by Jackson (1958).

On July 19, twenty bulbs were dug from each plot from the California Early garlic variety, cut horizontally through the middle of the cloves and graded as (1) perfect, (2) partially affected (1 to 3 bad cloves) and (3) culls (no more than 2 good cloves). Yield data was not taken on the California Early

variety since the stand was quite variable and cull garlic bulbs weighed about as much as good bulbs. Four-row plots 5.7 meters long of the California Late variety were dug and weighed July 30. Twenty bulbs were cut and graded with the same classification system used for both varieties. Yield data was expressed in tons per ha.

Data were analyzed with standard statistical analyses procedures.

RESULTS AND DISCUSSION

Three treatment effects are evident: (1) bad bulbs were markedly reduced with the 5.6 ton per ha lime treatment and essentially eliminated with the high lime rate, (2) increasing N increased the percentage of bad bulbs, (3) adding lime modified the adverse effects from high N.

California Early Variety

Table number 4 presents the data showing the effects of lime and N treatments on the percent of good bulbs identified when the California Early variety of garlic was graded.

Effects of fertilizer and lime treatments on the percentage of perfect bulbs were outstanding. A comparision of zero lime treatments (3 through 14) with 11.2 ton per ha lime treatments (23 through 34) shows this treatment eliminated the malady. Good bulbs from the zero lime treatments varied from 4 to 40% where N was applied. The 5.6 ton per ha lime treatment eliminated most of the problem with these treatments ranging from 74 to 90% perfect bulbs; however, it is important to note that all treatments with this lime rate had some bad bulbs. Treatments receiving no spring applied N (treatments 1 and 2) without lime had a marked improvement in the percentage of good bulbs (80 and 92%) when compared with other no lime treatments.

High rates of N application might have accentuated the problem. There were 18% good bulbs with the 112 kg N rate and 13% good bulbs with the 336 kg N rate at zero lime. When the high lime rate was applied, all bulbs were perfect with 112 kg N rate but 3 of the 6 treatments with 336 kg of N had 4 to 6 percent affected bulbs.

Chemical Composition - Plant Samples

Table 3 and 4 shows the effects of lime and fertilizer treatments on the concentration of P, K, Ca, Mg, Mn, and Zn found in leaves of the California Early variety for the April 5 and May 2 sampling dates, respectively. The effects of treatments on levels of Mn and P found in leaves are of greatest interest.

Application of lime decreased Mn levels for both sample dates. Manganese levels April 5 were 218, 99, and 73 ppm and for May 2 were 130, 74, and 49 ppm for 0, 5.6, and 11.2 tons per ha of lime respectively. The application of potassium consistently increased leaf Mn contents on both sample dates; this is evident by comparing treatments 3 vs. 4; 5 vs. 6; 9 vs. 10; 11 vs. 12; 15 vs. 16; 23 vs. 24; 15 vs. 26; 29 vs. 30; and 31 vs. 32. In each of these paired comparisons the even numbered treatments had received an application of potassium chloride which resulted in increasing the Mn level of leaf samples. When treatments 1 and 2 (that did not receive spring applied N) are compared with treatments 3 and 5 it is evident that application of N also increased leaf Mn levels.

Leaf Mn levels were about 1.5 times higher for the April leaf samples than for the May leaf samples. This higher level of Mn in younger plant material reflects greater availability of Mn during the winter rainy season since Mn contents generally increase as plants approach maturity.

Phosphorus application did not increase leaf P contents; this is evident by comparing all treatments with P vs. comparable N, K, lime treatments without P (i.e., 5 and 6 vs. 3 and 4). Application of lime consistently increased leaf P levels for the May samples. The mean P content in May for groups of 6 treatments receiving 112 or 336 kg of N per ha were .37% and .36% with 0 lime, .43% with 5.6 tons lime per ha, and .44% and .43% P with 11.2 tons of lime per ha.

Minor differences were evident when evaluating effects of fertilizer and lime treatments on the K, Ca, Mg, and Zn leaf contents. It might be significant to note that lime application reduced Zn contents for both sample dates and may indicate that Zn could be a problem when this crop is grown on calcareous soils. Data for K, Ca, and Mg are included to provide some information on relative levels of these nutrients for garlic leaves. Data from the May 2 samples reflect effects of the last increment of N applied after April 5. Treatment effects evident on April 5 samples were evident on the May 2 samples. The following factors can be used to convert May 2 analyses to April 5 analyses: Mn (1.60), P (0.88), K (1.20), Ca (0.80), Mg (0.80) and Zn (0.70)

California Late Variety Good Bulbs

A smaller experiment with 5 treatments was included on the California Late garlic variety. Effects of these treatments on yield, percent good bulbs and chemical analyses of plant samples is shown in Table 5.

It was expected from previous observations that the California Late variety was not as susceptible to this problem as the California Early variety. The data confirm this observation; there were 98 percent good bulbs with the 112 kg N rate and no lime. Good bulbs were decreased to 57 percent when the N rate was increased to 336 kg per ha without lime. This also confirmed the observation that increasing the rate of N fertilizer on acid soils accentuated the problem.

A uniform stand was obtained with the California Late variety so that yield data could be taken. Yields were not increased by increasing N application above 112 kg per ha.

It is important to note that Mn concentration for zero lime plots were about 3 times higher on the California Early variety that has much greater susceptibility to the malady. Mn values of 80 ppm can be compared with values of 240 ppm for comparable NPK treatments for the California Early variety. Manganese values were reduced to about 50 ppm with the application of lime.

While PK variables were not applied on the California Early variety, it was evident that lime application again increased the P concentration in garlic leaves. There were very minor effects of lime and N treatments on concentrations of other nutrients evaluated.

SUMMARY

The effect of lime application on correcting the low solids problem was dramatic. It is unusual to obtain such clear cut treatment effects with the first experiments established to evaluate a problem. While these experiments do not establish the specific soil acidity factor influencing the reduction in solids, the data do suggest Mn toxicity as the critical factor influencing severity of the problem.

The effect of N in accentuating low solids was established for both varieties. There was a marked increase in the percentage of good bulbs on the zero lime treatments where nitrogen was not applied (treatments 1 and 2). However, there were very few good bulbs with either rate of applied N for the California Early variety. The severity of the problem was much less with the California Late variety where a high percentage (98) of the bulbs were not affected when 112 kg N per ha had been applied with

the zero lime rate. On this variety, the 336 Kg N rate was required to produce a significant increase in bad bulbs at the zero lime treatment. Either rate of applied lime essentially cured the malady with this variety.

There was a distinct difference in the reaction of the two varieties evaluated with California Early being much more susceptible to decreases in soluble solids. Thus, there is a 3-way variety-lime-N interaction being expressed.

The rainfall during the winter of 1972-73 was much below normal. This means that reducing conditions were not as severe on poorly drained soils as would be found on winters with normal rainfall or during winters when the rainfall was 1.5 times normal as occurred during 1970-71 and 1971-72. The problem was so severe during these years that several fields were not harvested.

The results of this research indicate that the following management practices should probably minimize the occurrence of this problem:

1. Select soils that are well drained.

2. Lime any soils with a soil pH below 6.0.

3. Be sure that the lime is disced into the surface 5 to 7 cm of soil so that the limed soil will be accumulated in the raised bed that is formed during planting. It is critical that the lime not be plowed down to a depth of 20 to 25 cm.

4. Soil analyses should be used as a guide to fertilizer application and potassium chloride applications that would increase uptake of Mn should be limited.

5. Rates of N application should be limited to about 115 kg N/ha in the spring and it might be advisable to consider non-acid forming sources of N such as calcium nitrate for part of the spring N application.

Table 1. Effects of lime treatments on changes in soil analyses values
          (Sampled 7/10/73).

Lime applied	pH	SMP-LR* T/ha	Cations Ca	Meq/100g Mg
0	5.0	10.3	14.9	3.9
5.6 t/ha	5.4	6.1	17.8	4.5
11.2 t/ha	5.8	2.5	22.2	4.1

*SMP=LR gives a measure of the amount of lime that should be required
to reach pH of 6.4 if it was mixed throughout the surface 18 cm of soil
(2.5, 6.1, 10.3 T/ha = 1.1, 2.7, 4.6 T/A)

Table 2. Lime and fertilizer treatments applied, Chambers farm 1972-73.

No.	0 Lime	No.	5.6 T lime/ha	No.	11.2 T lime/ha
1.	$N_1\ P_0K_0$	15.	$N_1\ P_0K_0$	21.	$N_1\ P_0K_0$
2	$N_1\ P_0K_1$	16.	$N_1\ P_0K_1$	22.	$N_1\ P_0K_1$
3.	$N_1\ P_1K_0$	17.	$N_1\ P_0K_0$	23.	$N_1\ P_1K_0$
4.	$N_1\ P_1K_1$	18.	$N_1\ P_1K_1$	24.	$N_1\ P_1K_0$
5.	$N_1\ P_2K_1$	19.	$N_1\ P_2K_1$	25.	$N_1\ P_2K_1$
6.	$N_1\ P_2K_2$	20.	$N_1\ P_2K_2$	26.	$N_1\ P_2K_2$
7.	$N_2\ P_0K_0$			27.	$N_2\ P_0K_0$
8.	$N_2\ P_0K_1$			28.	$N_2\ P_0K_1$
9.	$N_2\ P_1K_0$			29.	$N_2\ P_1K_0$
10.	$N_2\ P_1K_1$			30.	$N_2\ P_1K_1$
11.	$N_2\ P_2K_1$			31.	$N_2\ P_2K_1$
12	$N_2\ P_2K_2$			32.	$N_2\ P_2K_2$
13.	$N_0\ P_0K_0$			33.	$N_0\ P_0K_0$
14.	$N_0\ P_1K_0$			34.	$N_0\ P_1K_1$

* N_0, N_1, N_2 = 0, 112, 336 kg N/ha (100, 300 lb N/A)

P_0, P_1, P_2 = 0, 50, 100 kg/P ha (100, 200 lb P_2O_5/A)

K_0, K_1, K_2 = 0, 90, 180 kg K/ha (100, 200 lb K_2O/A)

Each individual plot consisted of 4 rows (2 beds) 10 meters long.

Table 3. Effects of lime, N, P, and K treatments on the chemical composition of garlic leaves Sampled April 5, Chambers Farm, 1973.

Treatments					Composition of Leaf Samples May 2					
No.	L	N	P	K	Mn ppm	P%	K%	Ca%	Mg%	Zn ppm
1	0	0	0	0	102	.41	3.6	.48	.16	31
2	0	0	1	0	106	.37	4.1	.52	.17	23
3		1	0	0	162	.37	3.7	.47	.15	33
4		1	0	1	245	.33	3.9	.54	.16	28
5		1	1	0	224	.35	4.0	.54	.16	32
6		1	1	1	241	.37	3.8	.50	.16	34
15	1	1	0	0	80	.40	3.7	.48	.16	29
16	1	1	0	1	105	.35	4.0	.52	.16	29
17	1	1	1	0	103	.39	4.1	.52	.16	23
18	1	1	1	1	109	.38	3.9	.55	.16	25
21	2	0	0	0	37	.47	3.7	.52	.16	22
22	2	0	1	0	51	.35	4.0	.55	.14	16
23	2	1	0	0	70	.37	3.6	.51	.15	22
24	2	1	0	1	84	.33	3.6	.51	.14	21
25	2	1	1	0	66	.35	3.7	.52	.15	19
26	2	1	1	1	72	.37	3.8	.55	.15	22

Table 4. Effects of lime, N, P, and K treatments on the percentage of good bulbs, and chemical composition of garlic leaves sampled May 2, Chambers Farm, 1973.

| Treatments | | Good bulbs % | Composition of Leaf Samples May 2 | | | | | |
No.	L N P K		Mn ppm	P%	K%	Ca%	Mg%	Zn ppm
1	0 0 0 0	92	84	.44	3.0	.55	.19	.37
2	0 0 1 0	80	74	.40	3.0	.52	.18	.34
3	0 1 0 0	5	117	.34	3.4	.59	19	41
4	0 1 0 1	7	153	.38	3.2	.61	20	42
5	0 1 1 0	15	120	.35	3.1	.63	19	41
6	0 1 1 1	14	146	.40	3.4	.66	21	47
7	0 1 2 1	45	136	.38	3.3	.55	19	36
8	0 1 2 2	22	188	.37	3.2	.59	20	38
	Average		143	.37		.61		
9	0 2 0 0	19	100	.34	3.2	.62	19	40
10	0 2 0 1	15	124	.37	3.3	.69	20	43
11	0 2 1 0	4	106	.38	3.4	.60	20	39
12	0 2 1 1	9	140	.34	3.2	.63	19	41
13	0 2 2 1	19	148	.32	3.2	.66	19	37
14	0 2 2 2	15	138	.38	3.0	.59	20	39
	Average		126	.36		.63		
15	1 1 0 0	82	61	.47	3.2	.46	20	33
16	1 1 0 1	90	70	.40	3.2	.58	20	33
17	1 1 1 1	90	55	.40	3.0	.61	19	31
18	1 1 1 1	92	78	.46	3.1	.66	21	35
19	1 1 2 1	75	84	.43	3.4	.65	20	33
20	1 1 2 2	74	84	.43	3.2	.52	21	33
	Average		74	.43		.58		
21	2 0 0 0	100	30	.48	2.9	.60	19	28
22	2 0 1 0	100	35	.44	3.0	.64	19	26
23	2 1 0 0	100	41	.44	3.4	.70	20	32
24	2 1 0 1	100	48	.45	3.2	.71	21	36
25	2 1 1 0	100	39	.41	3.4	.78	21	31
26	2 1 1 1	100	43	.48	3.4	.70	20	36
27	2 1 2 1	100	73	.44	3.4	.70	19	27
28	2 1 2 2	100	67	.43	3.2	.67	19	27
	Average		52	.44		.71		
29	2 2 0 0	95	42	.43	3.4	.70	20	32
30	2 2 0 1	100	52	.41	3.4	.79	21	36
31	2 2 1 0	100	36	.45	3.4	.68	20	35
32	2 2 1 1	100	46	.42	3.5	.78	21	35
33	2 2 2 1	96	44	.40	3.4	.75	20	34
34	2 2 2 2	94	54	.45	3.2	.72	21	31
	Average		46	.43		.74		

[1] L1, 2 = 5.6, 11.2 T lime/ha (2.5 and 5.0 T/A)
N1, 2 = 112 g 336 kg, N/ha (100, 300 lb/A)
P1, P2 = 50, 100, kg P/ha (100, 200 lb P_2O_5 /A)
K1, K2 = 90, 180 kg K/ha (100, 200 lb K_2O/1)

Table 5. Effects of lime and N treatments on yield and percent good bulbs, and on chemical composition of garlic leaves. California Late Variety. Chambers Farm, 1973.

Treatments[1]		Good bulbs	T/ha	Composition of leaf samples May 2					
No.	L N P K	%		Mn ppm	P %	K %	Ca %	Mg %	Zn ppm
6	0 1 1 1	98	26.23	80	.35	3.3	.50	.18	34
12	0 2 1 1	57	25.00	80	.37	3.3	.47	.18	32
18	1 1 1 1	95	31.11	46	.39	2.9	.45	.18	31
26	2 1 1 1	100	28.67	54	.42	3.6	.55	.19	32
32	2 2 1 1	100	26.23	49	.40	3.5	.54	.19	30

[1] $L_{1, 2}$ = 5.6, 11.2 T lime/ha (2.5 and 5.0 T/A)

$N_{1, 2}$ = 112, 336 kg N/ha (100, 300 lb/A)

P_1, P_2 = 50, 100 kg P/ha (100, 200 lb P_2O_5/A)

K_1K_2 = 90, 180 kg K/ha (100, 200, lb K_2O/A).