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Title: EFFECT OF MEDIUM, FERTILIZER RATES AND TRANSPLANT METHODS ON THE GROWTH OF YOUNG APPLE TREES

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Dr. Robert L. Stebbins

This study compared leaf mold, bark, automobile waste and the combination of half leaf on the top and half bark on the bottom as growing media for young apple nursey stock. Although the chemical and physical analysis of leaf mold was superior to the bark, trees in leaf mold showed no difference from bark in all growth parameters. The analysis included total shoot growth, total shoot number, final trunk diameter and total plant weight.

For the low, medium and high fertilizer rates, only total plant weight showed a significant difference between low fertilizer rate and the other two. All other growth parameters showed no difference.

For root distribution at the medium fertilizer rate, leaf mold showed a significantly higher total root number than other media. Trees in leaf mold had significantly more root numbers in the upper 12.5 cm of medium.

Considering its lower cost, leaf mold is the best growth medium for young apple nursery stock.

Trees transplanted with medium made significantly more growth than trees transplanted with bare roots.

Effect of Medium, Fertilizer Rates and Transplant Methods on the Growth of Young Apple Trees

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This thesis is dedicated to

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Dr. Robert L. Stebbins

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EFFECT OF MEDIUM, FERTILIZER RATES AND TRANSPLANT METHODS ON THE GROWTH OF YOUNG APPLE TREES

I. INTRODUCTION

One current method for renewal in old orchards is to interplant one-year-old young trees between the old trees in the row. After the new trees are established, the old trees are pruned back, and eventually removed. Because of competition between the old and new trees, and problems left by the old orchard, the interplanted trees either die or grow slowly and are poorly shaped.

The purpose for this research is to improve upon the technique published by Jeffrey A. Kent " A Technique for the production of ready-to bear temperate zone fruit tree" by trying different media, fertilizer levels, and different transplant methods.

II. LITERATURE REVIEW

Apple Root Distribution and the Factors Affecting its Distribution

The main roots of apple trees are primarily horizontal and called extension roots. In mature apple trees they are located at a soil depth between 25-50 cm. (51, 53, 54). Most roots of one-year-old apple trees occur in the upper 26 cm, as compared to 1.2-2.5 m for mature trees (70). Root concentration was greater within a 1 m radius of the trunk than beyond it (68). The largest root mass was found in the top 11-30 cm layer of soil. Horizontal root distribution was radial irrespective of crown training (49).

Observation of 5-year-old trees of Golden Delicious on M.9 root system at 4 spacings $(2.4\ m)^2$, $(1.2\ m)^2$, $(0.6\ m)^2$ and $(0.3m)^2$, showed that at the wider spacings the root system was composed of horizontal major roots with fewer vertical sinkers than at the closer spacings. The weight, length, volume and surface area of the root systems decreased and the density of roots in the ground increased with density of planting. Spacing affected the distribution of roots with depth. At the closest spacing, 25% of root weight occurred below 50 cm, compared with 15% at the widest spacing. At all depths, root density increased as spacing decreased. At all spacings a greater proportion of major roots was found in the top 25 cm of soil (5).

In a Golden Delicious apple tree orchard, root distribution was markedly affected by the type of irrigation, especially in the 25-45 cm layer. Sprinkler irrigation led to a large amount of rootlets outside the crown. The highest root density was with drip irrigation, with most roots occurring between the tree and the emitter. Such root localization was not affected by fertilization. The zones of water and p absorption were mainly determined by soil physical conditions such as water retention and aeration and determined less by root density (42).

Weed cover of Artemisia princeps and Digitaria sanguinalis restricted the distribution of apple rootlets in the upper soil layers. Polygonum longisetum tended disrupt rootlet elongation but otherwise had little effect on apple root growth (28).

Factors Affecting Root Growth

Water

Transpiration by leaves is the driving force for the movement of water through plants. The amount of available water that can be stored by the medium is that water held between the permanent wilting point(-15bar) and the field capacity (-0.33 bar). The water potential at which wilting occurs is called the wilting point. At P.W.P., wilting is irreversible and the plant dies. It is generally considered that a water potential of -15 bar throughout the rooting zone would lead to the permanent wilting of the majority of crop plants (33) . But the rate of root extension starts to decrease at about -0.5 bar, though root extension may continue slowly until the water potential falls to -10 bars or lower (35) . The effects of anaerobic conditions due to excess water will be discussed later. Tree growth was greatest when irrigation was utilized to maintain the moisture level at field capacity (19) .

Under field conditions, variations in water supply are frequently the major cause of differences in the distribution of roots, particularly the depth they attain in the medium. In high rainfall, barley roots showed a higher % distribution in upper layers of the medium, only a little in lower layers of medium, but under low rainfall, barley showed higher % distribution in lower

layer of medium (20). Also in cotton the density of roots was also affected by the water supply. If the water supply was not enough, the root density increased with increasing depth; if the water supply was enough the density of root decreased with increasing depth (32) .

Because nutrient uptake is through water uptake, the water supply to the medium also has a profound influence on nutrient uptake. Calcium uptake by perennial ryegrass within the top 5 cm of soil increased with increasing water content (44) . Under drought conditions, the uptake of ammonium nitrate increased with increasing depth (22) . So if an orchard had a water supply problem, it is suggested that fertilizer be placed deeper in the soil, because the water content is more stable at greater depth .

Temperature

The temperature of the medium affects the type of root growth a plant makes. Low temperatures encourage white succulent roots that suberize slowly and show little branching, while high temperatures encourage a browner, finer and much more freely branching root system which suberizes fairly rapidly (58) .

The rate at which roots can take up water and nutrients from the medium also increases with medium temperature, and for some crops at least this rate may continue to increase until the temperature becomes sufficiently high to start harming the roots

(11).

Temperature affects the rate of growth. Within limits, increasing temperature speeds cell division and elongation. Temperature also influences the supply of carbohydrates, mineral nutrients, and water, all of which are essential for growth. The carbohydrates required at the growing point must be translocated from storage tissue or from the leaves. High temperatures favored more rapid translocation and accelerated respiratory activity. But if the temperature is too high in both roots and shoots, the ratio of respiration to protein synthesis may be so increased that the carbohydrate balance in the plant is depleted and growth of roots is consequently decreased. Low temperatures restrict the rate of water absorption by roots. Probably low medium temperatures impede root growth as a consequence of a limited water supply (17) . Dormant Delicious apple trees show the greatest root growth at 18.3°C, very little growth at 7.2°C or 10°C. There were striking effects of comparatively small differences in root temperature. It seems apparent that root growth in apple trees can be greatly modified by a difference of only a very few degrees in medium temperature (45) .

In one experiment, new root primorida were present at 4.4°C on March 20, but this seemed to be about the minimum temperature for root growth in dormant apple trees, after March 20, the trees were no longer dormant, some of these primorida developed into short new roots, though all appeared to be injured (7) .

Active root growth usually began as the mean medium temperature reached about 45°C, and the rate of growth increased with rising temperature up to maximum recorded, about 68°C at the 8 inch depth. The response of root growth to medium temperatures was local as well as general. In the spring most growth occurred in the upper layers of the medium, which warmed up first; in the winter most root growth was deeper in the medium (52).

Structure

Root growth in the medium is affected by the ability of the roots to find space to grow, or to force their way into the medium. Early in 1957 Wiersum provided clear evidence which showed roots could not penetrate rigid pores the diameter of which was less than that of the extending zone of the root (59). So root growth is affected by the external pressure and pore size. Root elongation of barley put under an external pressure of 0.2 bar was reduced. Under an external pressure roots were much thicker and the number of laterals per unit length of seminal root was much increased, so that the root volume was not greatly affected by pressures in the range encountered (25).

Bulk density is closely related to pore size. In the same medium, if the bulk density of the medium increases, its pore space and particularly that occupied by pores of large size is reduced (59).

The force a root can exert appears to depend on its diameter (6), and turgor pressure of the root cells, which, in turn, depends on the leaf turgor. During periods when the leaf is wilting, as happen in the middle of the day in hot semi-arid areas, root growth ceases (57).

This raised the basic problem of water source. The main source of water is from the medium. Since the medium structure determines the availablility of water, it affects root behavior. Not only water but also conduct of heat and gas are determined by the structure of the medium.

Aeration

Media have three phases, particle, water and air. The total space for water and air is called % pore space. Only with flooding and some special conditions does water equal % pore space, only in oven dry conditions does air equal % pore space. Pore space normally depends on the size of pores, rainfall and temperature.

The most important components of air in the medium are oxygen and carbon dioxide. In general, air above ground contains 79.01% N_2, 20.96% O_2, 0.03% CO_2, compared with soil air which contains 79% N_2, 20.3% O_2, 0.15-0.65% CO_2. Soil O_2 is a little less than atmospheric O_2, but CO_2 is almost 5 to 22 times more than atmospheric.

The respiration rate of plant roots varies with the O_2 supply

in the medium air. Although apple tree roots will grow slowly with as little as 3% oxygen, 10% is essential to attain good growth (48) .

Respiration provides the energy for various metabolic processes including active ion uptake by plant roots. Lack of O_2 can directly affect the carbohydrate metabolism of roots. Oxidative degradation of sugars is depressed and ethanol is produced by fermentation (31). Ethanol has a detrimental effect on plant growth and can result in considerable yield depressions of crops (21). Oxygen deficiency in the roots also impairs the synthesis of phytohormones such as cytokinins and giberellins.

Under anaerobic conditions the end products of anaerobic microorganisms can accumulate. These anaerobic metabolic end products include substances which are toxic to higher plants such as ethylene, methane, hydrogen sulphide, cyanide, butyric acid and a number of fatty acids. Plants affected by these toxins are impaired in growth and often show wilting symptoms. The detrimental effect of poor drainage on plant growth is thus more severe than can be accounted for by a simple lack of O_2 (37, 50).

pH

Most plant nutrients absorbed by plant roots are in the form of ions. The H^+ concentration of the medium solution has a pronounced effect on a number of medium constituents, especially

minerals, microorganisms and plant roots. High H^+ concentrations favour the weathering of minerals resulting in a release of various ions such as K^+, Mg^{2+}, Ca^{2+}, Mn^{2+}, Cu^{2+} and Al^{3+}. The solubility of salts including carbonates, phosphates, sulphates is higher in the lower pH range. High H^+ concentrations of the solution cause high concentrations of Al^{3+}. Levels as low as $1.1 * 10^{-5}$ M AL^{3+} cause considerable root damage (2).

PH also influences the occurrence and the activity of soil microorganisms. Generally below pH 5.5, fungi dominate in the soil and the rhizosphere, whereas at higher pH levels the bacteria are more abundant (71).

The uptake rate of various plant nutrients is also pH dependent. Generally, anions including nitrate and phosphate are taken up at a higher rate in the weak acid PH range. the uptake rate for cations seems to be highest in the more neutral pH range (4).

At very low pH levels (<3.0) cell membranes are impaired and become more permeable. This results in a leakage of plant nutrients and particularly of K^+ which diffuses out of the root cells into the medium (43).

So we can conclude that pH directly affects roots by changing the root cell permeablity, nutrients uptake, and indirectly affects roots by changing microorganisms, nutrient availability and the presence of toxic elements.

Salinity

The classification of salt-affected soil has been on the soluble salt (Electrical Conductivity) concentrations in extracted soil solutions and on the exchangeable sodium percentage (ESP) or sodium adsorption ratio (SAR) of associated soil.

Table 1 Traditional and Proposed Classification of Salt-affected Soil

	Normal Soil	Saline Soil	Sodic Soil	Saline Sodic
Traditional (72)	EC < 4 ESP<15%	EC > 4 ESP<15%	EC < 4 ESP>15%	EC > 4 ESP>15%
Proposed (69)	EC < 2 SAR < 15	EC > 2 SAR < 15	EC < 2 SAR > 15	EC > 2 SAR > 15

Soluble salts depress the water potential of the nutrient medium and hence restrict water uptake by plants, so plant growth in saline and alkali soil is often restricted due to a lack of water (8). Saline conditions restrict the synthesis of cytokinins in the roots and their translocation to upper plant parts (39). Cytokinin promotes cell division, leaf expansion, shoot initiation, translocation of assimilates and inorganic phosphorus and transpiration (60). The synthesis of abscisic acid on the other hand is promoted by salinity (41) which promoted

adventitious rooting and inhibits transpiration, root elongation and ion transport (60).

Plants growing on a saline medium can increase their internal osmotic concentration by production of organic acids or by increase in the rate of ion uptake. This lowering of the water potential in the plant roots and stimulation of water uptake is known as osmotic adjustment (9). The adequate turgor of plants growing in saline conditions implies that the detrimental effect of soluble salts on plant growth results from salt induced physiological disorders rather than osmotic effects (34).

Soil with high exchangeable sodium levels frequently crust badly and swell or disperse, greatly decreasing the hydraulic conductivity or permeability to water. Clay particles disperse and plug soil water flow channels. Swelling of particles into flow channels also slows water flow. Decreased permeability can interfere with the drainage and also slow water flow. Decreased permeability can interfere with drainage and with normal water supply and aeration required for plant growth (27).

Mycorrhizae

Mycorrhizal fungi are divided into two groups, ectotrophic and endotrophic. Endotrophic types are most found on deciduous fruit trees. The hyphae of endotrophic mycorrhizae penetrate the cells of the root cortex forming an internal hyphal network. Hyphae also

extend into the medium. For fruit trees the predominant type of fungal infection is by vesicular arbuscular mycorrhizae (VAM) (40)

.

Gigaspora margarita Becker and Hall, Glomus fasciculatum Gerd. and Trappe. and Glomus mosseae Gerd. and Trappe and other mycorrhizal fungi were found in Oregon orchards in association with apple (73).

Infected roots live longer than noninfected ones, the finest lateral rootlets which have a very short life in uninfected conditions and remain unbranched, respond to mycorrhizal infection by growing for a longer period of time and by branching (23).

Mason indicated that the number of mycorrhizal spores produced on strawberry and raspberry decreased with production of new roots and increased with cessation of root growth and onset of senescence (38).

Since colonization is favored in nutrient stress situations, an increased supply of mineral nutrients may reduce colonizaton (61). Different mycorrhizal fungi species respond differently to pH. Vigorous mycelial growth was observed on clover roots in a growth medium with 2 pH of 7 to 8, whereas at pH 4.5 fungal growth and colonization were inhibited (67). Apple trees failed to respond to G. Mosseae inoculation at pH 5.1, but grew well at pH 6.2.

Rhizosphere

The immediate neighbourhood of plant roots is of particular importance for plant nutrient turnover and availability. This part of the medium, which is directly influenced by the roots, is called the rhizosphere. This layer may be up to 1 to 2 mm thick (56).

The effect of the roots on the adjacent medium is mainly brought about by the release of organic and inorganic materials into the medium. Organic material arises from the sloughage of root material and also from direct root exudation (26).

Root sloughage is considered to be the main source of carbon released by roots. Besides this, the production of mucilage contributes much to the transfer of organic carbon from roots to medium. The mucilage is capable of adsorbing clay minerals (15) and brings about a close contact between the root and the medium, with the slime filling the spaces between roots and medium particles. This close contact is of importance for nutrient and water supply.

In general, people accept that to transplant with the medium on the roots is better than transplanting bare root. The close contact between root hairs and medium particles is destroyed and must re-established by production of slime and development of new root hairs after bare-root transplanting. The period following transplanting is thus a critical one because of this absence of a

close contact between roots and medium. The total amount of organic carbon released into the medium is 50% of the total C translocated from the tops to the roots of wheat (62).

Medium

Bark

The purpose of bark is to protect the stem from attack by pathogenic fungi, parasitic insects, and from desiccation. To carry out these functions it has evolved into a tissue which is extremely resistant to decay. The advantages of bark for potting are its porosity, non-coherence and light (1). the porosity range is from 31.5% to 54.7 %, and bulk density is 0.178g/cm^3. The disadvantage of bark is its comparatively low water retention which from 15% to 38% (30) is only one third of that of peat (1). One interesting character of Douglas-fir bark is that has a pH of around 4.0 (12, 36).

The major plant nutrient content of Douglas-fir bark, expressed as percent dry matter, is as follows: nitrogen 0.12, phosphorus 0.011, potassium 0.11, calcium 0.52, and magnesium 0.01 (12, 36). The price of bark was 12 dollars per cubic yard in Corvallis, Oregon in 1983, so the cost for the bark used in the experiment was around 8 dollars per tree.

Leaf mold

Analyses of a number of leaf molds showed that they generally contain excessive salts (63). Greenhouse and laboratory

observations suggest that when leaf mold is used in large proportions in a soil mix for container-grown plants, salts may damage young seedlings. Excess salts can be removed by leaching with liberal quantities of water before transplanting. Leaf mold is well-buffered at about pH = 7, which is considered optimal for most plant (63).

Compared with sawdust, peat moss, bark, chaff and ground chaff, leaf mold was the most porous organic material (3).

Compared with composts of pine needles, sphagnum peat, beech leaf mold, perlite, polystyrene, pumice, pine bark and Epiphyte Mix, leaf mold contained the most NPK and was suitable for growing many flowering species (3).

Composted leaf sweeping and pine bark were generally the most suitable substitutes for, or amendments, to peat moss (65).

III EXPERIMENTAL STUDY

Experiment I.

Materials and Methods

This experiment used apple, Malus domestica borkh.,c.v. Newtown Pipin on Malling Merton 106 (M M 106) rootstock. Seventy-two, one-year-old unbranched and bare-rooted trees were planted into a 32.4 m * 1.8 m * o.5 m plastic-lined, wooden box on March 30, 1983. Each of the seventy-two units had the same volume, $0.4m^3$, separated by plastic and wire into an individual isolated unit. Only the bottom had holes allowing water entry.

Three different media were used including bark, leaf mold and automobile waste (The auto waste primarily consisted of upholstery fabric and stuffing from recycled automobiles. As autos are prepared from melting the metal parts, the other parts are stripped and collected as waste. The cloth parts may have been treated with boron as a fire retardant.) The other combination consisted of half leaf mold on the top and half bark on the bottom.

Since the loading job was mainly done by a front-end loader, a split-plot design was chosen, each loading filled three units. The above four media arrangements were main plot, three fertilizer rates were sub-plot. All twelve treatments were repeated six times.

Three fertilizer rates were established:

Nutrient level #1 contained:

0.80 N in Kg/m^3 mixed in media as urea

0.24 P in Kg/m^3 mixed in media as concentrated super phosphate (0-45-0)

0.36 K in Kg/m^3 mixed in media as potassium sulfate (0-0-60)

0.56 dolomitic limestone Kg/m^3 mixed in media

0.56 gypsum Kg/m^3 mixed in media

Nutrient level #2 contained:

1.60 N in Kg/m^3 mixed in media as urea

0.48 P in Kg/m^3 mixed in media as concentrated super phosphate (0-45-0)

0.72 K in Kg/m^3 mixed in media as potassium sulfate (0-0-60)

2.27 dolomitic limestone Kg/m^3 mixed in media

2.27 gypsum Kg/m^3 mixed in media

Nutrient level # 3 contained:

2.40 N in Kg/m^3 mixed in media as urea

0.72 P in Kg/m^3 mixed in media as concentrated super phosphate (0-45-0)

1.08 K in Kg/m^3 mixed in media as potassium sulfate (0-0-60)

3.98 dolomitic limestone Kg/m^3 mixed in media

3.98 gypsum Kg/m^3 mixed in media

Concentrated super phosphate, potassium sulfate, dolomitic limestone, and gypsum had been mixed by hand into the media prior to tree planting. Urea was banded 30 cm from the trunk once a week

for eight weeks beginning June 10, 1983.

All trees were pruned back to 40 cm above the graft union on April 20, 1983. Each tree received 4 liters of water per day from 6 pm to 7 pm. The irrigation system consisted of a time clock solenoid valve/pressure regulator, polyethylene tubing, tubing stabilizer bar, and a Geor-Jet low pressure plastic sprinker (5.1 GPH at 15 PSI). The only management practice was hand weeding on a monthly basis.

Trunk diameter, shoot growth, and root distribution were measured as well as the dry weight of old roots, new roots, rootstock and shoots. Trunk diameters were measured on January 5, 1984, 5 cm above the graft union.

Total shoot growth was measured three times, August 24, 1983, November 26, 1983, and January 5, 1984. Leaf samples were taken on August 15, 1983, consisting of 15 disease-free leaves randomly selected from the middle of the current season's growth. The leaves were washed in a solution of 10 g EDTA (disodium salt) and 10 g Alconox in 20 liters of distilled water, then rinsed three times in distilled water. After rinsing, the leaves were dried in a 70'C oven for 48 hours, then ground in a Willey Mill (20 mesh screen) and stored in plastic bags. Before testing, the samples were redried. In the test, 1.0 g was used for mineral analysis, 0.4 g used for nitrogen analysis.

For mineral analysis, the samples were ashed in a Muffle furnace (Thermolyne) for six hours at 525'C, then treated with 5

ml of 20% HNO_3, allowed to stand 2-3 hours, then diluted with 15 ml distilled water. Samples were mixed throughly then allowed to settle overnight. An aliquot of 4.5 ml was removed from this solution the following morning and analyzed on a JARREL-ASH I CAP-9000 (Inductively Coupled Argon Plasma) Spectrometer.

Nitrogen content was determined by standard micro-kjedahl method (29). N, P, K, Ca, Mg, S were presented on a % dry weight basis, Mn, Fe, Cu, B, Zn, Al, Mo, Na, Se, As, Ba, Cd, Co, Li, Ni, Si, Sr were presented on a ppm basis.

Root distributions were measured by using a 0.9 m * 0.5 m wire screen, which was divided into 18 * 8 small units, each with an area 5 cm * 6.2 cm. The first measurement was taken from a plane 22.5 cm from the trunk. The second measurement was taken from a plane including the trunk, and parallel to the first plane. The third measurement was taken from a plane 22.5 cm from the trunk and 90' from the first two planes. The fourth measurement was taken from a plane including the trunk and parallel and the third plane. For all four measurements, the roots occurring on the plane were counted and each individual position and root number were recorded.

After measurement, the trees were harvested, cleaned and separated into old roots, new roots, rootstock and shoots, put into four bags, then dried in a 70'C oven for ten days. The dry weight was then measured.

For the media analysis, the total mineral composition of bark

and leaf mold was done at the Plant Analysis Laboratory at O.S.U. . The methods employed were the same as used for the leaf analysis. The other chemical analyses were done at the soil testing laboratory at O.S.U including:

1) PH : 1:2 soil to Solution Ratio and Glass Electrode PH Meter (29).
2) Lime requirement: The SMP Buffer method (66).
3) Extractable phosphorus: Dilute acid- fluoride method (Bray) (29, 14) .
4) Extractable Potassium, Sodium, Calcium, and Magnesium: Ammonium Acetate method (47).
5) Total Nitrogen: Micro-Kjeldahl method (16).
6) Cation exchange capacity: Ammonium Acetate method (64).
7) Total soluble salts: Electrical conductivity method (13).

The mycorrhizal fungi analysis was adapted from the method used in the USDA Laboratory at Corvallis, Oregon, which consists of the following six steps:

1) Fix roots for at least 4 hours in FAA, preferably overnight.
2) Clear roots in 10% KOH in 55'-60'C water bath overnight (12-15 hours).
3) Rinse twice in distilled water.
4) Place roots in dilute HCL for 1 hour at room temperature.
5) Place in 0.05 % trypon blue in lactoglycerin and put back into water bath (55-65'C) for ten minutes or more.
6) Pour off stain and destain in clear lactoglycerin.

For the water relation, the moisture retention curves were measured by the soil physics laboratory at O.S.U. . The methods adapted included the Pressure Membrane Extractor (15 bar) and the Pressure Plate Extractors (15 bar) method (46).

Freezing point measurements were taken twice a week while the media were freezing, by digging each of the media surfaces and measuring the depth of freezing level.

Temperature measurements were taken by a three-point soil thermograph on a constant basis, from October, 1983 to May, 1984. The daily high and low temperature were recorded beneath the soil surface, each using a 10 cm gradient as a measurement unit. The pH measurements were done by mixing water and media on a 1:1 volume basis.

The air capacity and water capacity were calculated by the method developed by Christy Lyn Holstead (18). The particle density, bulk density and percent of pore space were also calculated (46).

Results and Discussions:

Media Characteristics

The exchangeable sodium percentage (ESP) of leaf mold and bark were nearly the same, and less than 0.31 % . They also have similar sodium adsorption ration (SAR) values, 0.038 and 0.056. Both values are much less than 15 % for ESP and 15 for SAR, which indicates no problem with sodium, as shown in table 1.

From table 25. the lime requirement to raise bark to pH 5.6 per tree is calculated as follows :

$$\frac{3.9 \text{ Ton} \times 907 \text{ kg/Ton}}{4000 \text{ m} ** 2} \times \frac{20 \text{ inch}}{6 \text{ inch}} \times 0.9\text{m} \times 0.9\text{m} = 2.39 \text{ kg}$$

Bark was lower in all mineral elements than leaf mold with the exception of phosphorus. According to the information provided by the soil testing laboratory at O.S.U., a phosphorus concentration ranging from 15-20 ppm is enough for apple growth. The phosphorus concentration of leaf mold was 24 ppm, which can insure good growth.

From the Oregon State University Extension Service Fertilizer Guide FG 32, for new orchards , when potassium is over 150 ppm, and magnesium is over 0.5 meg/100g, the media contain enough of these elements . Leaf mold has 1182 ppm K, and bark 464ppm K both much higher than needed. Leaf mold had 11.2 meq/100g Mg and bark had 1.7meq/100g Mg both also higher than apple needed.

Since both leaf mold and bark have E.C. values less than 4 mmhos/cm, no salinity problem existed, as shown in table 1. The reason for the low E.C. of leaf mold is leaching of excess salts by water.

Leaf mold and bark had C.E.C. 69.4 and 45.2 meq/100g respectively. Both are higher than sand with 2.0 and clay soil with 57.5 . It is important for any propagation medium to have an adequate cation exchange capacity. If C.E.C. is too low, any nutrients either added or released by decomposition of the materials in the medium could very quickly be washed away during watering. A material with a high C.E.C. like leaf mold and bark could thus be expected to retain more of the released or added nutrients thus resulting in better plants growth.

Another advantage for leaf mold over bark was the higher total nitrogen, 0.78 %, which was 6.5 times that of the bark.
The data in table 3 show that leaf mold had a much higher nutrient content than bark. Although, as seem in tables 4 and 5, percent nutrient availability of leaf mold was lower than bark, leaf mold still maintained much higher nutrient levels available for the plant, with the exception of phosphorus.

The pH measurement in table 6 was conducted in water : medium (1 : 1) on a volume basis. It was very difficult to prepare the same volume of medium (irregular size, different material) as water. So the measurement of pH was mainly affected by difficulty in control of the volume of medium. Because of fertilizer

addition, volume control, different equipment (difference within 0.1), and differents method, pH readings in table 6 are different than in table 2.

For bark, which has smaller particle sizes, there was less problem of volume control, so much more accurate values were obtained than the other three media. Bark showed an increasing pH with increasing fertilizer rate, but from the SMP lime requirement test, on table 2, even the high fertilizer rate did not provide enough dolomitic limestone to raise the pH to 5.6.

The data in table 7 show leaf mold has the highest water available because it has the highest total pore space for holding water. Although automobile waste has intermediate total pore space, most of individual pore space was too large to hold water. This is the main reason that automobile waste showed the least plant growth.

The data in table 9 and 10, leaf mold showed the smallest temperature range. This was probably because it held the most water, was densly layered and darker in color. Bark showed the largest range, probably because of its coarse structure. All showed very little change at 20 cm depth.

Data in table 10 and 11 suggest that leaf mold can give the best protection from cold for the roots. Even at 10 cm depth, leaf mold maintained temperatures above 32 °F, preventing freezing damage to the roots even when atmospheric temperatures were reduced to 20 °F.

Table 2 Extractable chemical properties of leaf mold and bark

Medium	pH	P (ppm)	Extratable Bases K (ppm)	Ca meq/100g	Mg meq/100g	Na meq/100g	Total N %	C.E.C meq/100g	E.C. mmhos/cm	SMP
Leaf	6.6	24	1182	49.0	11.2	0.21	0.78	69.4	0.45	6.5
Bark	5.1	30	464	10.6	1.7	0.41	0.12	45.2	0.15	5.4

* The analyses fof this table were conducted by the Soil Testing Laboratory at O. S. U.

Table 3. Total chemical composition of leaf mold and bark (ppm)

Medium	N	P	K	Ca	Mg	Mn	Fe	Cu	B	Zn	S
Leaf	12400	1760	2420	32800	1930	443	3114	9	34	110	2770
Bark	1700	130	760	4290	190	70	304	3	4	12	390

Medium	Al	Mo	Na	Se	As	Ba	Cd	Co	Li	Ni	Si	Sr	Pb
Leaf	1910	1.1	58	0.1	18	151	1.6	1.7	3.5	4.2	1739	197	55
Bark	458	0.5	19	0.04	5	28	0.6	0.6	2.6	1.5	115	28	15

Table 4. Percent of macronutrient available in leaf mold (ppm)

	N	P	K	Ca	Mg
Total	12400	1760	2420	32800	1930
Available	7800	24	1180	980	224
%	62.9	1.4	48.8	3.0	11.6

Table 5. Percent of macronutrient available in bark (ppm)

	N	P	K	Ca	Mg
Total	1700	130	760	4290	190
Available	1200	30	464	212	34
%	70.6	23.1	61.0	4.9	17.9

Table 6 Effect of media and fertilizer rate on pH

Fertilizer rate	Medium			
	Bark	Leaf mold	Auto-waste	1/2 leaf + 1/2 bark
1X[z]	5.22[y]	5.35	6.26	5.98
2X	5.26	5.76	6.38	5.64
3X	5.36	5.50	6.46	5.63

[z]1X is 0.8 N, 0.24 P, 0.36 K in Kg/m^3 mixed in media
[y]The pH table was conducted by 0 60 pH meter (Beckman).
Reading on each sample were repeated 8 times.

Fig 1. Moisture Retention Curves

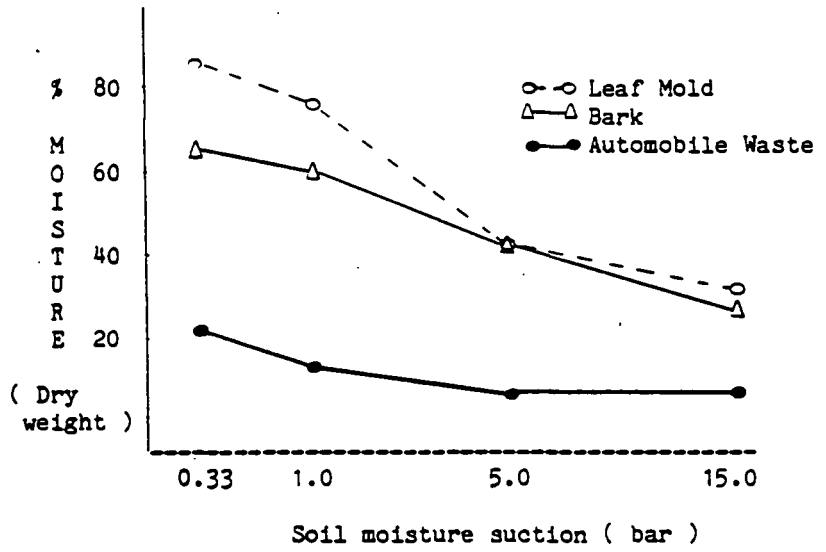


Table 7 Physical properties of media

Medium	Particle density g/cm³	Bulk density g/cm³	Total-pore space * %	Air capacity	Water capacity	Field * capacity %	Available water %
Bark	0.37	0.22	41	43	39	64	29.0
Leaf mold	0.50	0.25	50	47	38	61	47.3
Auto-waste	0.65	0.36	45	47	30	46	12.5

* Total-pore space, Field capacity were calculated by % dry weight.
Air capacity, water capacity were calculated by volume.

Table 8 Temperature records between September 1983 and May 1984
(not included Dec to Jan)

Depth(cm)	Range	Leaf mold	Bark	Auto-waste
10	high	55[z]	56	57
	low	48	42	46
	range	7	14	11
20	high	57	55	57
	low	54	52	54
	range	3	3	3
30	high	55	52	54
	low	52	51	54
	range	2[y]	1	0

[z]High : Daily high; Low :Daily low; Range : Temperature difference between high and low; All measurements were present as a Fahrenheit basis.
[y]Due to medium shrinkage, 30 cm was in the bottom of the container
Each measurement included all 3 media at the same depth

Table 9 Effect of media on temperature record between September 1983 and May 1984 (not included Dec to Jan)

Depth(cm)	Range	Leaf mold	Bark	Auto-waste	1/2 Leaf 1/2 Bark
10	high	51[z]	--	--	58
	low	46	--	--	53
	range	3	14	11	5
20	high	52	53	52	57
	low	51	49	50	56
	range	1	4	2	1
30	high	54	53	54	58
	low	52	52	54	56
	range	2	1	0	2
40	high	--	54	54	--
	low	--	52	52	--
	range	--	2	2	--

[z]High : Daily high; Low :Daily low; Range : Temperature difference between high and low; All measurements were present as a Fahrenheit basis.
Each measurement included all three different depths of the same medium

Table 10 Depth to which the media Froze in December, (cm)

Medium	Bark	Leaf Mold	Auto-waste
Depth	9	4	6

Table 11 Temperature records between December '83 and January '84

Depth(cm)	Range	Leaf mold	Bark
10	high[z]	40[y]	49
	low	34	28
	range	6	21
20	high	38	46
	low	32	30
	range	6	16
30	high	42	--
	low	39	--
	range	3	--
50	high	--	48
	low	--	38
	range	--	10

[z]High : Daily high; Low :Daily low; Range : Temperature difference between high and low;
[y]All measurements were present as a Fahrenheit basis.

Root Distribution

There was no significant difference between trees growing in leaf mold, bark, and 1/2 leaf + 1/2 bark in total shoot growth, final trunk X-section area, total root weight and total plant weight. Growth in auto waste was significantly less than in the other media, as shown in table 12. Total root number was less in bark than in leaf mold. This was because the roots in bark tended to be longer and thinner and have many small branches which were not counted, while the roots in leaf mold had relatively shorter, unbranched succulent roots.

The data in table 13 shows that trees in leaf mold had the highest number of roots in depth between 0 cm and 12.5 cm below the medium surface. Trees in 1/2 leaf + 1/2 bark had significantly lower numbers of roots in depth between 0 cm and 12.5 cm below the medium surface, and trees in bark or auto-waste had still lower numbers of roots in depth between 0 cm and 12.5 cm below the medium surface. The same pattern was seen in depth between 12.5 cm and 25 cm below media surface, but only the numbers for auto-waste were significantly different. Due to media shrinkage, depth between 25 cm and 37.5 cm below medium surface did not exist in leaf mold. Trees in bark had significantly more roots at depth between 25 cm and 37.5 cm below medium surface than trees in auto-waste or 1/2 leaf + 1/2 bark. There were no significant difference in root numbers above ground.

Looking at transverse-sections of the media in table 13, in area 1 (22.5 cm from trunk), auto-waste had no roots and the number of roots in the other treatments did not differ significantly. In area 2 (next to tree trunk), trees in leaf mold had the highest numbers of roots followed by trees in bark and 1/2 leaf + 1/2 bark. Trees in auto-waste had fewer roots than those in any other media. Only trees in leaf mold had significantly higher root numbers in area 3 (root initials next to tree trunk). In area 4 (root initials next to tree trunk perpendicular to area 3), root numbers for trees in leaf mold or 1/2 leaf + 1/2 bark were greater than for trees in auto-waste.

At the depth between 0 cm and 12.5 cm below medium surface, leaf mold not only showed the most stable and highest temperature during winter and spring but also showed the highest available water compared with bark, so at this depth the trees in the leaf mold had more root number than the tree in the bark, as shown in table 13.

Since bark has less available water than leaf mold, the roots in the bark needed a more extensive root system to ensure their water supply. Consequently, trees in the bark showed longer roots and more branches than the roots in the leaf mold. Since leaf mold has the highest available water, the tree in leaf mold has the highest root number, as shown in table 13.

The percentage of roots in depths between 0 cm and 12.5 cm below the medium surface and between 12.5 cm and 25 cm below

media surface did not differ significantly between media, as seen in table 14.

Leaf N and P contents were significantly lower in trees grown in auto-waste than in the other media, as shown in table 15. Leaf K was lower in trees grown in leaf mold than in those grown in bark, and still lower for those grown in auto-waste. Leaf Ca levels were highest for trees grown in leaves and bark, slightly lower for those in bark, and still lower for those grown in auto-waste. There was no significant difference in leaf Mg content of trees grown in any of the media.

Table 12 Effect of the Media on various growth parameters of young apple trees

Medium	Total shoot growth(cm)	Final Trunk X-section(mm^2)	Total Root number	Total Root weight(g)	Total Plant weight(g)
Bark	338 A[z]	314 A	70 B	87 A	366 A
Leaf Mold	388 A	314 A	102 A	89 A	369 A
Auto-waste	83 B	177 B	20 C	15 B	133 B
1/2 Leaf 1/2 Bark	318 A	283 A	68 B	77 A	332 A

[z]Mean separation in columns by LSD, 5% level.
Total root number was 75% of root number initiated from trunk.
Data from root distribution plot.

Table 13 Effect of media on root distribution of young apple trees

Medium	Total Root Number	0 cm to 12.5 cm	12.5 cm to 25.0 cm	25.0 cm to 37.5 cm	Above Ground	Area 1	Area 2	Area 3	Area 4
Bark	115 B[z]	22 C	46 A	47 A	0 A	21 A	49 B	34 AB	16 AB
Leaf mold	163 A	92 A	68 A	0 C	4 A	35 A	79 A	46 A	25 A
Auto-waste	27 C	12 C	8 B	6 BC	0 A	0 B	16 C	16 B	4 B
1/2 Leaf 1/2 Bark	124 B	58 B	47 A	18 B	0 A	32 A	42 B	27 B	23 A

[z]Mean separation in columns by LSD, 5% level.
Total root number was total root number measured in all different areas
Area 1 : Transverse section 22.5 cm from trunk
Area 2 : Transverse section next to tree trunk
Area 3 : Root initials next to tree trunk
Area 4 : Root initials next to tree trunk perpendicular to area 3

Table 14 Effect of media on percent of roots of young apple trees distributed at different depths

Medium	0 cm to 12.5 cm	12.5 cm to 25.0 cm	25.0 cm to 37.5 cm	Above Ground
Bark	26 A[z]	44 A	29 AB	0.3 A
Leaf mold	60 A	35 A	0 C	5.5 A
Auto-waste	34 A	28 A	38 A	0.0 A
1/2 Leaf 1/2 Bark	51 A	42 A	7 BC	0.0 A

[z]The values were caculated by the root number initiated from the trunk.
[z]Mean separation in columns by LSD, 5% level.

Table 15 Effect of media on leaf nutrient levels of young apple trees (% dry weight)

	Leaf Level				
Medium	N	P	K	Ca	Mg
Bark	4.12 A[z]	0.39 A	2.83 A	1.23 BC	0.34 A
Leaf Mold	3.86 A	0.37 A	2.28 B	1.35 AB	0.38 A
Auto-waste	2.27 B	0.15 B	1.29 C	1.12 C	0.37 A
1/2 Leaf 1/2 Bark	4.07 A	0.43 A	2.53 AB	1.44 A	0.37 A

[z]Mean separation in columns by LSD, 5% level.

Effect of Media and Fertilizer Rate

There were no significant interactions between media and fertilizer rates revealed in any of the growth parameters and macronutrient levels in leaf tissue.

There was no significant difference in total shoot number, total shoot growth (Nov. 26), final trunk diameter and total plant weight related to growth media, with the exception of auto waste. Shoot growth measured on August 24 was greater in leaf mold than in bark, as shown in table 16.

Active root growth usually began as the mean medium temperature reached about 45 'F, and the rate of growth increased with rising temperature up to 68 'F. Leaf mold showed a higher medium temperature compared with bark in the winter and spring, so roots in the leaf mold grew early and faster than the roots in the bark, so trees in the leaf mold had a better total shoot growth on August 24, as shown in table 16. But bark had a higher medium temperature on summer and fall, so roots in the bark grew faster than the roots in the leaf mold, so for the total shoot growth on November 26 there were no difference on total shoot growth , as shown in table 16.

There was no significant difference in total shoot growth or final trunk diameter due to the quantities of fertilizer and lime applied, as shown in table 17. Trees in the high fertilizer rate

had a slightly higher total shoot number than those which recieved the middle rate. However, total plant weight was slightly higher for trees which received the lower fertilizer rate, than for those which received the middle or high rates.

There are significant differences in plant dry weight due to the quantities of fertilizer and lime applied, as shown in table 18. Trees in the low fertilizer rate were higher than trees in the middle and high fertilizer rate in dry weight of all plant parts with the exception of root stock weight.

There are significant difference in leaf macronutrient content related to growth media, as shown in table 19. Trees in auto waste were lower than trees in other media in all macronutrients except Mg. Trees in 1/2 leaf + 1/2 bark were higher in P than trees in bark alone. Trees in leaf mold or 1/2 leaf + 1/2 bark were higher in Ca than trees in bark alone or in auto-waste. Trees in leaf mold had higher Mg than trees in bark. Trees in auto-waste had 7X higher B than the other media. This concentration was toxic to the trees in the auto-waste and may have been responsible for their lower total growth.

As shown in table 20, leaf macronutrient content was not significantly affected by quantities of fertilizers and lime applied, with the exception of leaf K. Leaf K was significantly lower in trees which recieved the middle and high rates of fertilizer than it was in those which received the lowest rate of

fertilizer.

Since no standard ranges are established for the nutrient levels of young apple trees, we can only compare the levels to those for mature trees, shown in table 40. Also, the condition of the media was constantly changing, yet we measured it at only one point in time. Ideally, measurements would begin as soon as the leaves fall from the tree or the bark is harvested and continue through the composting and use of the medium. These considerations do limit the usefullness of the information to a slight degree. It is impractical to obtain media of uniform consistency. To do so would be prohibitatively costly. It would be good to conduct an experiment with much larger amounts of medium in order to study the distribution of roots without the constrictions imposed by the containers. Never-the-less, we did find interesting differences in root distribution between bark and leaves.

CONCLUSIONS

Since 350-500 root samples were examined, and no mycorrhizae were found, we concluded that there were no mycorhizae on the experimental trees. Possible explanations for the lack of mycorrhizae are: in leaves, ample supplies of phosphorus and rapid root growth, for bark, low pH, high P, lack of spores in the medium. The automobile waste lacked all forms of life and had a

very objectionable smell. There may have been oil, gas, or other toxic substances present, such as boron or aluminium which were present in elevated levels in leaf samples (7X and 2X respectively).

Root distribution differed between leaf mold and the other two media, bark and auto waste. Root number was higher in leaf mold than in the other media.

The results of chemical analyses of the media showed that leaves contained more of all mineral nutrients than bark except phosphorus. Also, pH, SMP, and C. E. C., were higher for leaves than for bark.

The most important differences between bark and leaves may be in their physical properties. Available water in leaves was much higher than in bark. Leaf mold maintained a lower temperature range than the other media.

Leaf mold must be considered the best medium for young apple trees because the trees grew as much as in bark, yet the cost of the medium was much less. We recieved the leaves without cost, but we must assume that, under commercial conditions, the grower would have to pay at least the transportation costs.

Table 16 Effect of media on plant growth

Medium	Total shoot number	Total shoot growth(cm) Nov. 26	Total shoot growth(cm) Aug. 24	Final trunk X-section (mm^2)	Total plant weight (g)
Bark	6 A[z]	322 A	243 B	314 A	353 A
Leaf mold	6 A	360 A	289 A	314 A	389 A
Auto-waste	6 A	107 B	99 C	177 B	153 B
1/2 Leaf 1/2 Bark	5 A	332 A	267 AB	283 A	350 A

[z]Mean separation in columns by LSD, 5% level.

Table 17 Effect of fertilizer rate on plant growth

Fertilizer rate	Total shoot number	Total shoot growth(cm) Nov. 26	Total shoot growth(cm) Aug. 24	Final trunk X-section (mm^2)	Total plant weight (g)
1 X[z]	6 AB[y]	293 A	228 A	283 A	336 A
2 X	5 B	267 A	214 A	254 A	295 B
3 X	6 A	280 A	230 A	254 A	303 B

[z]1 X is 0.8 N, 0.24 P, 0.36 K in Kg/m^3 mixed in media.
[y]Mean separation in columns by LSD, 5% level.

Table 18 Effect of fertilizer rates on plant dry weight (g)

Fertilizer Rate	New Root Weight	Old Root Weight	Total Root Weight	Root Stock Weight	Shoot Weight	Total Stem Weight
1 X[z]	46 A[y]	36 A	82 A	114 A	141 A	255 A
2 X	39 B	28 B	67 B	107 A	121 B	228 B
3 X	35 B	31 AB	66 B	113 A	123 B	236 AB

[z] 1 X is 0.8 N, 0.24 P, 0.36 K in Kg/m^3 mixed in media.
[y] Mean separation in columns by LSD, 5% level.

Table 19 Effect of medium on levels of nutrients in leaf tissue of young apple trees

Medium	Leaf Level N	P	K	Ca	Mg	B[y]
Bark	3.89 A[z]	0.37 B	2.68 A	1.22 B	0.34 B	35 B
Leaf Mold	3.86 A	0.40 AB	2.36 A	1.46 A	0.40 A	36 B
Auto-waste	2.56 B	0.16 C	1.50 B	1.07 C	0.36 AB	220 A
1/2 Leaf 1/2 Bark	3.97 A	0.42 A	2.46 A	1.41 A	0.36 AB	37 B

[z]Mean separation in columns by LSD, 5% level.
[y]B is reported as ppm dry weight.
N, P, K, Ca, Mg are reported as % dry weight.

Table 20 Effect of fertilizer rate on levels of nutrients in leaf tissue

Fertilizer rate	Leaf Level N	P	K	Ca	Mg	B[y]
1 X	3.58 A[z]	0.34 A	2.43 A	1.32 A	0.35 A	93 A
2 X	3.55 A	0.34 A	2.20 B	1.28 A	0.36 A	83 AB
3 X	3.56 A	0.34 A	2.11 B	1.28 A	0.38 A	70 B

1 X is 0.8 N, 0.24 P, 0.36 K in Kg/m^3 mixed in media.
[z]Mean separation in columns by LSD, 5% level.
[y]B is reported as ppm dry weight.
N, P, K, Ca, Mg are reported as % dry weight.

Experiment II:

Materials and Methods

This experiment also used apple, Malus domestica Borkh c.v Newtown Pipin on Malling Merton 106 (MM 106) rootstock. Sixty two-year-old trees, containing six replications of ten of the twelve treatments of last year were used.

On February 25, 1983, all sixty trees were transplanted from the plastic-lined container into the field. The experiment was arranged in a split-plot design. Former treatments were the block, fertility level was the main-plot, and bare root or medium transplant was the sub-plot. Fertilizer rates were established as follows:

Nutrient level # 1 : 0

Nutrient level # 2 : 278 N Kg/ha as urea

Nutrient level # 3 : 557 N Kg/ha as urea

The urea was applied on June 10, 1983, and was banded 30 cm from the trunk.

Flower number, trunk X-section and shoot growth were measured. Flower number was measured twice before thinning. The flower count represented 100% of the flowers present on each tree. Two trunk diameter measurement were taken at 5 cm above the graft union. Initial values were taken on March, 1983 and final values January 5, 1984. Total shoot growth was measured on January 8,

1984. Leaf samples were taken on August 5, 1983, in experiment I.

Results and Discussion

There were no significant interactions between fertilizer rates and transplant methods for any of the growth parameters measured. As seen in table 21, Only total flower number showed a significant difference between the middle and high fertilizer rates.

Trees transplanted with medium grew more than those transplanted bare root, as indicated by total shoot number, total shoot growth, and final trunk X-section in table 22. Transplant method did not affect total flower numbers.

With the exception of lower leaf N at the lowest fertilizer rate, the rate of fertilizer application after transplanting did not affect leaf mineral contents, as shown in table 23.

Transplanting method did not affect leaf N, P, K, or Mg, as shown in table 24. Leaf Ca was higher and B lower in the trees transplanted with medium.

Because, during the period of transplanting, it rained continuously, the all the structure of the soil which was replaced into the holes in which the trees were planted, was destroyed. Since the trees had been grown in the medium for only one year, they had not developed a root system large enough to hold on to it when they were moved. Thus, in actuality, even the trees moved

"with medium" had very little bark still attached to the roots at planting. We placed about 10 liters of bark into the holes before and after setting the trees. Results might not have favored the trees "with medium" as much had the transplanting been done under more favorable conditions. These results indicate that additions of bark or other suitable organic material to the planting hole might increase first year growth of trees planted under rainy conditions whether container-grown or field grown.

Conclusions

Trees transplanted with the medium attached grew significantly more in the first year than did trees transplanted bare-root. The differences in growth rate could not be explained by differences in mineral analyses of the trees.

Table 21 Effect of fertilizer rate on plant growth

N Level (Kg/ha)	Total shoot number	Total shoot growth(cm)	Total flower number	Final trunk X-section(mm^2)
0	17 A[z]	350 A	31 AB	452 A
278	16 A	342 A	16 B	452 A
557	14 A	337 A	41 A	452 A

[z]Mean separation in columns by LSD, 5% level.

Table 22 Effect of transplant methods on plant growth

Transplant Method	Total shoot number	Total shoot growth(cm)	Total flower number	Final trunk X-section(mm^2)
Bare Root	13 B[z]	268 B	32 A	415 B
With Medium	18 A	418 A	27 A	491 A

[z]Mean separation in columns by LSD, 5% level.

Table 23 Effect of fertilizer rates on level of nutrients in leaf tissue

N Level (Kg/ha)	Leaf Level					
	N %	P %	K %	Ca %	Mg %	B %
0	2.50 B[z]	0.33 A	1.74 A	0.97 A	0.35 A	31 A
278	2.70 A	0.30 A	1.72 A	0.96 A	0.36 A	31 A
557	2.74 A	0.31 A	1.98 A	0.89 A	0.34 A	30 A

[z]Mean separation in columns by LSD, 5% level.

Table 24 Effect of transplant methods on level of nutrients in leaf tissue

Transplant Method	Leaf Level					
	N %	P %	K %	Ca %	Mg %	B ppm
Bare Root	2.65 A[z]	0.30 A	1.85 A	0.85 B	0.34 A	32 A
With Medium	2.63 A	0.32 A	1.78 A	1.03 A	0.36 A	29 B

[z]Mean separation in columns by LSD, 5% level.

LITERATURE CITED

1. Aaron, J. R. 1976 Conifer bark : Its properties and uses, Forestry Commission Record 110.

2. Adams, F. and Lund, Z. F. 1966 "Effect of chemical activity of soil solution aluminium on cotton root penetration of acid subsoils" Soil Sci. 101, 193-198.

3. Araki, K. 1981 Bulletin of the Vegetable and Ornamental Crop Research Station, No.8, 209-218, Ano, Mie, Japan.

4. Arnon, D.I. 1959 "Phosphorus and the biochemistry of photosynthesis" Agrochimica 3, 108-139.

5. Atkinson, D. ; Naylor, D. and Coldrick, G. A. ; 1976 "The effect of tree spacing on the apple root system " East Malling Research Station, Maidstone, UK. Horticultural research 16, 2, p89-105.

6. Barley, K.P. 1953 " The root growth of irrigated perennial pastures and its effect on soil structure " Aust. J. Agric. Res., 4,283

7. Batjer, L.P., Magness, J.R. and Regeimbal, L.O., 1939. " The effect of root temperature on growth and nitrogen intake of apple tree " Proc. Am. Soc. Hort. Sci. 37: 11-18.

8. Bernstein, L. and Hayward, H.E., 1958 Physiology of salt tolerance. Ann. Rev. Plant Physiol. 9,p25-46.

9. Bernstein, L. 1963 Osmotic adjustment of plant to saline media II Dynamic phase. Amer. J. Bot. 50 (4), 360-370.

10. Black C.A. 1965 Methods of soil Analysis, Part 1 p131-137

11. Bloodworth, M.E. "Effect of soil temperature on water use by plants " 1960 Trans. 7th Int. Congr. Soil Sci. 1, 153

12. Bollen, W.B. 1969. Properties of tree bark in relation to their agricultural utilization. U.S.D.A. Forest Service Research Paper PNW-128.

13. Bower, C.A. and L.V. Wilcox. 1965. Soluble salts. chap. 62 of Methods of analysis, part 2, (Agron. Monogr. 9),

Amer. Soc. Agron., Madison, Wisconsin, pp. 933-951.

14. Bray, R.H. and L.T. Kurtz. 1945. Determinination of total, organic and available forms of phosphorus in soils. Soil Sci. 59:39-45.

15. Breisch, I ; Guckert, A. and Reisinger, O ; 1975 " (F) Electromicroscopic studies on the apical zone of maize root " Soc. bot. Tr. Coll. Rhizosphere 122, 55-60.

16. Bremner, J.M. 1965. Total Nitrogen, Chap. 83 of Methods of Soil Analysis, part2, (Agron. Monogr. 9), Amer. Soc. Agron., Madison, Wisconsin, pp. 1149-1176.

17. Byron T. Shaw 1952 "soil physical conditions and plant growth" p380-398. Academic Press Inc.

18. Christy Lyn Holstead, 1983, pot plant. Grower Talks 47 (4), August 1983.

19. Cripps, J. 1971. The influence of soil moisture on apple root growth and root : shoot ratios. J. Amer. Hort. Sci. 46:121-130.

20. Ellis, F.B., Elliott, J.G., Barnes, B.T. and House, K.R. 1977. Comparison of direct drilling, reduced cultivation and ploughing on the growth of cereals. II spring barley on a sandy loam soil: Soil physical conditions and root growth. J. Agric. Sci.

21. Erickson, A.E. and Van Doren, D.N. : " The Relation of Plant Growth and Yield to Soil Oxygen. Availability, p.428-434. Trans. 7th Int. Congr. Soil Sci. Madison, Wisc., USA Vol III, 1960.

22. Garwood, E.A. and Williams, T.E. (1967). "Growth, water use and nutrient uptake from the subsoil by grass swards" J. agric. Sci. 69, 125-130.

23. Gerdemann, J.W.: " The plant root and its environment." 1974 Mycorrhizae p205-217. University Press of Virginia, Charlottesville.

24. Giustiniani, L.; Tesi, R. 1982 Notiziario di Ortolorofrutticoltura, 8,3, 100-1-3. Universita' di Pisa, Italy.

25. Gross M.J.: A.R.C. Letcombe Lab., Ann. Rept. 1969, 43; 1970,6

26. Hale, M.G. and Moore, L.D. 1979 " Factor affect root exudation " II: 1970-1978. Adv.Agron. 31, 93-124 (1974).

27. Hinrich L. Bohn, Brian L. McNeal, George A. O'connor 1979. Soil Chemistry p225.

28. Ito, M.; Ichimachi, T.; Hasebe, S.Ueki,K. 1981. "Some observations on the root development and distribution in apple trees as affected by the different weed cover " Weed research, Japan 26 (1) p 24-39 Kyoto University, Japan.

29. Jackson, M. L. 1958, Soil Chemical Analysis. Englewood Cliffs, N.J. Prentice - Hall, pp. 151-154.

30. Johnson, p. 1968. Horticultural and Agricultural uses of sawdust and soil Amendments. Technical Bulletin.

31. Kandler, O. 1958 " On the question of aerobic fermentation in root meristems." Planta 51, 544-546.

32. Klepper, B. Taylor, H.M., Huck, M.G. and Fiscus, E.L. 1973. Water relations and growth of cotton in drying soil. Agron. J 65, 307-310.

33. Kramer, P.J. 1969 Plant and Soil water relationships: A Modern Synthesis, MxGraw- Hill, New York.

34. Lagerwerff, J.V. and Eagle, H.E. : 1961, Osmotic and specific effects of excess salts on beans. Plant Physiol. 36, 472-477.

35. Lawlor, D.W. 1973. " Growth and Water absorption of wheat with parts of the roots at different water potentials New Phytol., 72, 297-305.

36. Lunt, O.R., and B. Clark. 1959. Horticultural application for bark and wood fragments. For. prod. J. 9:39A-42A.

37. Marschner, H. 1972 "Effect of O2 supply to roots on mineral uptake and plant growth." In: Pseudogley 8 Gley, Trans. Comm. V and VI of the Int. Soc. Soil Sci., 541 -555 (1972).

38. Mason, D.T. 1964. A survey of numbers of Endogone spores in soil cropped with barley, raspberry and strawberry. Hort. Res. 4:98:103.

39. Meiri, A. and Shalhevet, J. 1973. Crop growth under saline conditions. Ecological studies Vol. 5 p277-290.

40. Mengel K. and Kirkby A. " Principles of Plant Nutrition" 1982.c Mycorrhizae p86-89.

41. Mizrahi, Y., Blumenfeld, A. and Richmond, A.E. 1970. Abscisic acid and transpiration in leaves in relation to osmotic root stress. Plant Physiol. 46, p169-171.

42. Monnier,G; Cabibel, B.; Guennelon, R.; Habib, R. 1982 " problems posed by the water absorption and mineral nutrition of fruit trees under localized irrigation " Fruits 37 (3) p 189-193. Station de Sciences du sol, 84140 Montfavet, France.

43. Murphy, R. P. 1959 " Some factors influencing cation uptake by excised roots of perennial ryegrass. Plant and soil 10, 242-249.

44. Newbould, P (1969) " The absorption of Nutrients by Plants from Different zones in the soil" In Ecological Aspects of the Mineral Nutrition of Plants, ed. Rorison, I. H., Blackwell, Oxford, 177-190.

45. Nightingale, G.T. 1935 "Effects of Temperature on Growth, anatomy, and Metabolism of apple and peach roots." Botan. Gaz. 96:581-639.

46. Nyle C. Brady, 1974. The Nature and Properties of Soil p50-55.

47. Peech, M.L., T. Alexander, L.A. Dean, and J.F. Reed. 1947. Methods of soil analysis for soil fertility investigations. USDA Circ. 757, p25.

48. Pirone, P. P. 1978. Tree maintenance. Oxford University Press, London.

49. Polikarpov,V.P.; Adaskalitsii, M.M. 1977 "Root systems of bearing plamette apple trees " Vestnik sel Skokhozyaistrennnoi Naki, No.6. p.112-114.

50. Ponnamperuma, F. N. "The chemistry of submerged soils Adv. Agron. 24, 29-96 (1972).

51. Roger, W. S. 1935. "Some observations on roots of fruit trees". E. Malling Res. Ata. An. Rep. 4; 210-212.

52. Rogers, W.S. 1939 Root studies VIII Apple root growth in relation to root-stock, soil, seasonal and climatic factors. J. Pomol. Hort. Sci. :17:99-130.

53. Roger, W.S. and G.A. Booth. 1958. " The roots of fruit trees ". Sci. Hort. 14: 27-33

54. Rogers, W.S. and G.C. Head. 1968. "Factors affecting the distribution and growth of roots of perennial woody species, P. 280-295. In W.J. Whittington (ed). Root growth: Proceedings of the fifteenth Easter school in agriculture science, University of Nottingham . Plenum Press, New York.

55. Rorison. I.H. The effects of soil acidity on nutrient availability and plant respone. Plenum Press 1980. p283-304.

56. Rovira, A.D. ; 1961, Aust.J. agric. Res. 12, 77.

57. Russell, E.W. 1973 soil conditions and plant growth p530-532.

58. Russell, E.W. 1973 "soil conditions and plant growth" p401-402.

59. Russell Scott 1977 " Plant root systems " Mechanical impedance of growth. p170-190.

60. Russell Scott 1977 Plant root system p16-17.

61. Sanders F.E., B. Mosse, P. B. Tinker 1975 "The occurrence of mycorrhiza in crops as affected by soil fertility " In Endomycorrhizas London: Academic Press, pp. 495-509.

62. Sauerbeck, D. and Johnen, B. 1976 " (G) The turnover of plants during the growth period and its influence on soil respiration " Z.Pflanzenern. Bodenk, Heft 3, 315-328.

63. Sawhney B. L. 1976 Leaf compost for container-grown plants Hort. Science II (1) : 34-35.

64. Schollenberger, C. J. and R. H. Simon. 1945. Determination of exchange capacity and exchangeable bases in soils - ammonium acetate method. Soil Sci. 59:13-24.

65. Shanks, J. B. 1974 Maryland Florist No. 192, 7pp; maryland University, College Park, U.S.A.

66. Shoemaker, H.E., E.O. Mclean, and P. F. Pratt. 1961, Buffer methods for determining lime requirement of soil with appreciable amounts of extractable aluminum. Soil Sci. Soc. of Amer. Proc. 25: 274-277.

67. Skipper, H.D., and G.W. Smith. 1979, "Influence of soil pH on the soybean endomycorrhiza symbiosis." Plant and Soil 53:559-563.

68. Stoichkov, 1. 2nd Penkov, M. 1974. "The influence of Pseudopodzolic cinnamon forest and alluvial meadow soils on the root distribution of Newton Pippin and Wellington apple cultivars grafted on M.4. " Gradinarska i Lozarska Nauka 11, 5, P. 11-25.

69. Terminology Committee, Glossary of Soil Science Terms. Soil Science Society of America, Madison, Wisconsin 1973.

70. Torasaburo, S. 1938. "Apple root systems under different cultural systems". Proc. Amer. Soc. Hort. Sci. 36: 150 -152.

71. Trolldenier, G. 1971. Soil Biology, the Soil Organisms in the Economy of nature p116, Franckh'sche Verlagshandlung, Stuttgart.

72. U. S. Salinity Laboratory 1954.

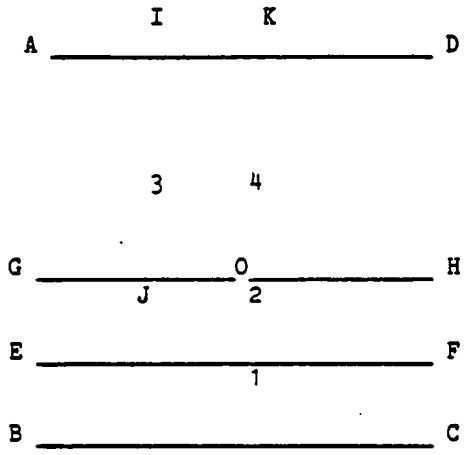
73. Yosef Ibrahim Geddeda 1982 "Apple Mycorrhizae and Their Effects on Growth and Nutrient Concentration In Apple Seedlings Grown in Two Soils with Varied Levels of P." PHD Thesis, Oregon State University.

APPENDIXES

Table 25 SMP Lime Requirement

SMP Buffer	Tons per Acre of 100 Score Lime Needed to Raise pH of surface 6 Inches of Soil to the following pH's			
	5.3	5.6	6.0	6.4
6.7	-	-	-	-
6.6	-	-	-	1.1
6.5	-	-	1.0	1.7
6.4	-	-	1.1	2.2
6.3	-	-	1.5	2.7
6.2	-	1.0	2.0	3.2
6.1	-	1.4	2.4	3.7
6.0	1.0	1.7	2.9	4.2
5.9	1.4	2.1	3.3	4.7
5.8	1.7	2.5	3.7	5.3
5.7	2.0	2.8	4.2	5.8
5.6	2.3	3.2	4.6	6.3
5.5	2.6	3.6	5.1	6.8
5.4	2.9	3.9	5.5	7.3
5.3	3.2	4.3	6.0	7.8
5.2	3.6	4.7	6.4	8.3
5.1	3.9	5.0	6.9	8.9
5.0	4.2	5.4	7.3	9.4
4.9	4.5	5.8	7.7	9.9
4.8	4.8	6.2	8.2	10.4

Fig. 2 Transverse section through the root media for root distribution

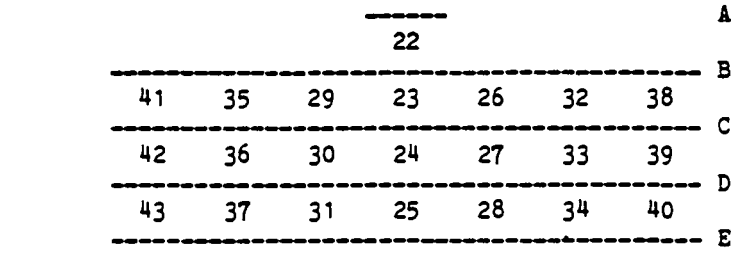


0 : Trunk position
1 : First cut measurement (DATA No. 1 to No. 21)
2 : Second cut measurement (DATA No. 22 to No. 43)
3 : Third cut measurement (DATA No. 44 to No. 55)
4 : Forth cut measurement (DATA No. 56 to No. 67)
AB = BC = CD = DA = 90 cm
AG = BG = DH = CH = AK = GO = 45 cm
BE = GE = CF = HF = AI = GJ = 22.5 cm

Fig 3 Map for first cut

19	13	7	1	4	10	16
20	14	8	2	5	11	17
21	15	9	3	6	12	18

Fig. 4 Map for Second cut



B : ground level
AB = BC = CD = DE = 12.5 cm
BC : depth1
CD : depth2
DE : depth3
AB : depth4

Fig. 5 Map for third cut

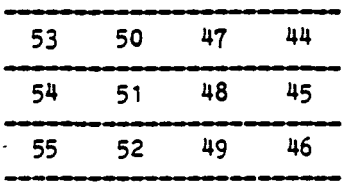


Fig. 6 Map for fourth cut

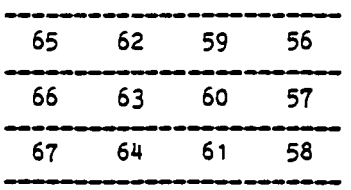


Table 26 Details of root distribution[y]

Medium	1	2	3	4	5	6	7
Bark	0.2 B[z]	3.8 A	0.8 A	0.0 B	0.6 AB	1.6 A	0.0 B
Leaf Mold	7.4 A	3.6 A	0.0 A	4.2 A	1.2 A	0.0 B	4.0 A
Auto-waste	0.0 B	0.0 A	0.0 A	0.0 B	0.0 B	0.0 B	0.0 B
H-leaf & bark	5.6 A	1.8 A	0.6 A	3.6 A	1.0 AB	0.8 AB	4.2 A

Medium	8	9	10	11	12	13	14
Bark	0.8 B	2.4 A	0.0 B	0.6 AB	2.4 A	0.0 B	0.4 A
Leaf Mold	1.4 AB	0.0 B	0.4 B	1.4 A	0.0 B	2.0 A	2.2 A
Auto-Waste	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B	0.0 A
H-leaf & bark	2.4 A	0.8 AB	1.6 A	0.6 AB	1.2 AB	2.0 A	1.4 A

Medium	15	16	17	18	19	20	21
Bark	3.4 A	0.0 A	0.8 AB	1.4 A	0.0 A	0.2 A	2.0 A
Leaf Mold	0.0 B	0.2 A	3.6 A	0.0 B	0.4 A	2.8 A	0.0 A
Auto-waste	0.0 B	0.0 A	0.0 B	0.0 B	0.0 A	0.0 A	0.0 A
H-leaf & bark	0.4 B	0.0 A	0.6 B	1.8 A	0.2 A	1.0 A	0.8 A

Medium	22	23	24	25	26	27	28
Bark	0.2 A	12.0 B	16.0 A	6.0 A	1.0 B	3.6 AB	2.2 A
Leaf Mold	3.6 A	32.2 A	10.4 AB	0.0 B	7.0 A	6.0 A	0.0 B
Auto-waste	0.0 A	6.8 B	4.2 B	4.6 AB	0.0 B	0.4 B	0.0 B
H-leaf & bark	0.0 A	18.0 AB	7.0 AB	1.6 AB	2.4 B	2.6 AB	0.6 AB

Medium	29	30	31	32	33	34	35
Bark	0.8 B	1.0 A	1.2 A	0.0 B	0.6 AB	1.2 A	0.0 B
Leaf Mold	6.2 A	4.2 A	0.0 B	1.4 A	1.0 A	0.0 B	1.4 A
Auto-waste	0.0 B	0.0 A	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B
H-leaf & bark	1.2 B	2.6 A	0.2 B	0.2 AB	0.2 AB	0.6 AB	1.0 AB

Medium	36	37	38	39	40	41	42
Bark	0.0 B	0.6 A	0.0 A	0.8 B	1.0 A	0.0 B	0.0 A
Leaf Mold	1.6 A	0.0 A	0.8 A	2.4 A	0.0 A	0.0 B	0.6 A
Auto-waste	0.0 B	0.0 A	0.0 A	0.0 B	0.0 A	0.0 B	0.0 A
H-leaf & bark	0.8 AB	0.2 A	0.2 A	0.8 B	0.8 A	0.4 A	0.2 A

Medium	43	44	45	46	47	48	49
Bark	1.0 A	0.6 A	1.2 A	1.4 A	0.0 B	1.0 B	3.2 A
Leaf Mold	0.0 A	1.6 A	3.2 A	0.0 B	2.0 A	3.2 A	0.0 B
Auto-waste	0.0 A	0.0 A	0.4 A	0.0 B	0.0 B	0.0 B	0.0 B
H-leaf & bark	0.6 A	2.8 A	4.0 A	0.8 AB	0.8 AB	1.4 AB	0.2 B

Medium	50	51	52	53	54	55	56
Bark	0.8 A	0.0 A	1.2 A	0.0 A	0.4 B	1.8 A	4.2 B
Leaf Mold	0.6 A	0.6 A	0.0 B	0.2 A	2.2 A	0.0 B	17.4 A
Auto-waste	0.0 A	0.0 A	0.0 B	0.0 A	0.0 B	0.0 B	1.0 B
H-leaf & bark	0.2 A	0.6 A	0.4 AB	0.4 A	0.4 B	0.6 AB	10.6 B

Medium	57	58	59	60	61	62	63
Bark	7.8 A	4.4 A	1.0 A	2.4 AB	6.0 A	0.8 A	0.6 A
Leaf Mold	7.8 A	0.0 B	2.2 A	5.2 A	0.0 B	0.0 A	0.6 A
Auto-waste	1.4 A	1.4 AB	0.0 A	0.0 B	0.0 B	0.0 A	0.0 A
H-leaf & bark	11.8 A	1.0 AB	2.4 A	4.4 A	1.6 B	1.0 A	1.0 A

Medium	64	65	66	67
Bark	0.8 A	0.0 B	0.4 B	1.2 A
Leaf Mold	0.0 A	0.4 A	2.6 A	0.0 A
Auto-waste	0.0 A	0.0 B	0.0 B	0.0 A
H-leaf & bark	1.2 A	0.0 B	0.8 B	1.4 A

[z]Mean separation in columns by LSD, 5% level.
[y]Mean number of roots observed per 188 cm^2.

Table 27 Effect of media on dry weight of young apple trees (g)

Medium	New Root Weight	Old Root Weight	Total Root Weight	Root Stock Weight	Shoot Weight	Total Stem Weight	Total Plant Weight
Bark	50 A[z]	38 A	87 A	123 A	156 A	279 A	366 A
Leaf Mold	57 A	32 A	89 A	120 A	160 A	280 A	369 A
Auto-waste	3 B	12 B	15 B	73 B	45 B	118 B	133 B
1/2 Leaf 1/2 Bark	43 A	35 A	77 A	116 A	139 A	254 A	332 A

[z]Mean separation in columns by LSD, 5% level.

Table 28 Effect of media and fertilizer rate on the growth of young apple trees

Medium	Fertilizer Rate	Total shoot number	Total shoot Growth(cm) Nov. 26	Total shoot Growth(cm) Aug. 24	Final trunk X-section (mm^2)	Totalplant weight (g)
Bark	1 X[z]	6	298	220	314	342
	2 X	5	328	243	314	366
	3 X	6	340	264	314	352
Leaf mold	1 X	5	371	290	346	431
	2 X	6	364	289	314	364
	3 X	6	345	289	314	372
Auto-waste	1 X	6	112	109	201	167
	2 X	5	83	81	177	133
	3 X	6	125	108	201	160
1/2 Leaf & 1/2 Bark	1 X	6	390	296	314	406
	2 X	5	296	244	283	317
	3 X	5	312	260	254	327

[z]1 X is 0.8 N, 0.24 P, 0.36 K in Kg/m^3 mixed in media.

Table 29 Effect of media and fertilizer rates on macro-nutrient levels in leaf tissue (% dry weight)

Medium	Fertilizer Rate	N	P	K	Ca	Mg
Bark	1 X[z]	3.79	0.34	2.82	1.23	0.30
	2 X	4.06	0.39	2.82	1.22	0.34
	3 X	3.80	0.38	2.40	1.21	0.37
Leaf mold	1 X	3.91	0.42	2.49	1.59	0.41
	2 X	3.81	0.38	2.33	1.36	0.37
	3 X	3.88	0.40	2.25	1.41	0.43
Auto-waste	1 X	2.63	0.16	1.86	0.98	0.34
	2 X	2.27	0.15	1.29	1.12	0.37
	3 X	2.77	0.18	1.34	1.11	0.36
1/2 Leaf + 1/2 Bark	1 X	4.05	0.42	2.56	1.47	0.37
	2 X	4.06	0.43	2.35	1.30	0.35
	3 X	3.81	0.41	2.46	1.38	0.36

[z]1 X is 0.8 N, 0.24 P, 0.36 K in Kg/m^3 mixed in media.

Table 30 Effect of media and fertilizer rate on dry weight of young apple trees (g)

Medium	Fertilizer Rate	New Root Weight	Old Root Weight	Total Root Weight	Root Stock Weight	Shoot Weight	Total Stem Weight
Bark	1 X[z]	60	32	93	112	138	249
	2 X	53	37	90	122	154	276
	3 X	46	34	82	127	145	272
Leaf mold	1 X	64	42	106	132	192	324
	2 X	59	30	89	119	156	275
	3 X	44	41	85	130	157	287
Auto-waste	1 X	10	20	29	82	56	138
	2 X	3	12	15	73	45	118
	3 X	10	20	30	80	50	130
1/2 Leaf + 1/2 Bark	1 X	49	48	96	132	117	309
	2 X	40	33	74	115	128	243
	3 X	40	30	70	116	140	256

[z]1 X is 0.8 N, 0.24 P, 0.36 K in Kg/m^3 mixed in media.

Table 31 Effect of media on plant dry weight

Medium	New Root Weight	Old Root Weight	Total Root Weight	Root Stock Weight	Shoot Weight	Total Stem Weight
Bark	53 A[z]	35 A	88 AB	120 A	146 A	266 A
Leaf Mold	56 A	38 A	94 A	127 A	169 A	296 A
Auto-waste	8 C	17 B	25 C	78 B	51 B	129 B
1/2 Leaf 1/2 Bark	43 B	37 A	80 B	121 A	149 A	270 A

[z]Mean separation in columns by LSD, 5% level.

Table 32 Effect of media and fertilizer rates on micro-nutrient levels in leaf tissue

Medium	Fertilizer Rate	Mn	Fe	Cu	B	Zn	S	Al	Mo	Na
Bark	1 X	209	135	3.64	38.2	20.4	0.160	59.2	0.183	94.7
	2 X	241	129	2.82	33.6	29.8	0.188	49.2	0.180	89.7
	3 X	203	132	3.24	34.0	26.2	0.202	48.3	0.172	94.8
Leaf Mold	1 X	193	134	6.83	35.3	45.1	0.215	49.8	0.365	84.8
	2 X	144	138	5.54	35.8	32.8	0.213	53.3	0.267	96.8
	3 X	145	148	5.42	37.1	34.6	0.202	64.3	0.230	106.0
Auto-waste	1 X	83	164	8.01	259.0	19.8	0.147	102.3	0.267	140.3
	2 X	89	189	9.35	226.8	25.3	0.163	122.2	0.233	187.7
	3 X	86	158	8.07	173.6	19.1	0.163	91.2	0.248	140.3
1/2 Leaf	1 X	199	141	7.90	39.4	45.9	0.205	52.8	0.295	112.3
+	2 X	158	145	6.01	37.0	36.4	0.210	61.2	0.235	94.0
1/2 Bark	3 X	176	144	4.68	34.2	33.6	0.225	57.5	0.187	99.3

Medium	Fertilizer Rate	Si	Sr	Se	As	Ba	Cd	Co	Li	Ni
Bark	Low	349.7	57.8	0.049	2.85	39.7	0.080	0.190	20.7	0.777
	Middle	292.5	50.2	0.051	2.85	31.1	0.081	0.167	19.0	0.702
	High	264.0	39.7	0.052	2.64	27.4	0.078	0.175	22.5	0.715
Leaf mold	1 X	270.5	80.7	0.059	3.14	65.7	0.086	0.182	14.5	0.697
	2 X	254.8	65.3	0.052	2.96	45.0	0.076	0.168	17.2	0.672
	3 X	300.7	66.8	0.053	3.18	47.7	0.081	0.163	15.8	0.677
Auto-	1 X	335.3	47.7	0.045	3.05	22.5	0.083	0.162	101.0	1.582
waste	2 X	432.2	59.3	0.047	3.33	32.1	0.060	0.148	74.7	2.253
	3 X	328.8	51.8	0.048	2.98	29.0	0.082	0.158	108.0	1.637
1/2 Leaf	1 X	318.7	73.8	0.055	2.96	66.8	0.079	0.175	12.3	0.755
+	2 X	294.3	68.7	0.053	2.93	51.7	0.084	0.168	17.2	0.727
1/2 Bark	3 X	278.2	59.3	0.052	2.92	44.8	0.074	0.167	12.8	0.742

[z] 1 X is 0.8 N, 0.24 P, 0.36 K in Kg/m^3 mixed in media.

Table 33 Effect of media on micro-nutrient level in leaf tissue of young apple trees

Medium	Leaf Level Mn	Fe	Cu	B	Zn	S
Bark	218 A[z]	132 B	3.23 C	35 B	26 B	0.18 AB
Leaf Mold	160 B	140 B	5.93 B	36 B	38 A	0.21 A
Auto-waste	86 C	170 A	8.48 A	220 A	21 B	0.16 B
1/2 Leaf 1/2 Bark	178 B	143 B	6.19 B	37 B	39 A	0.21 A

Medium	Leaf Level Al	Mo	Na	Se	As	Ba
Bark	52 B	0.18 C	93 B	0.051 AB	2.78 B	32.7 B
Leaf Mold	56 B	0.29 A	96 B	0.055 A	3.09 A	52.8 A
Auto-waste	105 A	0.25 B	156 A	0.047 B	3.12 A	27.9 B
1/2 Leaf 1/2 Bark	57 B	0.24 B	102 B	0.053 A	2.94 AB	54.4 A

Medium	Leaf Level Cd	Co	Li	Ni	Si	Sr
Bark	0.080 A	0.18 A	20.7 B	0.73 B	302 AB	49.2 B
Leaf Mold	0.081 A	0.17 A	15.8 B	0.68 B	275 B	70.9 A
Auto-waste	0.075 A	0.16 A	94.6 A	1.86 A	365 A	52.9 B
1/2 Leaf 1/2 Bark	0.079 A	0.17 A	14.1 B	0.74 B	297 AB	67.3 A

[z]Mean separation in columns by LSD, 5% level.
S is reported as % dry weight. Micronutrients are reported as ppm dry weight.

Table 34 Effect of fertilizer rate on micro-nutrient level in leaf tissue of young apple trees

Fertilizer	Leaf Level					
Rate	Mn	Fe	Cu	B	Zn	S
1 X[z]	171 A[y]	143 A	6.59 A	93 A	33 A	0.18 B
2 X	158 A	150 A	5.93 AB	83 AB	31 A	0.19 AB
3 X	152 A	145 A	5.35 B	70 B	28 A	0.20 A

Fertilizer	Leaf Level					
Rate	Al	Mo	Na	Se	As	Ba
1 X	66 A	0.28 A	108 A	0.052 A	3.00 A	48.7 A
2 X	71 A	0.23 B	117 A	0.051 A	3.02 A	40.0 B
3 X	65 A	0.21 B	110 A	0.051 A	2.93 A	37.2 B

Fertilizer	Leaf Level					
Rate	Cd	Co	Li	Ni	Si	Sr
1 X	0.082 A	0.18 A	37.1 A	0.95 A	318 A	65.0 A
2 X	0.075 A	0.16 A	32.0 A	1.09 A	318 A	60.9 A
3 X	0.079 A	0.17 A	39.8 A	0.94 A	293 A	54.4 B

[z]1 X is 0.8 N, 0.24 P, 0.36 K in Kg/m^3 mixed in media.
[y]Mean separation in columns by LSD, 5% level.
S is reported as % dry weight.
All micro-nutrients are reported as ppm dry weight.

Table 35 Effect of transplant methods and N level on the growth of young apple trees

N Level (Kg/ha)	Transplant Method	Total shoot number	Total shoot growth(cm)	Total flower number	Final trunk X-section(mm^2)
0	Bare Root	16	317	47	452
	With Medium	18	383	15	491
278	Bare Root	14	261	16	415
	With Medium	19	424	16	491
557	Bare Root	10	226	33	415
	With Medium	18	448	49	491

Table 36 Effect of Transplant methods and N level on macro-nutrient levels in leaf tissues of young apple trees

N Level (Kg/ha)	Transplant Method	Leaf Level					
		N %	P %	K %	Ca %	Mg %	B ppm
0	Bare Root	2.47	0.31	1.86	0.89	0.35	33
	With Medium	2.53	0.35	1.63	1.06	0.34	29
278	Bare Root	2.82	0.29	1.84	0.85	0.35	31
	With Medium	2.57	0.31	1.60	1.08	0.37	30
557	Bare Root	2.67	0.30	1.85	0.82	0.33	31
	With Medium	2.80	0.31	2.10	0.96	0.36	29

Table 37 Effect of transplant methods and N level on micro-nutrient levels in leaf tissue of young apple trees

N Level (Kg/ha)	Transplant Method	Leaf Level Mn	Fe	Cu	B	Zn	S
0	Bare Root	110	151	6	33	16	0.158
	With Medium	119	160	6	29	15	0.160
278	Bare Root	127	170	6	31	18	0.160
	With Medium	118	155	6	30	14	0.153
557	Bare Root	121	168	7	31	17	0.160
	With Medium	114	151	6	29	16	0.165

N Level (Kg/ha)	Transplant Method	Leaf Level Al	Mo	Na	Se	As	Ba
0	Bare Root	103.4	0.166	127.9	0.047	2.92	14.74
	With Medium	115.9	0.190	146.3	0.050	3.06	18.83
278	Bare Root	119.8	0.166	125.2	0.047	3.15	13.56
	With Medium	101.3	0.202	125.7	0.052	3.00	18.79
557	Bare Root	115.8	0.159	138.2	0.046	3.05	14.47
	With Medium	86.7	0.184	117.6	0.048	2.83	16.81

N Level (Kg/ha)	Transplant Method	Leaf Level Cd	Co	Li	Ni	Si	Sr
0	Bare Root	0.065	0.143	31.4	0.618	500.9	40.2
	With Medium	0.066	0.140	28.9	0.641	499.8	45.1
278	Bare Root	0.063	0.145	18.4	0.644	478.5	37.0
	With Medium	0.069	0.136	12.7	0.613	448.5	47.9
557	Bare Root	0.064	0.157	24.4	0.652	501.2	38.4
	With Medium	0.063	0.144	10.8	0.556	395.7	42.9

S is reported as % dry weight.
All micro-nutrients are reported as ppm dry weight.

Table 38 Effect of N rate on micro-nutrient level in the leaf tissue of young apple trees

N Level (Kg/ha)	Leaf Level					
	Mn	Fe	Cu	B	Zn	S
0	114 A[z]	156 A	5.99 A	31 A	15 A	0.16 A
278	123 A	163 A	6.01 A	31 A	16 A	0.16 A
557	118 A	159 A	6.51 A	30 A	16 A	0.16 A

N Level (Kg/ha)	Leaf Level					
	Al	Mo	Na	Se	As	Ba
0	110 A	0.18 A	137 A	0.048 A	2.99 A	16.8 A
278	111 A	0.18 A	125 A	0.049 A	3.08 A	16.2 A
557	101 A	0.17 A	128 A	0.047 A	2.94 A	15.6 A

N Level (Kg/ha)	Leaf Level					
	Cd	Co	Li	Ni	Si	Sr
0	0.066 A	0.14 A	30 A	0.63 A	500 A	43 A
278	0.066 A	0.14 A	16 B	0.63 A	463 A	42 A
557	0.063 A	0.15 A	18 B	0.60 A	448 A	41 A

[z]Mean separation in columns by LSD, 5% level.
S is reported as % dry weight.
All micro-nutrients are reported as ppm dry weight.

Table 39 Effect of transplant method on micro-nutrient level in leaf tissue of young apple trees

Transplant Method	Leaf Level Mn	Fe	Cu	B	Zn	S
Bare Root	120 A[z]	163 A	6.60 A	32 A	17 A	0.16 A
With Medium	117 A	155 A	5.75 B	29 B	15 B	0.16 A

Transplant Method	Leaf Level Al	Mo	Na	Se	As	Ba
Bare Root	113 A	0.16 B	130 A	0.046 B	3.04 A	14.2 B
With Medium	101 A	0.19 A	130 A	0.050 A	2.96 A	18.1 A

Transplant Method	Leaf Level Cd	Co	Li	Ni	Si	Sr
Bare Root	0.064 A	0.15 A	25 A	0.64 A	494 A	38 B
With Medium	0.066 A	0.14 B	18 A	0.60 A	448 A	45 A

[z]Mean separation in columns by LSD, 5% level.
S is reported as % dry weight.
All micro-nutrients are reported as ppm dry weight.

Table 40 Tentative leaf element level for Newtown in Oregon

Range	N	K	P	Ca	Mg	Mn	Fe	Cu	B	Zn
A	1.5	0.9	0.10	0.50	0.18	20	40	1	25	10
B	2.3	1.2	0.13	0.60	0.23	25	50	2	30	15
C	2.6	3.0	0.60	2.5	1.0	200	400	50	75	80
D	3.0	4.0	0.65	3.0	2.0	450	500	100	100	300

Less than A = Deficiency
A to B = Below Normal
B to C = Normal
C to D = Above Normal
Greater than D = Excessive

N, K, P, Ca, Mg are reported as % dry weight.
Mn, Fe, Cu, B, Zn are reported as ppm dry weight.