Residual Lime Effect in Soils on Certain Mineral Elements in Barley, Fescue, and Oats

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Significant changes in plant mineral composition due to residual lime effects in the soil were shown in fescue, oats, and barley four, nine, and 11 years after application. In general, copper, magnesium, and manganese levels showed significant decreases in fescue the third and fourth years, whereas calcium was significantly increased. Iron, phosphorus, and zinc contents were unaffected. The oat composition showed copper, zinc, and manganese significantly lowered and magnesium increased. Calcium, iron, and phosphorus were unaffected. Barley grown on the Davidson soil showed calcium, iron, and manganese contents significantly decreased, while copper, magnesium, phosphorus, and zinc levels showed some changes in composition, but were not significant. Barley grown on the Tatum soil showed calcium, iron, manganese, and phosphorus significantly changed by one or more lime levels. The calcic application on the Tatum soil showed significant changes in calcium, phosphorus, iron, manganese, and zinc levels in the composition of barley on one or more applications.

Lime continues to be a most important agent to correct and control soil acidity in this country and other parts of the world. Many observations have been made on the use of lime, its effect on the soil and on plant composition. Adams and Pearson (1967) found the response to lime varies considerably for different crops on the same soil. They further observed that liming acid soils tends to decrease the availability of several soil-supplied nutrients which resulted in "over-liming injury" since the availability of some nutrients was decreased to a deficient level. They also found that changes in concentrations of P, K, S, B, Cu, Mo, and Zn in plants were due to the effect of lime. Foy and Brown (1964) showed great differences in response to lime, even among varieties of the same species. Weeks and Lathwell (1967) noted that a number of states in the Northwestern U.S.A. recommend liming of the soil to less than pH 6.5 because there is danger of inducing deficiencies of various trace elements of higher pH values. He also showed that the composition of red clover, oats, and timothy for 10 different elements taken from all parts of Pennsylvania was markedly affected by limit levels.

Other workers (Blevins and Massey, 1959; Fisher, 1969; Seitz *et al.*, 1959; Wear and Patterson, 1962; and Weeks and Lathwell, 1967) confirm the effect of soil liming on the composition of plants and the uptake of minerals. The residual effects of lime on the composition of certain plants have been reported by Price and Moschler (1965). They found that residual lime in the soil resulted in significant changes in the plant composition of peanut foliage, soybean foliage, and orchardgrass seven and nine years after lime application. Copper, Co, Mn, Fe, and Zn were significantly lowered in each plant, whereas Mo was significantly increased. Controlled experiments by Moschler *et al.* (1962) established in 1953 and 1954 over wide areas of Virginia continue to provide samples to study residual lime effects on plant composition. This study shows the effects of lime on the mineral composition of a legume (fescue) during the first four years after treatment, and two small grains (oats and barley) nine and 11 years after lime treatment. Lime applications range from 0 to 24 tons per acre, which represent normal to extreme treatments. For further comparisons, three applications of calcitic limestone are shown for barley grown on the Tatum soil.

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PROCEDURES

Samples were collected from lime plots in three areas of Virginia: fescue (Ky 31) samples, 6 to 10 inches in height, from Groseclose silt loam at the Blacksburg Experiment Station; oat (Andrew) samples, 15 to 18 inches in height, from Dunmore silt loam at the Glade Spring Experiment Station; barley (Wong) samples, 6 to 8 inches in height, from Tatum silt loam and Davidson clay loam at the Orange Experiment Station. The Groseclose and Dunmore soils are very productive, well-drained, and formed in residuum of dolomitic limestone and slide breccia. The Tatum silt loam is Typic Hapludults, clayey, mixed, and thermic. The Davidson clay loam is Rhodic Paleudults, clayey, kaolinitic, and thermic. The Groseclose silt loam is Typic Paleudults, clayey, kaolinitic, and mesic.

Dolomitic limestone (54.5% $CaCO_3$ and 44.4% $MgCO_3$) was used at all locations. However, on the Tatum soil, a calcitic limestone (92.2% $CaCO_3$ and 2.10% $MgCO_3$) was also used in separate plots with barley. Fertilization varied, but in most cases the rates used were less than those generally recommended; it is believed that neither crops nor fertilization materially influenced pH or base relationships in the soil. Alfalfa was grown on the Tatum soil 8 years prior to 1964, when the plots were disked and barley seeded.

Calcium, copper, iron, magnesium, manganese, and zinc were determined using a 303 Perkin-Elmer atomic absorption spectrophotometer ("Analytical Methods," 1968). Phosphorus was determined according to official methods of the A.O.A.C. (1965). Soil pH was determined with a Model G Beckman pH meter, using a 1 to 1 soil water ratio and a half-hour equilibration period. The analyses were reported on a dry weight basis. Wet digestion (nitric and perchloric acids) was used instead of dry ashing.

DISCUSSION AND RESULTS

The effects of various levels of lime application on the mineral contents of fescue, oats, and barley are shown in Table I. In general, lime treatments significantly increased the calcium contents of fescue over consecutive years, with the high treatment rates showing the highest levels of calcium. Copper levels declined progressively after the first two years and were significantly lowered the third and fourth years by the two highest lime treatments. Differences were apparent in the iron content of fescue, but there were no consistent decreases

Table I. Mineral Content of Plant Tissue and Soil pH

	Plant[a]	Lime Added, Tons												
		0	1	2	3	4	6	8	12	16	24	1[h]	4[h]	16[h]
Ca, p.p.m.	Fescue,[b]	5220.00c[c]			5965.00bc		6670.00ab		6845.00a		7365.00a			
	Fescue[b]	4356.00c			4840.00c		5996.00b		6248.00a		6656.00a			
	Fescue[b]	4795.00c			5555.00b		6130.00b		6815.00		7100.00a			
	Fescue[b]	5010.00d			6160.00c		6690.00b		7535.00a		7550.00a			
	Oats[d]	2425.00a	2447.00a	2450.00a		2500.00a		2787.00a						
	Barley[e]	2956.00a[f]	2262.50b	2118.75b		2225.00ab		2500.00ab						
	Barley[g]	1537.50e	2150.00c	1889.00cd		2243.75c		2482.00b		2368.75b		1887.50cd	3312.50a	3550.00a
Cu, p.p.m.	Fescue	9.60a			6.02b		7.14b		9.60a		9.62a			
	Fescue	6.60ab			6.30bc		7.14a		7.02ab		5.80c			
	Fescue	8.60a			8.25ab		7.86b		6.82c		6.50c			
	Fescue	7.87a			7.57a		6.32b		5.85c		5.52c			
	Oats	11.05a	9.15bc	8.50bc		7.88c		10.25ab						
	Barley	7.65a	8.55a	7.62a		7.87a		8.25a						
	Barley	4.02a	3.65a	4.20a		3.83a		4.25a		3.67a		3.77a	3.62a	3.94a
Fe, p.p.m.	Fescue	116.20a			112.20a		114.41a		109.90a		114.20a			
	Fescue	87.40a			82.40a		84.00a		84.00a		87.40a			
	Fescue	102.20a			106.20a		108.40a		101.20a		103.00a			
	Fescue	169.20a			149.40a		156.40a		146.80a		147.20a			
	Oats	68.50a	68.50a	64.85a		74.80a		84.12a						
	Barley	67.25a	41.75cd	36.50d		46.50bc		50.50b						
	Barley	121.00c	202.75a	136.50bc		140.00bc		186.75a		140.00bc		112.50c	171.50ab	134.50abc
Mg, p.p.m.	Fescue	2830.00a			2655.00a		2845.00a		2605.00a		2720.00a			
	Fescue	2440.00a			2392.00a		2468.00a		2400.00a		2440.00a			
	Fescue	2770.00a			2705.00a		2681.00a		2435.00b		2490.00b			
	Fescue	2850.00a			2910.00a		2760.00a		2450.00b		2470.00b			
	Oats	1135.25d	1331.00c	1456.00c		1648.50b		2082.55a						
	Barley	1850.25c	1940.00bc	2040.00bc		2146.00ab		2337.22a						
	Barley	825.00a	1087.00a	1281.00a		1700.00a		1893.00a		1681.00a		756.00a	968.00a	1043.00a
Mn, p.p.m.	Fescue	294.80a			144.80b		120.40c		94.80d		85.60d			
	Fescue	224.00a			133.60b		116.40bc		98.00d		93.20c			
	Fescue	234.60a			186.20b		143.80c		96.60d		93.00d			
	Fescue	226.20a			184.80b		139.40c		93.40d		90.60d			
	Oats	133.25a	108.60b	87.85c		44.70d		31.50e						
	Barley	84.97a	83.50a	63.11c		70.39b		64.16c						
	Barley	114.00a	71.75c	40.25d		36.00d		38.25d		34.45d		95.25b	37.36d	34.73d
P, p.p.m.	Fescue	3300.00a			3100.00a		3000.00a		3300.00a		3000.00a			
	Fescue	3300.00a			3300.00a		3300.00a		3300.00a		3300.00a			
	Fescue	3400.00a			3200.00a		3200.00a		3300.00a		3200.00a			
	Fescue	3400.00a			3500.00a		3600.00a		3500.00a		3600.00a			
	Oats	2200.00a	2200.00a	2200.00a		2300.00a		2700.00a						
	Barley	2400.00a	2800.00a	2600.00a		2700.00a		2700.00a						
	Barley	3900.00e	4100.00cde	4000.00de		4500.00bcd		4600.00abc		4800.00ab		3800.00e	4600.00abc	5100.00a

Zn, p.p.m.	Fescue	28.30a			24.60b		23.15b		22.40b		22.15b			
	Fescue	27.09a			25.68a		26.86a		26.86a		26.36a			
	Fescue	30.25a			30.95a		30.20a		29.55a		28.90a			
	Fescue	31.70a			30.80a		30.85ab		29.15b		29.35b			
	Oats	24.00a[f]	20.75bc	22.70ab		20.05c		20.35bc						
	Barley	23.11b[f]	21.72ab	24.28a		19.42b		21.28ab						
	Barley	19.57a	17.94ab	15.62bc		16.20bc		16.26bc		16.31bc		16.42bc	13.87cd	12.41b
Soil pH	Fescue	5.62e			6.38d		6.78c		7.30b		7.54a			
	Fescue	5.84d			6.44c		7.00b		7.82a		7.98a			
	Fescue	5.74d			6.26c		6.78b		7.62a		7.68a			
	Fescue	5.68d			6.18c		6.46b		7.32a		7.42a			
	Oats	5.00d	5.32c	5.38c		5.75b		6.65a						
	Barley	5.65c	5.82c	6.18b		6.55ab		6.72a						
	Barley	5.20f	5.70e	6.12d		6.50c		6.88b		7.08b		5.60e	6.88b	7.30a

[a] Fescue analyses are averages of 5 replications; others are averages of 4 replications.
[b] Blacksburg location, Grosclose s.l., 4 consecutive years.
[c] a, b, c, etc., averages (1% level), any two means not having the same letter are significantly different; any two means having the same letter are not significantly different (Duncan 1955).
[d] Glade Spring location, Dunmore s.l., 11 years after lime application.
[e] Orange location, Davidson c.l., 11 years after lime application.
[f] 5% level for zinc (oats); calcium, zinc (barley, Davidson).
[g] Orange location, Tatum s.l., 9 years after lime and calcitic application.
[h] Tons calcitic limestone (calcic)added.

with increasing lime application. Magnesium contents showed little change except in the third and fourth years, with a significant decrease at the two highest lime levels. As expected, the manganese content was progressively and significantly lowered by all treatments through the 6-ton applications, with a leveling-off at the two highest rates. Phosphorus contents were unaffected. Differences were apparent in zinc levels, with a significant decrease the first and fourth years after treatment.

The residual effects of lime application, after 11 years, on the mineral contents of oats showed the calcium content to be unaffected, while the copper levels were significantly lowered by the 1- and 4-ton lime applications. Iron and phosphorus contents were unaffected. Magnesium levels were significantly increased by all lime applications. However, manganese content was progressively and significantly lowered by all treatments. Zinc levels were significantly lowered at the 1-, 4-, and 8- ton lime rates.

Comparison of the mineral contents of barley from 2 different soil types, nine and 11 years after lime applications, are also shown in Table I. For descriptive simplicity, the barley grown on Davidson soils will be referred to as Davidson barley and from the Tatum soils as Tatum barley. The residual effect of calcitic limestone after nine years on the composition of Tatum barley is shown. The Davidson series are considered good productive soils, whereas the Tatum series are considered poor to fair in productivity.

Calcium levels in Davidson barley were significantly lowered by 1-, 2-, and 4-ton lime rates, with only slight changes at the higher applications. Decrease in Cu content in barley was not consistent with treatments. Iron content was significantly decreased by 1-, 2-, and 8-ton levels of lime. A significant increase of magnesium levels in Davidson barley was shown at the 4- and 8-ton levels. Manganese was progressively and significantly lowered by 2-, 4-, and 8-ton lime rates. Phosphorus was unaffected and zinc was significantly increased by 2-ton lime levels.

Calcium levels in Tatum barley 6 showed progressive increases with lime treatments and a significant increase at the 4- and 16-ton calcic rates. Copper levels in Tatum barley were much lower than those of Davidson barley and showed no changes due to lime treatments. Iron was significantly increased by 1- and 8-ton rates of lime and also 4 tons of calcic. Magnesium levels were consistently lower than in Davidson barley and showed no significant effects due to lime or calcic treatments. As expected, manganese was significantly lowered by 1, 2, 4, and 8 tons of lime, and also significantly lowered by the 4- and 16-ton calcic treatments. Zinc levels were significantly decreased by 2-ton lime rates and significantly decreased by 4- and 16-ton calcic rates.

The various levels of lime applied in these studies resulted in a progressive shift of the pH of the soil from acid range to a level approaching or exceeding neutrality. It is not possible to predict significant liming effects from pH values alone, because of plant, soil, or climatic influences. In some instances, significant composition effects were noted with little or no change in soil pH.

These observations, in general, confirm the published literature concerning the relationship between soil acidity and plant uptake or mineral elements. Most previous studies have examined these relationships only during brief periods following lime application. These results emphasize the sustaining effects of lime treatments in the soil on the mineral composition of plants four, nine, and 11 years after application. Obviously, they have important implications in terms of sustaining optimum health in grazing animals with respect to both major and minor elements (Price and Hardison, 1963).

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