Effects of soil pH and nutrients on growth of apple seedlings grown in apple replant disease soils of British Columbia

T. S.C. Li and R.S. Utkhede[1]

Relationships between McIntosh apple seedling growth and pH along with soil nutrients in 568 apple replant disease (ARD) soils were examined by regression analysis. Sixty percent of the ARD soils in the Okanagan-Similkameen valleys had pH values between 6-7.5. All three major nutrient elements (N, P and K) had positive relationships with plant height when the soil pH was ≥ 8. When the soil pH was lower than 5.4, only P had positive relationships with plant height. When the soils were treated with monoammonium phosphate or ammonium nitrate, pH had significant negative relationships with the plant height.

Can. Plant Dis. Surv. 71:1, 29-32, 1991.

On a étudié par analyse de régression les rapports qui existent entre la croissance de jeunes pommiers McIntosh, le pH et les substances nutritives de 568 sols atteints de la maladie de la replantation. Soixante pourcent de ces sols dans les vallées de l'Okanagan-Similkameen affichent des PH variant de 6 à 7,5. Les trois éléments nutritifs principaux (N, P et K) montrent une corrélation positive avec la hauteur des plants lorsque le pH du sol est ≥ 8. Mais lorsque le pH du sol est inférieur à 5,4, seul le P affiche une corrélation positive avec la hauteur des plants. Lorsque les sols sont traités au phosphate d'ammonium primaire ou au nitrate d'ammonium, le pH montre une corrélation négative significative avec la hauteur des plants.

Introduction

Apple plants of all ages can tolerate extreme soil pH levels which may have an adverse effect on ARD. In pot experiments Hoestra (1968) found good growth of apple seedlings at pH 3.8. Donoho *et al.* (1967) showed that apple trees grew well at pH 3.6 to 4.5, if all other conditions were good. In pot and field experiments, it has been shown that acidification of the soil could alleviate or solve the problem of apple replant disease (Hein, 1972; Hoestra, 1968 and 1973; Hoestra and Kleijburg, 1967; Jonkers and Hoestra 1978). Soils with a low pH are far less conducive to specific apple replant disease than near-neutral soils (Savory 1967). Acidification of ARD soils with neutral pH levels may have a growth stimulating effect on seedlings which is equal to the effect of chloropicrin treatment (Hoestra 1968). In England, replant disease was not observed in soils with pH levels in between 4 and 4.5 (Upstone 1977), although it is well known that apple trees do not grow well at low soil pH levels. In the Okanagan valley, internal bark necrosis may became serious in plants grown in soils at pH under 5.6 and especially when the leaf manganese concentration is above 120 ppm (Fisher *et al.* 1977). In Italy, low pH levels may cause some nutrients to be unavailable to apple trees (Fregoni and Visai, 1970) and deficiencies of Mn and Cu have been observed in trees growing in soils at pH under 5.0 (Mulder and Butijn 1963).

This paper describes relationships between soil pH, nutrients and the growth of apple seedlings based on 568 apple replant disease soil samples and the effect of nitrogen, phosphorus and other minor nutrients on apple seedling growth.

Materials and methods

The occurrence of apple replant disease in the Okanagan-Similkameen valleys of British Columbia was determined by growing apple seedlings in 568 soil samples collected from old apple orchards throughout the valley. Each soil sample was collected from the root zones 5 to 30 cm below the surface under 3-4 standing fruit trees with a total weight of about 25 kg, and was mixed thoroughly and sieved through a 6 mm sieve to remove stones and the larger root fragments. The samples were stored in polyethylene bags at 18-20°C.

For chemical analyses, half litre soil samples were sent to the Soil Testing Laboratory, British Columbia Ministry of Agriculture and Fisheries, 1873 Spall Road, Kelowna, British Columbia, V1Y 4R2.

McIntosh apple seedlings were used for the pathogenicity tests. The seeds were placed on moist paper towels, sealed in plastic bags and stratified at 0-2°C for 10 weeks. The seeds were then planted in a peat moss and perlite mixture (1:1). Germination occurred within one week at 20°C and seven days later, the seedlings were selected for uniformity. For each treatment 0.5 L of a soil sample was placed in six replicate 10 cm (round) pots and one seedling was planted in each pot. The seedlings were grown in a greenhouse (20 ± 2°C) with fluorescent light (140 lux) to supplement natural daylight for a 14 h photoperiod. For the fertilizer treatments, monoammonium phosphate

[1] *Agriculture Canada, Research Station, Summerland, British Columbia, Canada V0H 1Z0.*

Accepted for publication August 21, 1990.

(11-55-0, 1 g/L) and ammonium nitrate (34-0-0, 0.33 g/L), were mixed with the soil separately one day prior to transplanting of apple seedlings. Controls were orchard soil without any treatments. Plant height was recorded 14 weeks after transplanting. The data for plant growth at different pH levels or levels of nutrients and the regression coefficients are presented in this report.

Results and discussion

I. Variation in pH, N and P levels.

About 60% of the soil samples had pH values between 6 and 7.5 (Table 1) which is considered the optimal range for growing apple trees (Jonkers and Hoestra 1978). Hoyt and Neilsen (1985) observed significant positive relationships between tree size and pH levels in three of six orchards studied. Values of pH higher than 8 and lower than 5.4 were observed in 3.6% and 9.1% of the soil samples, respectively, which is considered to be inadequate for good growth of apple trees and require lime or sulphur treatment before planting.

Total available nitrogen levels in the soil samples were divided into three groups: low (0-10 ppm), medium (11-30 ppm) which is the recommended level for apple production, and high (≥ 31 ppm). About one third of the samples had levels of available N within each of the three groups (Table 1).

Table 1. Percentage of soil samples with various levels of pH, nitrogen and phosphorus

pH levels		%
> 8		3.6
7.6-7.9		12.4
6.0-7.5		60.4
5.5-5.9		14.5
< 5.4		9.1
N (ppm)		
0-10	(low)	27.9
11-30	(medium)	39.4
31	(high)	32.7
P (ppm)		
0-30	(low)	21.4
31-60	(medium)	26.1
61-100	(high)	19.6
101	(very high)	32.9

Table 2. Regression coefficients between N, P and K in soil and the growth of apple seedlings at 5 pH ranges

	pH levels				
Nutrients	> 8	7.6-7.9	6-7.5	5.5-5.9	< 5.4
N	0.29*	1.00*	0.08*	0.16*	0.05
P	0.42*	0.02	0.09*	0.004	0.13*
K	0.68*	0.02	0.03	0.005	0.001

* Significant at $P = 0.05$.

Phosphorus levels in soils (Table 1) were divided into four categories, low (0-30 ppm), medium (31-60 ppm), high (61-100 ppm) and very high (≥ 101 ppm). Twenty-one percent of soils had low levels of phosphorus and 33% of soils had very high levels.

II. The effect of pH, N, P and K on plant growth.

A. Relationship between pH and N, P, K. Nitrogen level in soils and plant height had significant positive relationships at all pH levels except 5.4 (Table 2). Significant relationships were also observed between P levels and plant height in 3 ranges of pH levels (≥ 8, 6-7.5, and < 5.4). This indicates that higher P levels in the soil within these three pH groups have a positive effect on the growth of apple seedlings. This is in contrast to the findings of Wilcox *et al.* (1947) who reported that additional P was not essential for orchard soils of the Okanagan-Similkameen valleys. Soil pH influences the solubility of the essential nutrients that are capable of interacting with soluble P. In general, if the soil pH is lower than 5.4, Fe and Al will fix P in the soil and it will not be available for plants. On the other hand, with higher soil pH, Ca and Mg will interact with P, which would affect the availability of these nutrients (Bradfield *et al.* 1935; Ellington 1978; Munson 1978). Apple seedling growth was increased with increased levels of K in the soil in the pH ranges of ≥ 8. It is interesting to note that all three major nutrient elements had positive relationships with plant growth in the group of pH ≥ 8.

B. Relationship between P and pH, N. No significant effect was observed in plant growth between pH and 4 levels of phosphorus in the soil (Table 3). However, plant growth showed significant increases with higher N in the soil within the groups of medium, high and very high levels of P.

III. The effect of pH, K, Ca and Mg on plant growth after application of monoammonium phosphate in the soil.

In the last five years, the orchardists of British Columbia have been using monoammonium phosphate to obtain good growth of apple trees during their planting on

Table 3. Regression coefficients between pH, nitrogen levels and the growth of apple seedlings at 4 phosphorus levels

	Phosphorus levels (ppm)			
Soil factors	Low <30	Medium 31-60	High 61-100	Very high >101
pH	-0.03	-0.001	0.003	-0.02
Nitrogen level	0.02	0.07*	0.07*	0.13*

* Significant at P = 0.05.

replant disease soils. The results of the present experiment indicated that plant growth was negatively affected with soil pH when the soils were treated with monoammonium phosphate (11-55-0) (Table 4). This shows significantly higher growth at low soil pH when the supply of N and P is adequate. This confirms earlier observations made by Jonkers and Hoestra (1978), Tiedjens and Black (1932) and Jonkers *et al.* (1980). Tiedjens and Black (1932) indicated that, at lower pH, plant growth was better as nitrate nitrogen was absorbed more efficiently by the roots. Plant height was not affected by K in the soils which were supplemented with mono-ammonium phosphate (N and P). Wilcox *et al.* (1947) reported that the Okanagan-Similkameen valley soils had adequate K and additional K would not enhance plant growth.

Table 4. Regression coefficients between plant height and pH, K, Ca and Mg after monoammonium phosphate soil application

	Soil factors			
	pH	K	Ca	Mg
Plant height	-0.15*	-0.02	-0.06*	-0.01

* Significant at P = 0.05.

When the orchard soils had adequate supplies of N and P, Ca showed negative effects on plant height (Table 4), but was not affected by Mg. This indicates that under adequate N and P levels in the soil, plant growth will increase with low Ca contents.

IV. Relationship between plant height and pH, P after the application of ammonium nitrate in the soil.

It is a general practice for the orchardists in British Columbia to apply ammonium nitrate (34-0-0 NPK) to apple trees to obtain good growth. The results of the present experiment indicated that when ammonium nitrate was applied to the soils, plant height was negatively affected by soil pH levels (Table 5). However, plant height had a positive relationship with P when the level of N in the soil was amended. These results and those in Table 4 indicate that the growth of apple seedlings is better in soils with ample N, a lower pH and high P level.

Table 5. Regression coefficients between plant height and pH, P after ammonium nitrate was applied

	Soil factors	
	pH	P
Plant height	-0.13*	0.09*

* Significant at P = 0.05.

Acknowledgements

The authors wish to thank Drs. J.T. Slykhuis and J.M. Yorston for supplying part of the data used in this paper. We thank Mr. W. Van Lierop of British Columbia Ministry of Agriculture and Fisheries for chemical analysis of soils, Mr. J. Wild for statistical analysis of the data, and Dr. P.B. Hoyt for his constructive criticism and valuable suggestions for interpretation of the data.

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