J. Amer. Soc. Hort. Sci. 103(3):302–305. 1978.

Plant and Soil Effects of Fertilizer and Lime Applied to Highbush Blueberries[1]

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Additional index words. nitrogen, phosphorus, potassium, dolomitic lime, micronutrients, *Vaccinium corymbosum*

Abstract. **Changes in pH and concentration of P, K, Ca and Mg in the soil were monitored during an 8-year period in a blueberry field cleared for cultivation just prior to establishment. The influence of 3 rates of N, P, K and 2 rates of lime upon these parameters, yield, and foliar elemental levels of highbush blueberry (*Vaccinium corymbosum* L. cv. Wolcott) were determined. Soil pH increased from 3.7 to 4.1 during the study when lime was not applied. Application of N and K increased and P decreased soil pH. Foliar N, P and K reflected the amount applied, but foliar concentration of Ca and Mg was influenced in only 3 years by application of dolomitic lime. Yield was increased by the intermediate level of K (47 kg/ha) and the intermediate and high levels of P (25 and 50 kg/ha) compared with the O rates. Yield was not increased by N above the base rate of 34 kg/ha. Bush mortality was increased by high levels of N (168 kg/ha), P (50 kg/ha) and K (94 kg/ha) compared to the O rates. Increasing N or P delayed but K hastened fruit ripening. Lime application did not influence yield. The effect of treatments upon certain foliar micronutrients are presented and discussed.**

The soil requirements of highbush blueberries relative to organic matter (8), pH (7), and cations (2) is well documented. A review by Ballinger (3), cites numerous reports which illustrate the response of blueberries to fertilizer. There is general agreement that the optimum pH for blueberries is lower than for almost all other crops. However, changes in soil chemical properties induced by soil amendments and cultivation after clearing have not been elucidated.

In the research reported here the influence of various rates of N, P, K and lime applications upon chemical content of soils, nutrient content of foliage, fruit yield, plant mortality and maturity of blueberries has been determined. An earlier report (5) listed the influence of soil treatments in the same experiment upon growth and foliar elemental content during the years of establishment.

Materials and Methods

A description of treatments, experimental design, foliar sampling procedures and methods of chemical analysis has been published previously (5). Virgin land was cleared of pine trees in 1963; the soil, primarily a Leon fine sand (sandy, siliceous aeric Haplaquod) with a small area of Lynn, Haven fine sand (sandy, silicious typic Haplaquod) was tilled in 1964, and blueberries were planted in 1965. Lime (2016 kg/ha) was applied to half the test area to establish soil pH levels prior to planting. No additional lime was applied. Fertilizer treatments since 1968 were 34, 84, and 168 kg of N, O, 25, and 50 kg of P, and O, 47, and 94 kg of k/ha annually with 0.25, 0.5, and 0.75 of that amount applied from 1965 through 1967 respectively.

Berries were harvested by hand each year at intervals of 5 to 8 days. Berries from each plot were weighed and 100 berry samples refrigerated for subsequent analysis. A weighted harvest date for fruit was calculated by multiplying the weight of fruit harvested each date by the number of days elapsed since the first picking date. The sum of the products for all harvests was divided by the total weight of fruit harvested from the plot each year. The result, expressed in days, is designated as coded harvest date. Weight/berry and number of berries/bush were calculated from the 100 berry sample from each plot. Data was statistically analyzed according to Li (9) for each year and for all years of the experiment following the 1972 season.

Results and Discussion

There are normally changes in several soil parameters in the first few years after land is brought into cultivation. These include loss of organic matter and shifts in the base saturation. In this study, the soil was sampled in 1964, one year after the land was cleared and again in 1972. Between 1964 and 1972 there was an increase in soil pH and a decrease in soil Ca, but little if any change in other soil cations or soil P where these elements had not been applied (Table 1).

Application of N resulted in an increase in soil pH and a decrease in soil K concn. Since the source of N was NH_4NO_3, some decrease in soil K may have resulted from NH_4^+ replacing K^+ on the exchange complex with resultant leaching of K. The increase in soil pH, even with the use of an acid forming N source, may be related to the increased soil organic matter breakdown that resulted from N application.

Table 1. The influence of N, P, K and lime applied to blueberries upon certain soil chemical factors, 1972.

Treatment	Application (kg/ha)	Soil Content (kg/ha) Ph	P	K	Ca	Mg
N	34	4.10	38.1	150	428	108
	84	4.14	37.2	139	415	109
	168	4.25	34.5	121	421	109
P	0	4.27	16.6	146	352	99
	25	4.11	41.4	136	442	119
	50	4.15	51.8	130	471	109
K	0	4.08	34.3	62	433	113
	47	4.14	37.4	147	437	109
	94	4.27	38.1	202	392	105
Lime	0	4.09	35.7	141	345	96
	2016	4.24	37.7	133	498	121
Prior to treatment, 1964		3.70	13.5	57	439	105
LSD 5% (NPK)		.10	10.1	21.2	70	14
(Lime)		.08	8.3	17.4	57	12

[1]Received for publication October 12, 1977 Paper No. 5427 of the Journal Series of the North Carolina Agricultural Experiment Station, Raleigh, NC 27607.

Application of P increased soil levels of P, Ca, and Mg, but decreased soil pH. During the course of the experiment approx 300 kg/ha of P was applied and only a small portion of this could be accounted for by a weak acid extract of the soil. The low P retention is because P leaches rapidly from these soils (6). Loss of P is also indicated in that application of 25 kg/ha annually resulted in a marked increase in soil P, but application of an additional 25 kg/ha resulted in only a small increase above that obtained with the first increment. The increase in soil Ca resulting from P application is because Ca was supplied in concn super phosphate. The behavior of soil Mg related to P application was not linear nor was the decrease in soil pH.

Application of K resulted in a marked increase in soil K and increased soil pH. It appears that this soil has the capacity to retain K to a greater extent than P.

The only influence of lime, 7 years after application, was a slight increase in soil pH, Ca, and Mg. Levels of Ca and Mg were lower in 1972 than when the experiment started in treatments where lime or P was not applied. The increase in pH, after 7 years, even where lime was not applied may be related to the breakdown of organic matter, release of cations, and loss of exchange capacity in the soil.

Soil application of N, P and K resulted in increases in foliage concn of the respective element in each year of the experiment (Fig. 1, 2, 3). In most cases this increase in foliar level, related to fertilizer application, was greater in the later compared to the early years of the experiment.

Although the magnitude of the influence of N varied with years, the increase in foliar concn of N and K as well as the decrease in Ca and Mg resulting from N application was rather consistent. In the case of Ca, N fertilization exerted no influence in 1967, but was rather consistent in lowering the Ca concn of the foliage after that date. Concn of Mg was changed much less than was that of Ca or K by N application.

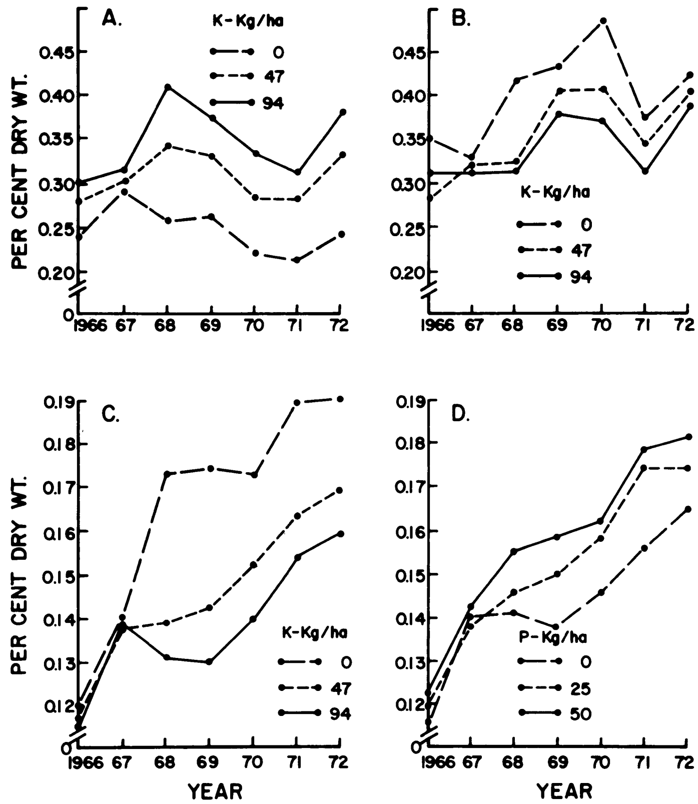

Fig. 2. Influence of K application upon the foliar concn of (A) K, (B) Ca, (C) Mg and (D) of P application upon foliar Mg concn.

Concn of K in the foliage in all years of the experiment was at or below the sufficiency level proposed by Ballinger (3), yet, in several years of the experiment K application exerted a depressing effect on yield. The decrease in Ca resulting from K application was rather linear except during the first year of the experiment. Concn of Mg was not influenced by K application the first 2 years, but was depressed by K fertilization after that period.

The foliar concn of Mg was increased by P application after the first 2 years. Although the application of concd superphosphate increased soil Ca, this increase was not reflected in changes in foliar levels of Ca.

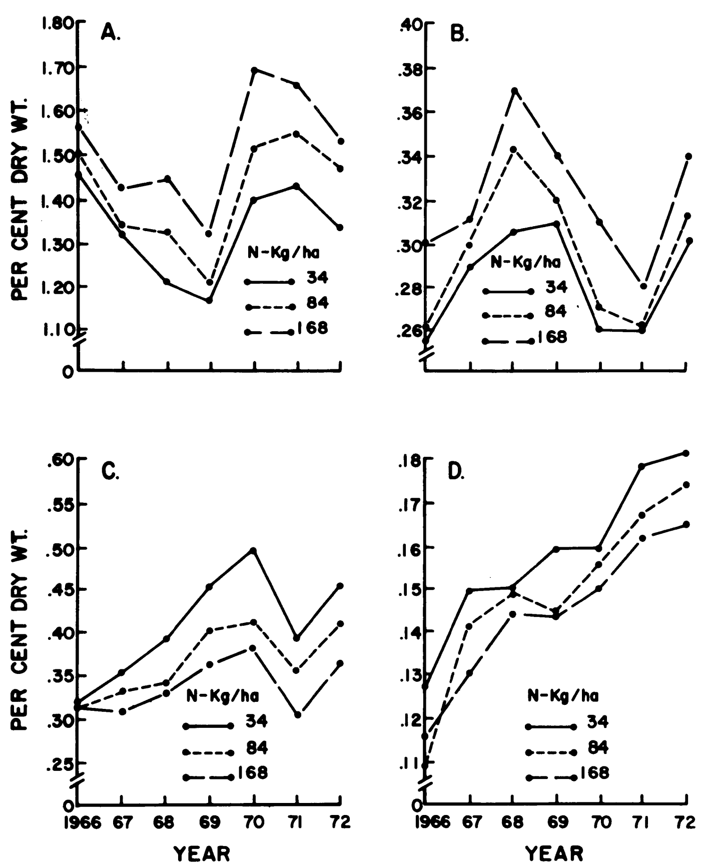

Fig. 1. Influence of N application upon foliar concn of (A) N, (B) K, (C) Ca, and (D) Mg.

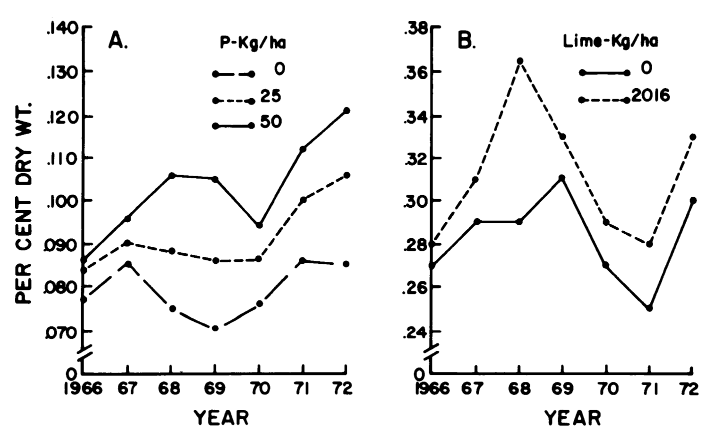

Fig. 3. Influence upon foliar concn of (A) P by P application and (B) K by lime application.

The increase in soil levels of Ca and Mg which was still evident (Table 1) 7 years after application of dolomitic lime did not result in changes in foliar levels of Mg. Even the increased soil Ca levels did not exert a significant effect on foliar Ca every year. Lime application exerted a greater influence upon foliar concn of K than upon Ca or Mg.

It was expected that N, P, or K application would result in foliar increase in the element applied. Likewise, variations in concn as well as differences in the magnitude of the effect of fertilization among years were expected. However, that the application of N as well as K increased K foliar concn while depressing the concn of Ca and Mg was not expected. Soil reaction was near pH 4 in all treatments for the duration of the experiment. This would account for most, if not all, of the N applied as NH_4^+ remaining rather than being converted to nitrate. Thus, the monovalents NH_4^+ and K^+ appear to exert similar influences. The influence of treatments upon the foliar concn of Fe, Zn, and Cu was similar in 1966 and 1972, but the concn of Fe and Cu was lower in 1972 (Fig. 4). Mn was also much lower in 1972 (average of 107 ppm in 1966 and 64 ppm in 1972) but foliar concn was not influenced by treatment and data are not shown.

The application of N increased Fe both years and decreased Cu and Zn in 1972. Mn, Cu, and Fe in 1966 were all near or below the critical level proposed by Ballinger (3), regardless of treatment, and each was even lower by 1972. The soil in this experiment is composed almost totally of organic matter and quartz sand and contains essentially no inorganic colloids. Thus, the positively charged micronutrients available to plants consist of those on the exchange sites of the organic matter complex plus those released from breakdown of organic matter. Since organic matter contains only small amounts of these elements, the supply to plants is limited. Also, since clearing, the soil pH has increased from 3.70 to 4.10. Since the availability of Fe, Zn, Cu, and Mn all decrease as pH increases, the soil pH may be sufficiently high to lower the availability of those elements below the critical level. Finally, it has been proposed by Cain (4) that the utilization of Fe may be altered by the foliar content of the basic cations Ca, Mg, and K. In this work the concn of Ca and K was lower the first year than in most years of the experiment, while Mg increased rather linearly during the 7 year period. The increase of Fe and Cu resulting from lime or N application in 1966 and 1972 may be related to increased organic matter breakdown and release of Cu and Fe from the organic matter complex. Previous work (11) with similar soils has noted increases in foliar concn of Cu resulting from lime application. Foliar concn of B was determined only in 1968 and was decreased from 37 to 28 ppm by the application of either N or K. This decrease was rather linear as rates increased, and as noted earlier with foliar concn of K, Ca, and Mg, the effect of N and K was similar.

The deleterious influence of N, P, and K at high rates is apparent in Table 2. The highest rate of each element is about twice the suggested rate for blueberries in North Carolina. When N application was increased from 34 to 84 kg of N/ha, the suggested rate, yield was not affected though an additional increment of N depressed yield. The harmful influence of lime reported by Bailey (1) and also observed in the early years in this study (5), was no longer evident in 1972 and had not influenced total yield during the experiment.

High rates of fertilizer decreased the number of living bushes, thus, when total yield is considered the harmful influence of high rates of N, P, and K is accentuated. In no case was the damage associated with visible salt damage. Rather, most of the injury and bush loss occurred during the fall and winter months when soluble salts in the soil were low. In addition,

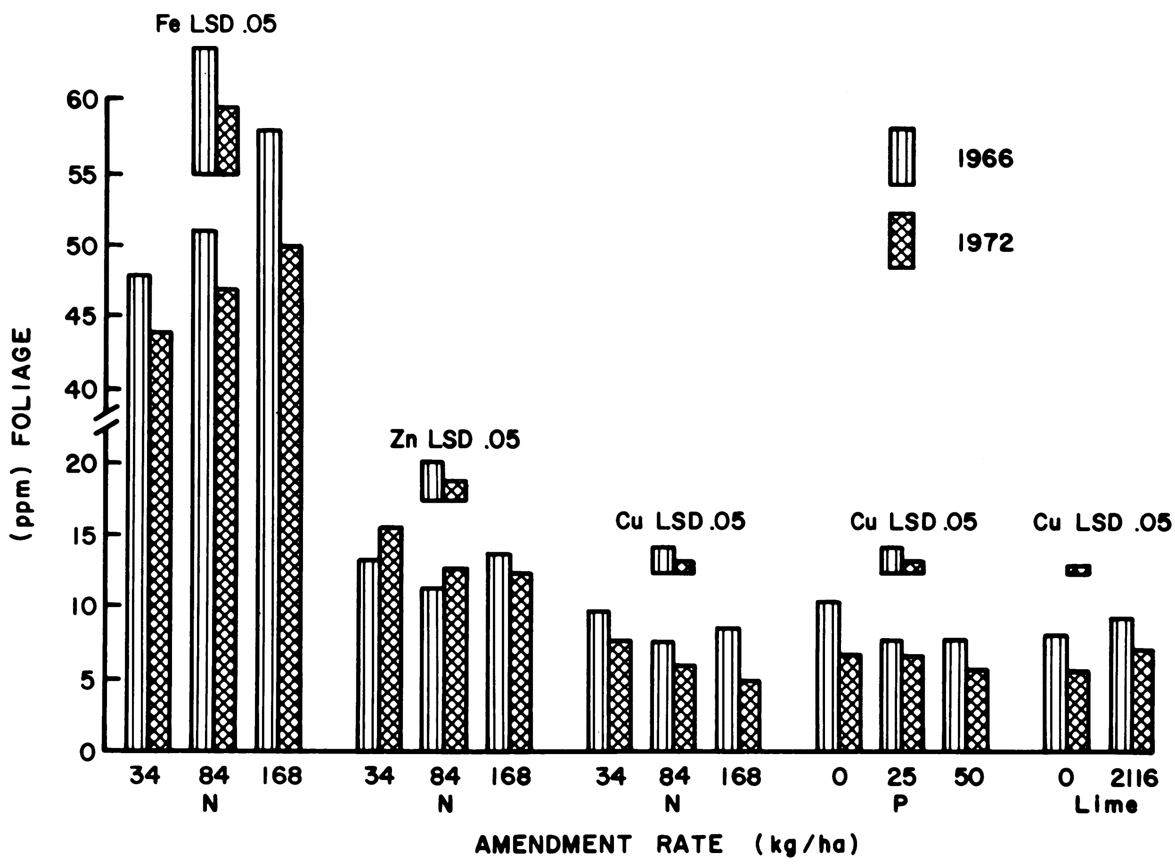

Fig. 4. The influence of rate of N, P, and lime upon the elemental concn of certain micronutrients in blueberry foliage in 1966 and 1972.

Table 2. The influence of N, P, K, and lime applied to blueberries upon yield, time of ripening, berry weight and bush mortality in Duplin County, N.C.

Treatment	Rate (kg/ha)	Yield (kg/bush) 1967-1972	Coded harvest[z] 1967-1972	Berry wt (g) 1969-1972	% bushes living 1972
N	34	2.53	7.4	1.31	95
	84	2.53	8.2	1.24	93
	168	2.17	9.1	1.24	77
P	0	2.18	7.7	1.27	93
	25	2.58	8.4	1.26	89
	50	2.48	8.4	1.27	84
K	0	2.33	8.4	1.27	91
	47	2.49	8.3	1.28	92
	94	2.41	7.7	1.26	83
Lime	0	2.41	8.3	1.27	90
	2016	2.40	8.1	1.26	88
LSD 5% (NPK)		0.15	0.42	.038	6.6
(Lime)		NS	NS	NS	NS

[z]Days following the first harvest when 50% (by weight) of the crop was ripe.

although P, K, and lime rates did not influence berry size, both rates of N above the 34 kg/N/ha reduced berry size.

Application of N delayed fruit ripening about 2 days and P application a much shorter but still significant period. In contrase, K at the highest rate hastened fruit ripening.

With all variables the final increment of N, P, or K did not increase yield and with N, resulted in a significant yield decrease. One factor not evident from the data is the high variability in growth of bushes with similar treatments within the planting. Although the soil was predominantly Leon fine sand (sandy, siliceous aeric Haplaquod) gradating to Lynn Haven fine sand (sandy, siliceious typic Haplaquod) in the more poorly drained portions of the field, the depth to the Bh horizon was quite variable and the white sandy A_2 horizon varied in thickness. Recent evidence by Lilly et al., (10) delineates marked differences in vigor of blueberry bushes growing within a soil mapping unit. In their work poor performance, and in some sites total failure, was related to the absence of a well defined white sandy A_2 horizon.

These results provide evidence that application of N, P, K or lime not only influence the foliar concn of the element applied, but also may alter the concn of elements not applied. This may be importnat when certain nutrients are near the critical level. The data also indicate the application of N, P, or K influenced soil pH during the course of the experiment. The behavior of applied nutrients, and their influence upon other elements in the soil, may be quite different than normally expected in a mineral soil because of the absence of layer silicates in the soils used in this experiment. Finally, the critical level of a given element in the foliage may vary between geographical locations. In this study foliar concn of N, P, and K were near or below the published critical level reported in studies from other areas, yet increasing foliar concn of these elements resulted in diminished fruit yield and increased bush mortality.

Literature Cited

1. Bailey, J. S. 1940. The effect of lime application on the growth of cultivated blueberry plants. *Proc. Amer. Soc. Hort. Sci.* 38:465-470.
2. ————————, C. T. Smith and R. T. Weatherby. 1949. The nutritional status of the cultivated blueberry as revealed by leaf analysis. *Proc. Amer. Soc. Hort. Sci.* 54:205-208.
3. Ballinger, Walter E. 1966. Soil management, nutrition and fertilizer practices. p. 132-178. *In* Paul Eck and Norman F. Childers (eds.) Blueberry culture, Rutgers Univ. Press, New Brunswick, N.J.
4. Cain, J. C. 1952. A comparison of ammonium and nitrate N for blueberries. *Proc. Amer. Soc. Hort. Sci.* 59:161-166.
5. Cummings, George, C. Bickford and L. Nelson. 1971. Fertilizer and lime rates influence highbush blueberry growth and foliar elemental content during establishment. *J. Amer. Soc. Hort. Sci.* 96:184-186.
6. Fox, R. L. and E. J. Kamprath. 1971. Adsorption and leaching of P in acid organic soils and high organic matter sand. *Soil Sci. Soc. Amer. Proc.* 35:154-155.
7. Harmer, P. M. 1944. The effect of varying the reaction of organic soil on the growth and production of the domesticated blueberry. *Proc. Soil Sci. Soc. Amer.* 9:133-141.
8. Johnston, S. 1942. The influence of various soils on the growth and productivity of the highbush blueberry. *Quart. But. Mich. Agri. Expt. Sta.* 24:307-310.
9. Li, Jerome, C. R. 1944. Design and statistical analysis of some confounded factorial experiments. *Iowa Agr. Expt. Sta. Bul.* 333.
10. Lilly, Paul J., V. S. Jenkins and C. M. Mainland. 1975. Investigations of soil and other factors influencing plant failure of North Carolina highbush blueberries. *N. C. Agr. Expt. Sta. Tech. Bul.* 230.
11. Younts, S. E. and Robert P. Patterson. 1964. Copper-lime interactions in field experiments with wheat: yield and chemical composition data. *Agron. J.* 56:229-232.