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This study was undertaken in a Red Delicious apple orchard in Oregon's Hood River Valley to determine if low leaf P concentrations were contributing to such observed orchard disorders as poor shoot growth, shoot dieback and small fruit size at harvest.

Subsurface applications of lime and superphosphate had no effect on leaf P concentration, shoot growth and apple volume. Leaf P concentrations declined slightly (-.01% to -.02%) from 1978 to 1979 while shoot growth decreased (-6.2 cm to -9.0 cm) and apple volume increased (+31.12 cm^3 to +39.56 cm^3).

A Phosphorus Nutrition Study of Apples on a Volcanic Ash Soil

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

A PHOSPHORUS NUTRITION STUDY OF APPLES ON A VOLCANIC ASH SOIL

INTRODUCTION

In Oregon's Hood River Valley, certain apple and pear orchards are characterized by poor shoot growth, shoot dieback and small fruit size at harvest. In August of 1965, leaf analysis was obtained from 2 orchards which expressed these symptoms. Leaf analysis indicated that Mg levels were deficient and N levels were below normal when compared to the standard leaf element levels for Oregon apples.

In the spring of 1966, fertilizer plots were established within the orchards. Foliage sprays of .46 Kg of Mg chelate per tree and 2.3 Kg and 4.5 Kg of Mg sulphate per tree were applied in a randomized block design. One Kg of actual N was also applied throughout the orchards. The August 1966 leaf analysis showed an increase in the N levels of both orchards, while the Mg levels were increased slightly in one but remained unchanged in the other. Poor shoot growth and small fruit size at harvest continued in both orchards despite the N and Mg applications. The 1966 leaf samples were later analyzed for P which was present at concentrations of .10% and .11% on a dry weight basis. For apples in Oregon, leaf P levels below .12% are considered below normal and leaf P levels below .10% are considered deficient.

Soil samples taken in March of 1978 indicated that available P at the 12 inch depth was present at only 9 parts per million. Only 1% of the soils tested in the Hood River Valley had P levels this low. Since growth is limited by the nutrient present in the least amount, it was thought that the symptoms of poor shoot growth and small fruit size at harvest might be attributed to low P levels. However, response of established apple trees to soil applications of P are rare. Therefore, the following study was undertaken to determine if:

1. The concentration of P in the leaves could be increased by soil applications of phosphates.
2. The symptoms of poor shoot growth and small fruit size at harvest could be overcome by P applications.

LITERATURE REVIEW

There have been few reports of established apple trees responding favorably to P applications. A 15 year old Rome Beauty apple orchard which received annual soil injections of 22. 7 Kg of treble superphosphate per tree for 4 years showed no marked response from the phosphate treatments, though leaf analysis indicated a slightly higher P content in the treated trees when compared to the control plot which received no superphosphate (20).

In other studies the leaf concentration of P in newly planted apple trees was raised by mixing 9. 1 Kg of superphosphate with the soil in the hole at planting time (21). Treated trees had a leaf P concentration of .44% dry wt. compared to .15% dry wt. for the control trees. The P treatment increased trunk growth, weight of root growth and weight of top growth when compared to the control trees which received no P (21). However, 3 year old trees on the same soil failed to respond to a water injection of 22. 7 Kg of superphosphate at a depth of 1 meter. The leaf concentration of P for both treated and control trees was .22% dry wt.

These studies were carried out on an Aiken clay loam in the Sierra foothills at Paradise, California. The volcanic Aiken soil because of its low available P and its high capacity for phosphate fixation, was considered the most P deficient soil in California.

The extreme P deficiency of this soil made it a classic for studying the phosphate nutrition of fruit trees.

In latter studies on the Aiken soil (22), 18 different annual crops failed to make satisfactory growth unless phosphates were added. Though leaf analysis did not suggest a P deficiency, 3 year old Red Delicious apples failed to respond to yearly injections of 5605 Kg of superphosphate per ha. There were no differences in growth, yield and fruit quality between untreated and fertilized trees. This study clearly showed that the phosphate response of annual crops cannot serve as criteria of the phosphate needs of fruit trees.

Injection of phosphates into the rootzone was necessitated by the fact that P moves down very slowly when placed on the soil surface. It has been shown that when phosphates were applied to an orchard sod there was little, if any percolation below a 7.6 cm depth (14). Experiments in California orange groves have shown that more than 60% of the accumulation of P from the application of phosphates and organic materials over a 28 year period was still in the top 15 cm of soil and 80% was present in the top 30 cm (31). The slow leaching of P through the soil is due to fixation and precipitation by Fe and Al compounds in acid soils (12, 34, 37) and by Ca compounds in neutral and alkaline soils (17, 23 a and b, 37). Volcanic ash soils which contain large amounts of amorphous minerals namely allophane can fix large quantities of P by anion exchange (37). This process is pH dependent and the more acid the soil the greater the extent of phosphate adsorption.

In other early field studies with P, a complete 7-8-5 fertilizer and "N only" fertilizers were applied to apple trees which had received "N only" fertilizers since planting (29). After 7 years there were no significant differences in growth or yield between any of the treatments. These findings are of little significance since the complete fertilizer was applied to the surface as was the "N only" fertilizers. In a plot adjacent to this study 16% phosphate fertilizers were applied to a sod mulch for 18 years at the rate of 448 Kg per ha, yet 5 cm below the surface the amount of available P was the same as in untreated soils (29).

In a latter study on the same soil, broadcast applications of superphosphate tagged with P^{32} were effective in supplying mature apple trees with P_2O_5 (10). Uptake of P_2O_5 occurred only on mulched trees where the fertilizer penetrated to a depth of 10 and 20 cm. No uptake occurred at the 5 cm depth of penetration. Where fertilizer penetrated to a 10 cm depth, 2.68% to 3.78% of the P_2O_5 in the sample tissues was obtained from the fertilizers and where penetration was 20 cm deep as much as 5.77% of the P_2O_5 in the tissue came from the fertilizer. Organic matter added to the soil as an amendment is effective in increasing the availability of soil P (9). No uptake of P_2O_5 was observed in the trees growing in sod.

Unfortunately, no comparisons were made on growth or yield between the trees which absorbed P and the trees which did not absorb P (10).

In a similar study a deeper penetration of P in an orchard soil was also obtained when superphosphates were applied to an organic mulch as opposed to a sod covercrop (39). After 3 consecutive years of broadcast applications of superhposphate to a 24 year old Stayman Winesap orchard, the trees growing on sod had a higher leaf P concentration than the mulched trees. However, the increases in leaf P did not result in greater growth or yield.

Over a 4 year period P applications to 23 year old Jonathan trees had no significant effect on trunk growth, fruit yield, number of fruits per tree and red fruit color (27). Unfortunately, no leaf analysis data was obtained during this study so the effect of the phosphate treatments on the P content of the leaves is not known. The phosphate fertilizers were broadcast on each plot so downward penetration of P into the rootzone is questionable. The soil type, an Ephrata fine sandy loam, was high in available P and had a low capacity for phosphate fixation.

In a Massachusetts' McIntosh orchard, on a Gloucester fine sandy loam, there was no significant increase in leaf P or in yield when comparing a complete 7-7-7 fertilizer with "N only" fertilizers (40).

Three typical Red Delicious orchards in Central Washington which had received heavy applications of P and K for 10 years had nearly the same leaf concentrations of P and K as trees in adjacent orchards which had received "N only" fertilization for the same period of time (2). In a survey of North Carolina apple orchards, there was essentially no difference in P or K between leaf samples from trees that had or had not received P or K fertilizers respectively (38).

Mature Cox's Orange Pippin and Worcester Pearmain trees over a 10 year period, showed significant increases in trunk girth and yield from broadcast applications of superphosphate (5). The study was carried out at the Efford Experimental Horticulture Station, Lymington, Hants, England on a brick-earth type soil containing approximately 50% find sand, 15% silt and 20% clay. This was one of the few field studies with mature bearing trees where a crop response to fertilizer P was associated with an increase in leaf P.

A significant increase in vegetative growth and leaf P in young Jonathan trees on MM104 was obtained by mixing different rates of superphosphate with the soil in the hole at planting time (35). Despite the initial presence of medium to high levels of P in the soil an increase in vegetative growth and leaf P was observed both in the nursery and also in the orchard after transplanting. When P was withheld from the trees the second year after transplanting a decrease in leaf P was accompanied by a lower growth rate when compared to the previous season. It was concluded that it may be necessary to apply phosphate fertilizers annually to young fruit trees in order to prevent a decline in the level of leaf P. Early researchers also observed an increase in vegetative growth and leaf P of young apple trees when superphosphate was mixed with the soil in the hole at planting time (21). However, permanent trees on the same soil failed to respond to heavy subsurface applications of P.

On a Hayesville clay loam, low in available P with a high P fixing capacity, leaf P concentration and trunk circumference in young Red and Golden Delicious apples was increased by surface and subsurface applications of superphosphate (32). Subsurface applications of superphosphate to Red Delicious were more effective in raising the leaf P concentration than were surface applications. In Golden Delicious there was no difference in leaf P content due to method of application. Though subsurface applications of superphosphate resulted in initially higher leaf concentrations of P when compared to surface applications there was no sustained maintenance of those levels above conventional surface applications. It was thought that if the subsurface applications of P had been distributed throughout the soil volume instead of in discrete zones the subsurface response may have been sustained. It is likely that as the roots developed into areas of lower P a smaller percentage remained in the P enriched zones and a drop in leaf P resulted.

The literature suggests that young transplanted apple trees appear to have some requirement for P and will respond favorably to phosphate applications However, the response of mature, bearing apple trees to fertilizer P is less pronounced and is usually nil.

The fact that mature bearing apple trees so seldom respond to phosphate applications is not surprising when the total P needs of the tree are considered. A mature apple tree with 25 bushels of fruit required only .23 Kg of P per year (16). Only 10.4 Kg of P is permanently removed per ha per year from a 1000 box yield of apples (2). P is not needed in large quantities because it is recycled in energy exchange by the breaking and forming of such high energy bonds as adenosine triphosphate. P is also recycled annually by mature fruit trees by migrating from the leaf into the wood prior to leaf fall (22). Since P is not a major component of structural tissue, it is quite mobile within the plant and will migrate from older tissue to developing meristems.

Since Bould's *et al*. (5) study appears to be one of the few cases where mature, bearing apple trees have responded favorably to fertilizer P, a closer look at his data is warranted.

Although there was a significant increase in leaf P from phosphate applications for 9 out of 10 years for 2 apple varieties, only 1, Cox's Orange Pippin, showed a significant increase in marketable yield after 10 years. A significant increase in trunk girth accompanied an increase in leaf P only 3 times in 9 years for Cox's Orange

Pippin and only twice for Worcester Pearmain in the same period. Only once was a simultaneous increase in marketable yield and trunk girth observed in response to an increase in leaf P and this occurred only in Worcester Pearmain. Nevertheless, this seems to be the most pronounced case to date of mature bearing apple trees responding favorably to field applications of fertilizer P.

MATERIALS AND METHODS

This experiment was undertaken in the upper Hood River Valley 4 Km south of Parkdale, Oregon in a Red Delicious apple orchard on seedling rootstock owned by Harry Ethell. The elevation of the orchard is 610 M with an average frost-free period (0°C) of 100 to 120 days (1). The mean annual air temperature is 7.2°C to 9.4°C and the average annual precipitation is 89 to 114 cm with most of this coming between the months of October and April as snow (1). During the growing season, water was supplied by gravity flow sprinklers. The orchard is located on a Parkdale loam on a 0 to 2% slope with an available water capacity of 25 to 43 cm (1). The Parkdale loam is a member of the medial mesic family of Umbric Vitrandepts. The orchard spacing is 8 M x 8 M with 158 trees per hectare. The trees have an average spread of 5.5-7.3 M, an approximate height of 5.5 M and are 35 years old. The orchard covercrop consists mainly of native perennial grasses which are present within and between the tree rows. The grass is kept in check by early spring rotovating and frequent summer mowings. No herbicides were used prior to or during the experiment for weed control.

The experimental design was a split-plot with lime versus no lime as the main plots. The subplots consisted of no P and the placement of P at 15 and 30 cm depths around the the tree. The 6 treatments were replicated 10 times for a total of 60 trees and assigned randomly. Young interplant trees and trees with excessive dieback were excluded from the random selection process.

The lime was applied in a super saturated solution by pressure injection in a 1.8 M radius around the entire tree at a depth of 15 to 30 cm. Each of the 30 trees in the lime treatment received 10 Kg of 93% $CaCO_3$ (1435 Kg per ha). The lime treatments were applied from March 31 to April 23, 1978. The P treatments consisted of placing a continuous band of 8.2 Kg of treble superphosphate (0-45-0) around the tree in a 1.8 M radius at a depth of 15 and 30 cm. The P treatments were applied from June 21 to July 6, 1978. The control trees received no lime and no superphosphate.

Based on need from the August leaf analysis of 1978, all trees within the experiment received a blanket application of Mg sulphate, Zn sulphate and Urea N.

The Zn was applied as a dormant spray at a rate of 18.1 Kg of 36% Zn sulphate crystals per ha at the silver tip stage of development on April 20, 1979. Nine Kg of Mg sulphate (.9 Kg actual Mg) were applied with a drop spreader within the dripline of all the trees on March 16, 1979. One and one-tenth Kg of Urea was broadcast annually to all the trees on April 5, 1978 and 1979.

The effects of the treatments were measured by leaf analysis, apple diameter/volume conversions and shoot length of the current season's growth by comparing the results of 1978 with those of 1979.

Each year on August 21, midshoot leaves from the current season's growth were obtained for leaf analysis. K, P, Ca, Mg, Mn, Fe, Cu, B, and Zn were determined by direct reading spark emission spectroscopy (8). Total N in the leaf was determined by the modified Kjeldahl method using a Technicon Auto Analyzer (33).

Apple diameter measurements were taken on September 30, 1978 and September 28, 1979, 135 days after full bloom of each year. Apple diameters were converted to spherical volume to give a better indication of fruit growth. Fifty apples were measured from each tree, with an equal number of measurements randomly obtained from the number of main laterals present on each tree. Likewise, 50 shoot measurements (length-cm) from the current season's growth were obtained from all trees during the dormant season.

At the beginning of the experiment, soil samples were taken at 15 and 30 cm depths to determine the pH, cation exchange capacity (CEC), extractable bases and extractable P.

Soil samples were also taken during August of 1979 to measure the effects of the lime treatments on soil pH and extractable Ca and to determine what effects the blanket application of Mg sulphate had on exchangeable Mg. Soil samples were obtained at 15 and 30 cm depths within the dripline of the trees where the lime and Mg sulphate treatments were applied and also beyond the dripline-outside of the treated area so a comparison could be made between treated and non-treated soil.

The pH was measured by a modification of method 3-26 as described by Jackson (18) while CEC was determined by a modification of the method described by Pratt (30). The extractable bases were determined by the ammonium acetate method (28) and extractable P was determined by the dilute-acid fluoride method as described by Bray and Kurtz (3). All soil samples were analyzed by the O. S. U. Soil Testing Laboratory.

During the study the pruning program was maintained by the grower. In March of 1978 the trees received a light heading back in order to maintain the desired row spacing and height. Watersprouts within the tree canopy were also removed. In March of 1979 the pruning consisted mainly of watersprout removal.

RESULTS AND DISCUSSION

The mainplot treatments, lime versus no-lime had no significant effect on leaf P, shoot length and apple volume. Although the liming treatment significantly increased the soil pH at the 15 cm depth leaf P levels did not respond to the rise in soil pH and declined slightly from 1978 to 1979. The other leaf element levels were also not affected by the increase in soil pH. Both the lime and no lime plots showed a decrease in shoot length from 1978 to 1979 and an increase in apple volume over the same period. The lime application also increased extractable Ca levels at depths of 15 and 30 cm. However, the leaf Ca levels in both limed and nonlimed trees increased greatly from 1978 to 1979. The large increase in leaf Ca in all trees in 1979 may have been due to the heavier crop in 1979 when compared to 1978. In late April of 1978 subfreezing temperatures in the Parkdale area caused an extremely light fruit crop for that season. The fruit crop in 1978 averaged about 1 box per tree compared to an estimated average of 6 boxes per tree in 1979. Apple trees with a crop of fruit will accumulate higher leaf levels of N, Ca and Mg than trees with little or no fruit (7, 15, 19, 25). An increase in N and Mg from 1978 to 1979 accompanied the increase in leaf Ca. The N application rates (.45 Kg/tree) were the same for 1978 and 1979. Based on need identified by the August leaf analysis of 1978, Mg sulphate was applied to all trees during March of 1979. Therefore, the increase in leaf Mg could be the result of the increased fruit load in 1979, the Mg sulphate or possibly a combination of the two. Soil analysis indicated that the exchangeable Mg had increased at the 15 and 30 cm depths but as has been shown (4) the correlation between soil Mg and leaf Mg is quite low. The overall increase in leaf Mg from 1978 to 1979 seems significant since the 1979 leaf concentrations have climbed from the "below normal" into the "normal" range when compared to the standard leaf element levels for apples in Oregon.

The subplot treatments of superphosphate with or without lime and the control which received neither lime nor superphosphate were consistent with the mainplot treatments. Leaf P levels tended to decline slightly from 1978 to 1979 while shoot length decreased and apple volume increased. Furthermore, the leaf levels of the other essential elements were not affected by the subplot treatments.

The increase in apple volume from 1978 to 1979 among all treatments was accompanied by an overall decrease in shoot length even though leaf N levels increased from 1978 to 1979. The overall vigor of the trees may have increased slightly during the 2 year study since apple volume increased greatly from 1978 to 1979, despite a much heavier fruit yeild in 1979. The fruit crop in 1978 was so light that when apple measurements were taken one of the trees

Table 1. Mean soil analysis for the Ethell Red Delicious apple orchard from 1978 to 1979.*

	Depth 15 cm						
	pH	P	K	Ca	Mg	CEC	%BS
$\bar{x}$	5.7	13	.38	2.5	.38	15.6	21%
	Depth 30 cm						
	pH	P	K	Ca	Mg	CEC	%BS
$\bar{x}$	6.3	9	.37	3.4	.36	13	32%

%BS - Percent Base Saturation

P values in parts per million

K, Ca, Mg and CEC values in meq/100 g of soil

*Means pooled over 10 replications

Table 2. Mean soil pH within the dripline of the tree where the line was applied compared to the nontreated area outside of the dripline. *

	Depth 15 cm	Depth 30 cm
Within dripline	6.8	6.5
Outside dripline	6.1	6.2
LSD 5%	.29	N.S.

*Means pooled over 4 replications

Table 3. Mean extractable Ca within the dripline of the tree where the lime was applied compared to the nontreated area outside of the dripline. *

	Depth 15 cm	Depth 30 cm
Within dripline	11.8	6.5
Outside dripline	3.9	4.1
LSD 5%	6.1	2.1

Values expressed in meq./100 g of soil

*Means pooled over 4 replications

Table 4. Mean extractable Mg within the dripline of the tree where the Mg sulphate was applied compared to the nontreated area outside of the dripline. *

	Depth 15 cm	Depth 30 cm
Within dripline	1.50	.75
Outside dripline	.50	.32
LSD 1%	.27	.40

Values expressed in meq./100 g of soil

*Means pooled over 6 replications

Table 5. The change in mean shoot length (cm) of the current season's growth of Red Delicious apples from 1978 to 1979.

Treatment	1978	1979	Change
+ Lime - P	33.0	26.8	-6.2
+ Lime P 15 cm	32.2	24.8	-7.4
+ Lime P 30 cm	32.6	25.2	-7.4
- Lime - P	33.5	26.1	-7.4
- Lime P 15 cm	31.0	24.9	-6.1
- Lime P 30 cm	33.1	24.1	-9.0
			N.S.

Table 6. The change in mean apple volume (cm^3) of Red Delicious apples from 1978 to 1979.

Treatment	1978	1979	Change
+ Lime - P	90.50	128.22	+37.22
+ Lime P 15 cm	93.25	127.54	+34.29
+ Lime P 30 cm	96.13	128.33	+32.20
- Lime - P	95.18	126.30	+31.12
- Lime P 15 cm	95.08	134.60	+39.56
- Lime P 30 cm	94.21	130.60	+36.39
			N.S.

Table 7. The change in mean leaf element levels of Red Delicious apples from 1978 to 1979. *

Treatment + Lime - P

Year	N	K	P	Ca	Mg	Mn	Fe	Cu	B	Zn
1978	2.10	1.28	.16	.84	.21	29	73	7	41	9
1979	2.26	1.34	14	.99	.27	25	57	6	33	7
Change	+.16	+.06	-.02	+.15	+.06	-4	-16	-1	-8	-2

Treatment + Lime P 15 cm

Year	N	K	P	Ca	Mg	Mn	Fe	Cu	B	Zn
1978	2.17	1.26	.16	.79	.20	26	73	7	40	9
1979	2.19	1.27	.15	1.01	.27	23	57	6	33	7
Change	+.02	+.01	-.01	+.22	+.06	-3	-16	-1	-7	-2

Treatment + Lime P 30 cm

Year	N	K	P	Ca	Mg	Mn	Fe	Cu	B	Zn
1978	2 09	1.33	.15	.82	.22	24	68	7	39	8
1979	2.18	1.26	.15	.99	.28	20	53	6	32	7
Change	+.09	-.07	.00	+.17	+.06	-4	-15	-1	-7	-1

Treatment + Lime - P

Year	N	K	P	Ca	Mg	Mn	Fe	Cu	B	Zn
1978	2.02	1.32	.16	.78	.20	25	74	7	39	9
1979	2.15	1.37	.14	.96	.26	20	54	6	33	7
Change	+.13	+.05	-.02	+.18	+.06	-5	-20	-1	-6	-2

Treatment - Lime P 15 cm

Year	N	K	P	Ca	Mg	Mn	Fe	Cu	B	Zn
1978	2.11	1.33	.16	.76	.20	25	69	8	41	8
1979	2.22	1.33	.15	.94	.27	23	56	6	34	6
Change	+.11	.00	-.01	+.18	+.07	-2	-13	2	-7	-2

Treatment - Lime P 30 cm

Year	N	K	P	Ca	Mg	Mn	Fe	Cu	B	Zn
1978	2.06	1.31	.16	.75	.20	29	71	7	40	9
1979	2.13	1.23	.14	.93	.26	22	51	6	33	7
Change	+.07	-.08	-.02	+.18	+.06	-7	-20	-1	-7	-2

N, K, P, Ca and Mg expressed in percent dry weight.

Mn, Fe, Cu, B and Zn expressed in parts per million.

*Change in leaf element levels from 1978 to 1979 N. S.

Table 8. Standard leaf element levels for Oregon apples as determined by the O. S. U. Plant Analysis Laboratory.*

	N	K	P	Ca	Mg	Mn	Fe	Cu	B	Zn
A-Deficient	1.6	.9	.10	.5	.18	20	40	1	25	10
B-Below Normal	2.0	1.2	.13	.6	.24	25	50	2	30	15
C-Normal	2.3	3.0	.60	2.5	1.00	200	400	50	80	80
D-Above Normal	3.0	4.0	.65	3.0	2.00	450	500	100	100	300

*Excluding Newton and Golden Delicious

N, K, P, Ca and Mg expressed in percent dry wt.

Mn, Fe, Cu, B and Zn expressed in parts per million had only 26 apples, yet the apple volume in 1978 was considerably smaller than in the heavier cropping year of 1979. The N application rates were the same for 1978 and 1979 and sprinkler irrigation provided adequate water throughout both growing seasons.

There seems to be no good explanation for the failure of the trees to respond with an increase in leaf P to phosphate applications at 15 and 30 cm depths, in a continuous band around the entire tree. However, the results are consistent with those of past researchers (2, 21, 22, 40) who likewise obtained no significant increase in leaf P from soil applied phosphates.

Three possible reasons have been suggested as to why fruit trees probably do not respond to soil applied phosphates: (1) fruit trees need less P than annuals, (2) fruit trees can possibly extract greater quantities from the "unavailable source," (3) fruit trees can accumulate greater quantities annually due to their perennial growth (22).

The young bark and wood of mature apple trees stores sufficient quantities of P to supply a substantial proportion of the yearly requirement for that element (2). From the differences in content of old and young tissue it was estimated that a mature apple tree has the capacity to store .03 Kg of P per year. Therefore, mature apple trees do not have to rely solely on the soil for their P requirements as do annuals.

It has been estimated that with 124 trees per ha producing 1000 boxes of apples only 17.7 Kg of P are removed per ha, per season (2). When the number of Kg removed per ha are divided by the number of trees per ha the annual P requirement of a mature apple tree is quite small. The P percentage in an apple is as low as .095% (15). The rate of formation of soil solution P for 3 different soils was found to be at least 14.6 to 16.8 Kg per ha, per hour, which exceeds the rate at which P is absorbed by plants by a factor of at least 250 (13). Since fruit trees have their roots continuously in contact with a large volume of soil, the P supplying power of a soil does not appear to be a limiting factor in satisfying the modest P requirements of an apple tree.

In this study it was confirmed that the roots had penetrated the P band yet from 1978 to 1979 there was a slight decrease (-.01% to -.02% dry wt.) in leaf P. This strongly suggests that the uptake of P is controlled by more than supply alone. This is contrary to N and K uptake since high concentrations of N and K in the soil often results in "luxury consumption" of these nutrients. Even trace elements when present in high concentrations in the nutrient media can accumulate in toxic quantities in plant tissue. Why P was not taken up in greater quantities when it was so readily available is an interesting phenomena. The failure of the trees to respond to an available supply of P may suggest that P uptake is a selective process but currently there are no carrier-mediated ion transport theories which suggest that the uptake of one ion is regulated more closely than the uptake of another ion. High rates of N fertilizers have been known to depress P uptake but the N applications for 1978 and 1979 (.45 Kg/tree) were not excessive and should not have affected leaf P levels.

The pH of the solution diffusing out of a granule of mono-calcium phosphate (dominate phosphate of superphosphate) is quite acid (.6-1.5), very reactive and will dissolve Fe and Al compounds into solution and form insoluble precipitates of Fe and Al phosphates. However, banding superphosphate reduces the fixation of phosphate with Fe and Al compounds and greatly increases the concentration and accessibility of phosphate ions for plant consumption.

Banding reemphasizes the fact that the supply of P to the trees is apparently not a problem and leaves us to assume that some other mechanism must regulate P uptake.

The roots were tested for the presence of mycorrhiza and the amount of mycorrhiza present did not differ greatly from the numbers present in other orchards. Since our present knowledge on the association between mycorrhiza and fruit tree nutrition is limited, no inferences were made from the data.

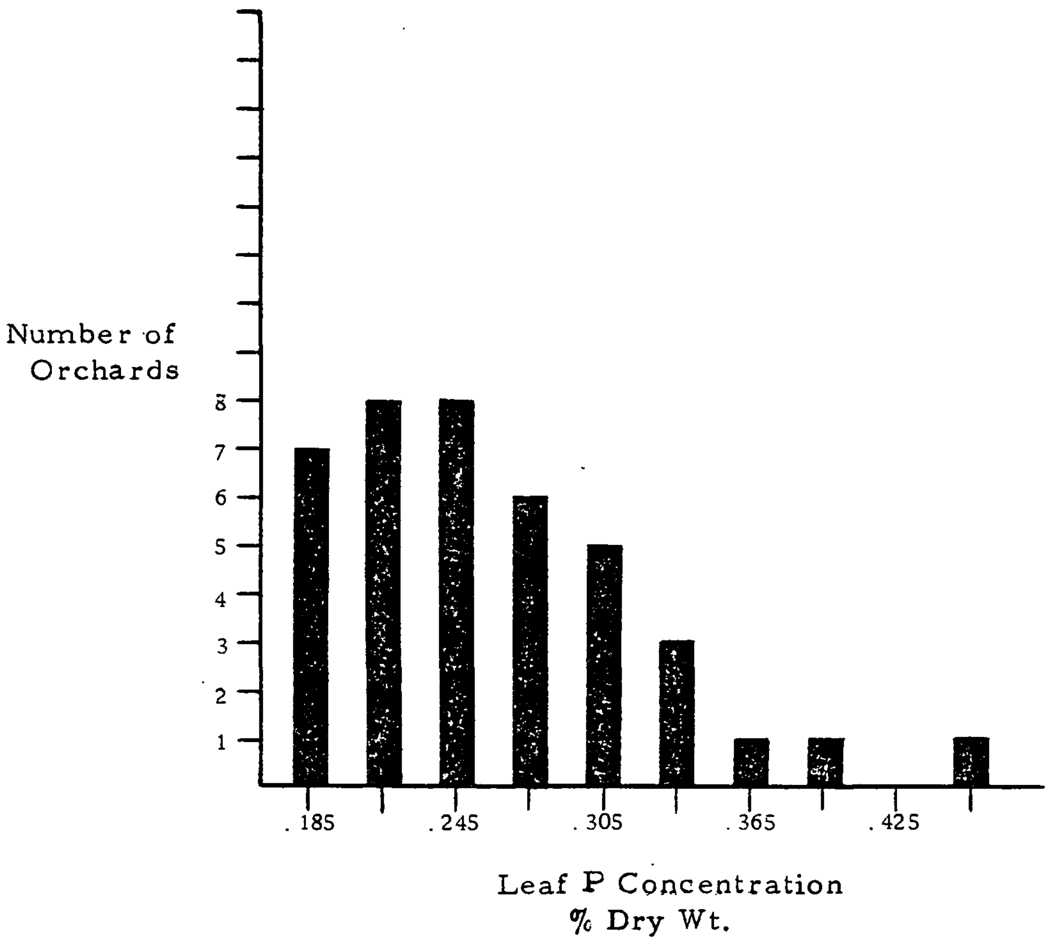
The slight decrease in leaf P may be attributed to the medium cropping year of 1979 compared to the light cropping year of 1978.

Although it is generally agreed that an increase in crop results in an increase in leaf N, Ca and Mg and a decrease in leaf K, the effects of cropping on leaf P is not so clear cut. In some studies leaf concentrations of P have decreased during a cropping year (7, 11, 19) while other studies have shown leaf P levels to increase during a cropping year and decrease during the nonfruiting year of a biennial variety (6, 25, 36).

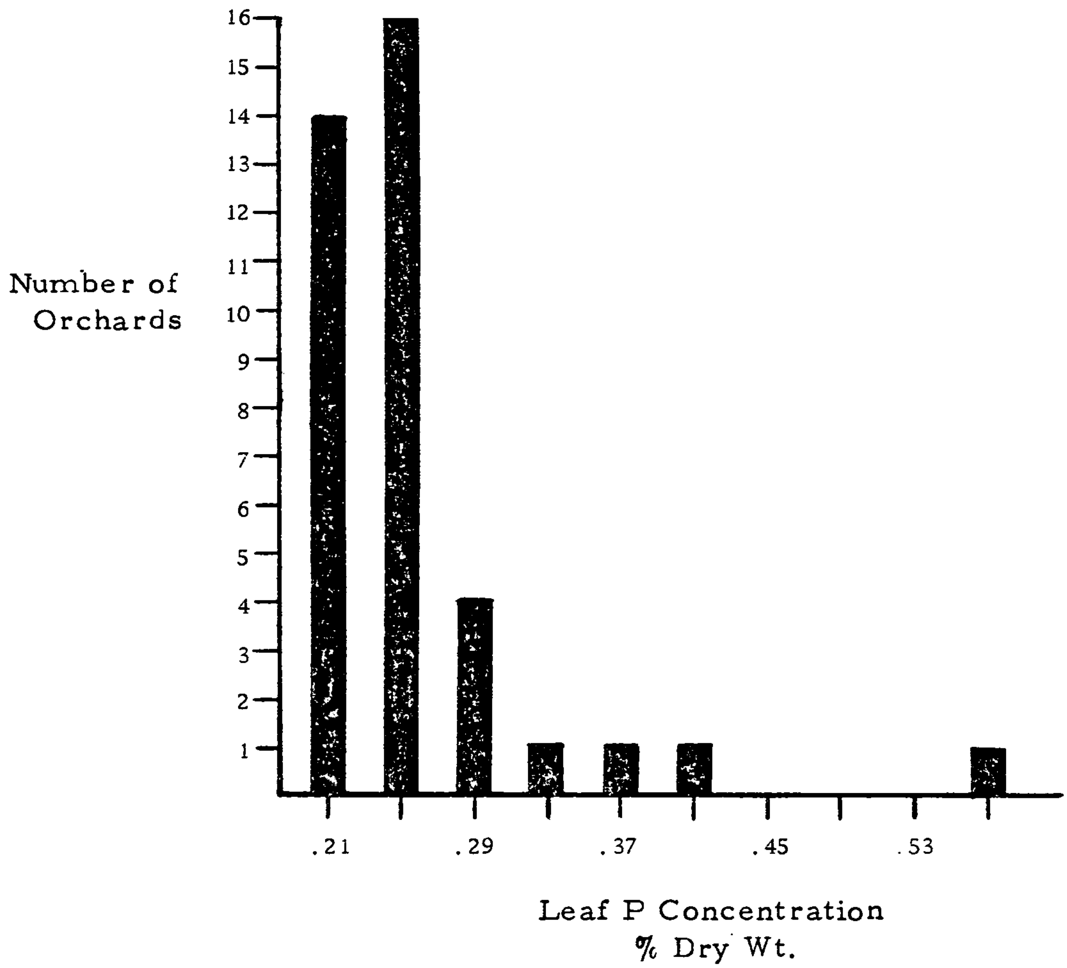
The leaf P levels of the Ethell orchard are not deficient but they are considerably lower than the leaf P levels of other orchards throughout the Hood River Valley. From leaf samples submitted by growers, none of the apple orchards from any area of the Hood River Valley had leaf P concentrations below .17% dry wt. in 1978 or 1979. The average leaf P concentration for both years was .25% dry wt. Furthermore no significant differences in leaf P levels were observed between apple orchards in the Parkdale area and the lower Hood River Valley. Out of 80 leaf samples submitted by pear growers in 1979, 15 samples representing 15 different orchards had leaf P levels in the "below normal" range (less than .13% dry wt.). Eleven of these 15 orchards are located on the Parkdale soil series. Three of these pear orchards have deficient leaf P levels of .09%, .08% and .06% dry wt. Therefore, it is not uncommon to find low concentrations of leaf P in orchards on the Parkdale loam soil.

The results of the liming treatment seem to suggest that the P

Histogram - 1. 1978 leaf P concentrations for Hood River Valley apple orchards participating in the extension diagnostic testing program.



Histogram - 2. 1979 leaf P concentrations for Hood River Valley apple orchards participating in the extension diagnostic testing program.



supplying power of the Parkdale loam soil is not responsible for the low leaf P levels in pear orchards in the Parkdale area. The volcanic Parkdale loam soil is low in available P and has a high capacity for phosphate fixation due to the presence of large amounts of amorphous minerals (namely allophane) and their high anion exchange capacity. The anion exchange mechanism is pH dependent and the lower the soil pH the greater the extent of phosphate adsorption. Liming an acid amorphous soil dissociates H^+ ions into solution and leaves a negative charge on the mineral surface. Positive binding sites for adsorption of phosphates and other anions are reduced and greater amounts of soluble phosphates and other anions remain in solution.

The liming treatment in this study was shown to significantly increase the soil pH at the 15 cm depth but no increase in leaf P was observed in any of the lime treated trees when compared with the trees which were not limed. The mechanism of anion exchange is an acceptable working theory and it is not unfair to assume that since the soil pH was increased the supply of soluble phosphates was also increased. Since the leaf P levels of both limed and nonlimed trees in the Ethell orchard had equal leaf P concentrations, the P supplying power of the Parkdale loam does not appear to be directly responsible for the low leaf P levels. Furthermore, leaf P levels between adjacent pear orchards on the Parkdale loam soil can vary by as much as .10% dry wt.

The August 1978 leaf analysis indicated a severe Zn deficiency existed within the orchard. Zn levels throughout the treatment plots were frequently below 10 ppm where Zn deficiency is thought to begin. The dieback symptoms throughout the orchard are characteristic of a Zn deficiency. Terminal growth is stunted and rosetting and "little leaf" symptoms are quite prevalent. A dormant application of Zn sulphate was applied during April of 1979 in an attempt to correct the deficiency. However, the August 1979 leaf analysis indicated that the dormant spray was ineffective as Zn levels continued to decline. Orphanos (26) also found dormant sprays of Zn sulphate to be totally ineffective in raising leaf levels of Zn in Starking Delicious apples. He found foliar sprays to be more effective in raising the Zn content of sprayed leaves and expanding leaves but when the shoot apex was protected from the spray the leaves developing thereafter did not have a higher Zn content, indicating that Zn translocation from older to new leaves is limited.

In summary the mainplot treatments of lime and the subplot treatments of superphosphate had no effect on shoot length, apple volume or leaf element levels. Overall, shoot length decreased from 1978 to 1979 while apple volume greatly increased.

The decrease in shoot length was probably the result of the increased fruit load and the declining Zn levels. Leaf element levels were not affected by the mainplot or subplot treatments but a general increase in N, Ca and Mg was observed among all treatments. The increase in N, Ca and Mg was attributed to the increased fruit load in 1979 as opposed to the light fruit crop in 1978. Leaf P levels declined slightly from 1978 to 1979 despite the presence of apple roots within the phosphate band.

The dieback symptoms which have plagued the orchard throughout suggest a Zn deficiency and leaf analysis has confirmed that a severe Zn deficiency exists. A dormant spray of Zn sulphate was ineffective in raising the leaf Zn levels. Foliar sprays of Zn sulphate and Zn chelates should be applied in an attempt to correct the Zn deficiency which at the present time seems to be the nutrient most limiting to plant growth.

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