bud cultures (2). A similar association between ABA levels and fruit growth exists in *Prunus cerasus* (6).

The high concentrations of ABA observed as the fruits approached maturity suggest that some association may exist between ABA level and ripening. ABA levels increase during ripening of pears (11), strawberries (12) and grapes (4). In sour cherry, inhibitors increased from the onset of stage III until the ground color changed from green to yellow, but then decreased (6).

Whether or not ABA plays a role in the control of the fruit development and ripening remains to be established; if it has a role, it must be a complex one. However, this role cannot be elucidated by exploring changes in endogenous levels of the hormone, for compartmentation and availability within the cell deserve consideration. In fact ABA might act by restricting, perhaps via modified membrane permeability, a promoter to particular organelles or by making inhibitors available to their sites of action. This could make its level in the tissues as a whole a misleading physiological parameter.

Literature Cited

1. Addicott, F. T., H. R. Carns, J. L. Lyons, O. E. Smith, and J. L. McLeans. 1964. On the physiology of abscisins. p. 687-703. *In* J. P. Nitsh (ed.) Regulateurs naturels de la croissance végétale. *Coll. Intern. Centr. Nat. Rech. Sci.* No. 123. Paris.
2. Altman, A. and R. Goren. 1971. Promotion of callus formation by abscisic acid in *Citrus* bud cultures. *Plant Physiol.* 47:844-846.
3. Blumenfeld, A. 1970. Interaction of kinetin and abscisic acid in the growth of soybean callus. *Plant Physiol.* 45:535-536.
4. Coombe, B. G. and C. R. Hale. 1973. The hormone content of ripening grape berries and the effects of growth substance treatment. *Plant Physiol.* 51:629-634.
5. Davis, L. A. and F. T. Addicott. 1972. Abscisic acid: Correlations with abscission and with development in cotton fruit. *Plant Physiol.* 49:644-648.
6. Davison, R. M., R. M. Rudnicki, and M. J. Bukovac. 1976. Endogenous plant growth substances in developing fruit of *Prunus cerasus* L. V. Changes in inhibitor (ABA) levels in the seed and pericarp. *J. Amer. Soc. Hort. Sci.* 101:519-523.
7. El-Antably, H. M. M., P. F. Wareing, and J. Hillman. 1967. Some physiological responses to D, L. abscisin (dormin). *Planta* 73:74-90.
8. Giulivo, C. and A. Ramina. 1975. Effect of (2-chloroethyl)phosphonic acid (CEPA) on ^{14}C-indolacetic acid (IAA) and ^{14}C-sucrose translocation in excised peach pedicels. *Riv. Ortoflorofrutticol. Ital.* 5.
9. Milborrow, B. V. 1967. The identification of (+)-Abscisin II [(+)-Dormin] in plants and measurement of its concentration. *Planta* 76:93-113.
10. Nitsch, J. P. and C. Nitsch. 1956. Studies on the growth of coleoptile and first internode sections. A new, sensitive, straight-growth test for auxins. *Plant Physiol.* 31:94-111.
11. Rudnicki, R., J. Machnik, and J. Pieniazek. 1968. Accumulation of abscisic acid during ripening of pears (Clapp's Favourite) in various storage conditions. *Bul. Acad. Polon. Sci.* 16:509-512.
12. Pieniazek, J. and N. Pieniazek. 1968. Abscisin II in strawberry plants at two different stages of growth. *Bul. Acad. Polon. Sci.* 16:127-130.
13. Smith, O. E. 1969. Changes in abscission-accelerating substances with development of cotton fruit. *New Phytol.* 68:313-322.
14. Taylor, H. F. 1968. Carotenoids as possible precursors of abscisic acid. p. 22-35 *In* Plant growth regulators. *S. C. I. Monograph* No. 31, London.
15. Weinbaum, S. A., C. Giulivo, and A. Ramina. 1977. Chemical thinning: ethylene and pre-treatment fruit size influence enlargement, zuxin transport, and apparent sink strength of French prune and 'Andross' peach. *J. Amer. Soc. Hort. Sci.* 102:781-785.
16. Zùcconi, F. 1975. Reassessment of the relationship between hormonal and development changes during abscission with particular reference to peach (*Prunus persica* (L.) Batsch) fruit. PhD Thesis, Michigan State Univ. East Lansing.

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-09-01 via Open Access. This is an open access article distributed under the CC BY-NC-ND license (https://creativecommons.org/licenses/by-nc-nd/4.0/). https://creativecommons.org/licenses/by-nc-nd/4.0/

J. Amer. Soc. Hort. Sci. 105(3):468–472. 1980.

Comparison of Apple Planting Methods[1]

Tara Auxt, Steven Blizzard, and Kendall Elliott
Division of Plant Sciences, West Virginia University, Morgantown, WV 26506

Additional index words. tree planting, *Malus domestica*

Abstract. **The tractor-mounted soil auger, a commonly used machine for simplifying the planting of apple (*Malus domestica* Borkh.) trees, was shown to create a compact hole wall that remains evident over time. Penetrometer measurements of 1- to 3-year-old auger plantings were significantly higher at the interface of bisected tree holes than at either the backfill or undisturbed soil regions. In a comparison of the auger to a backhoe, a commercial tree planter, a ditch trencher, and an auger modified to fracture the sides of the planting hole, shoot length and anchorage measurements of trees planted by the alternative planting methods surpassed those planted by the conventional auger. Trees planted by backhoe or tree planter were most successfully established.**

Basic principles of tree planting have not changed as they have traveled through the texts of pomologists such as Wilkinson (14), Chandler (2), Tukey (11), Teskey and Shoemaker (10), Childers (3) and Westwood (13). The main objective is to dig a hole sufficiently large to accommodate the roots without much bending and to get good root-soil contact.

Although principles have been well established, there is very little numerical data concerning selection of a planting procedure, Stringfellow (7) in 1896, Card (1) in 1898, and Pickering (4) in 1905 conducted the earliest comprehensive studies on methods of planting. Pickering demonstrated that trees could be successfully planted by a number of methods, provided that there was intimate root-soil contact. Card compared the effect of size of hole on tree growth and found very few differences. Stringfellow wrote a book about his success with severing roots and planting with a spud bar. Some years later Van Der Slikke (12) and Preston (5) revived this work, with the aim of exploiting the method for complete mechanical planting. Van Der Slikke reported planting 3 times faster with the Stringfellow method. Preston observed that trees planted without roots and left unpruned did not differ in size from trees that were planted with roots and headed. More recently, Tennes and Burton (8, 9) discovered significant growth increases of peach

[1]Received for publication September 12, 1979.
The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper must therefore be hereby marked *advertisement* solely to indicate this fact.

and cherry trees planted by their continuous planter over those planted by the auger method.

Labor shortages and the trend toward high density planting systems have forced apple growers to replace hand-digging of planting holes with mechanical methods. A readily available machine for this purpose was the tractor-mounted auger. Although augering planting holes and hand backfilling is a widely accepted practice, it has been noted that as the auger drills the planting hole a compact wall is formed. Observations in West Virginia of auger-planted trees indicated that the compact interface was possibly inhibiting normal root development. To establish the importance of the planting method in orchard establishment and if a correlation exists between tree growth and planting method, a study was designed that quantitatively evaluated the compaction created by the auger and investigated alternative planting methods.

Materials and Methods

Preliminary compaction study of auger-planted trees. One- to 3-year-old auger plantings in each of 6 orchard soil types were bisected in an initial experiment. A ditch trencher was used to bisect 10 trees holes in each soil type. Comparisons of differences in soil compaction within the backfilled area, at the area which will be referred to as the hole "interface," and in the undisturbed soil outside of the hole were made with a penetrometer. The measurements were taken summer, 1977, at a 20-25 cm depth. The analysis of soil resistance to root penetration was a split plot in a completely random design with subsampling.

Comparison of tree planting methods. The auger was compared to other planting methods in a follow-up study initiated in spring, 1977, with an examination of 4 methods of planting fruit trees. A subsequent trial began the following year, replicating 3 of the same treatments and adding 2 planting methods. A backhoe, mechanical ditch trencher, 30 cm auger, 60 cm conventional auger, 60 cm modified auger, and newly-developed fruit tree planter were compared. The 60 cm modified auger was fabricated by welding a blade to the side flange to facilitate fracturing the sides of the planting hole. 'Granny Smith'/Malling (M) 26, 'Stayman'/M 9/Malling Merton (MM) 106, and 'York'/M 26 were planted in the 1977 plot, and 'Golden Delicious'/MM 111, 'Stayman'/MM 106, and 'Rome'/MM 111 were planted for the 1978 study. The experimental design of the 1977 planting was split plot with repeated sampling, and the design of the 1978 plots was completely random (cultivars analyzed separately). All plots were on soil classified as Hagerstown and Frederick cherty silt loam, a deep, well-drained limestone soil with a high moisture capacity.

Depth of planting holes was 45-60 cm. Width varied with the planting implement. Auger-drilled holes were 30 cm or 60 cm in diameter, depending upon the size of the drill. The trencher chain cut a 10 × 45 cm ditch. In 1977, a backhoe with a 46 cm bucket was used, and in 1978 the backhoe used had a 30 cm bucket. The subsoiler on the commercial tree planter plowed a trench 20 cm wide. A mole hole system at the base of the trench allowed space for root expansion.

Planting holes were backfilled by hand around all the trees except for those set by the tree planter. As the roots were covered, the soil was tamped thoroughly. Trees were lifted and lowered slightly while filling the holes. With the continuous planter, only the setting of the tree was done by hand. Two large tires pulled the soil back into the trench and packed it around the tree roots.

Trees planted by each of the methods were compared on the basis of scion vigor and root establishment. Vigor was evaluated by measuring total shoot length at the end of each growing season. Selected trees were uprooted with a forklift the following spring to measure anchorage, and thus root development. The force required to uproot the trees was determined by a load cell coupled to a X-Y recorder (Fig. 1). At the conclusion of the study, roots of trees planted by each method were excavated to investigate signs of growth restriction. Exposing the root systems entailed digging a trench outside of the root zone and slowly washing soil away from the roots into the ditch with a high pressure hydraulic sprayer (14.06 kg/cm^2).

Results

Compaction study of auger-planted trees. An examination of the root systems of 1- to 3-year-old trees that were planted using an auger provided the first indication of compaction. Extension roots were either deformed or constricted in diameter, and secondary and tertiary roots circled the interface of the planting hole.

Penetrometer measurements supplied a quantitative evaluation of the root penetration problem (Table 1). Undisturbed soil, interface, and backfill measurements were significantly different for all soil types, except for Wheeling silt loam where measurements of the undisturbed soil and interface were the same. The interface of the other 5 soil types was more resistant to probe penetration than either the disturbed or the undisturbed soil.

1977 tree planting plot. Shoot measurements for 2 consecutive years were significantly lower for auger plantings (Table 2). Trees planted with the backhoe exhibited 100% greater growth the first year and 40% greater growth the second year than trees planted with the 30 cm auger. By comparison trees planted with the 60 cm auger and the trencher demonstrated total shoot growth that was 40% lower than that of

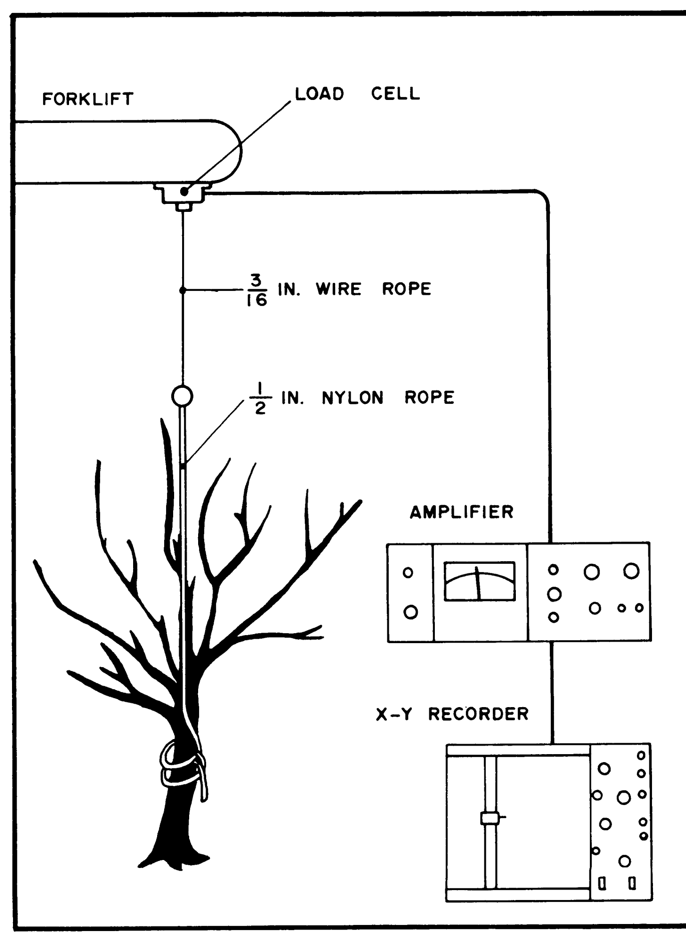

Fig. 1. Block diagram of tree-lifting apparatus. A linear variable differential transformer (LVDT) system was used in 1978, and a strain gauge system was used in the second year.

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-09-01 via Open Access. This is an open access article distributed under the CC BY-NC-ND license (https://creativecommons.org/licenses/by-nc-nd/4.0/). https://creativecommons.org/licenses/by-nc-nd/4.0/

Table 1. Soil resistance to root penetration at 3 West Virginia locations in the rhizosphere of young apple trees planted with a 60 cm auger.

Soil type[z]	Location[y]	Penetrometer measurements[x,w] (kg/cm^2)
Wheeling silt loam	Undisturbed soil	7.56a
Pt. Pleasant	Interface	7.37a
	Backfill	1.68b
Monongahela loam	Undisturbed soil	5.37a
Hamlin	Interface	6.96b
	Backfill	2.38c
Culleoka-Westmoreland silt loam	Undisturbed soil	5.26a
Morgantown	Interface	6.90b
	Backfill	2.14c
Hagerstown silt loam	Undisturbed soil	4.62a
Kearneysville	Interface	5.76b
	Backfill	1.09c
Frankstown shaly silt loam	Undisturbed soil	2.95a
Hedgesville	Interface	3.95b
	Backfill	.60c
Murrill gravelly loam	Undisturbed soil	6.35a
Arden	Interface	7.29b
	Backfill	2.73c

[z]Planted, in order of appearance, springs 1976, 1975, 1977, 1977, 1976. Measured June 14, 15, 21, 28, 17, 16 in 1977, respectively.

[y]Subsampling technique. Two measurements were taken at each location.

[x]Means of 10 auger-drilled holes in each soil type.

[w]Mean separation within a soil type, by Duncan's new multiple range test, 5% level. The test was conducted separately for each soil type, although Analysis of Variance indicated significant overall differences due to location. There was no indication of a soil type-location interaction.

backhoe plantings in 1977 and 15% (significant) and 8%, respectively, lower the following year. The growth results are not separated by cultivar because a statistical analysis revealed no significant differences among rootstock/scion combinations. Anchorage measurements followed a pattern similar to growth measurements (Table 2). One year after planting, the only significant difference was between the backhoe and the other treatments, but 2 years later, anchorage of trencher-planted trees was comparable to backhoe-planted trees. Representative roots excavated from backhoe and trencher plantings showed

Table 2. Total shoot growth and anchorage, for 2 consecutive years, of apple trees planted by each of 4 methods.

Tree planting method[z]	Total shoot growth (cm)[y,w]		Uproot force (kg)[x,w]	
	1977	1978	1978	1979
Back hoe	353a	1238a	125A	161A
Ditch trencher	238b	1145ab	103B	126A
60 cm auger	252b	1081b	90B	125B
30 cm auger	174c	891c	88B	140B

[z]Planted May 8, 1977.

[y]Mean total growth of 60 trees in 1977 and 42 trees in 1978, measured August 30, 1977 and Sept. 1, 1978.

[x]Mean anchorage of 20 trees, uprooted March 13, 1978 and March 17, 1979.

[w]Mean separation by Duncan's multiple range test, 5% level for shoot growth and at the 1% level for anchorage.

Table 3. Shoot measurements of 1-year-old apple trees as influenced by planting method.

Tree planting method[z]	Total shoot growth (cm)[y,x]		
	Golden Delicious	Stayman	Rome
Backhoe	645a	267a	
Tree planter	616a	253a	432a
Ditch trencher	610ab		
Conventional 60 cm auger	546b		362b
Modified 60 cm auger		251a	444a

[z]Planted May 8, 1978.

[y]Mean total growth of 36 trees, measured Sept. 1, 1978.

[x]Mean separation by Duncan's multiple range test, 5% level.

uninhibited extension. Roots of auger plantings penetrated weak areas of the hole interface, but some had to circle before finding an exit. During the excavation of a 30 cm auger hole, it was interesting to observe that a portion of the interface, circled by two lateral roots, was the last fragment of soil to succumb to the high pressure sprayer.

1978 tree planting plots. Shoot measurements of the 1978 plantings indicated that the backhoe, the tree planter, the ditch trencher and the modified auger methods were comparable and that all, except the trencher, surpassed the conventional 60 cm auger (Table 3). Tree planter and backhoe 'Golden Delicious' plantings showed 15% to 20% greater growth than conventional auger plantings. Shoot growth of trencher-planted trees was 12% greater than that of 60 cm auger-planted trees, but this difference was not significant. The growth of 'Rome' trees planted by the modified auger or the tree planter exceeded by 20% that of trees of the same variety planted by the conventional auger. Anchorage averages on the 'Rome' block were significantly higher for continuous-planted trees than for either modified or conventional auger-planted trees (Table 4). Excavation of typical 'Rome' trees from each of the 3 treatments revealed possible causes for the differences in anchorage (Fig. 2). Root systems of trees planted by the mechanical planter showed even scaffolding and proliferous expansion. Modified auger-planted tree roots were well distributed but less dense. Roots excavated from conventionally augered holes were sparse with irregular ramification. A vertical sinker and several lateral roots were observed circling the planting hole. In the excavation figures, roots were arranged as found in soil.

Discussion

The preliminary study of auger-planted trees and the comparison of the auger to other planting methods indicated that root development and expansion were restricted by the bounds of the augered hole. The compact interface that forms as the

Table 4. Anchorage of 1-year-old 'Rome' trees as influenced by planting method.

Tree planting method[z]	Uproot force (kg)[y,x]
Tree planter	153a
Modified 60 cm auger	131b
Conventional 60 cm auger	121b

[z]Planted May 8, 1978.

[y]Mean anchorage of 18 trees, uprooted March 16, 1979.

[x]Mean separation by Duncan's multiple range test, 1% level.

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-09-01 via Open Access. This is an open access article distributed under the CC BY-NC-ND license (https://creativecommons.org/licenses/by-nc-nd/4.0/). https://creativecommons.org/licenses/by-nc-nd/4.0/

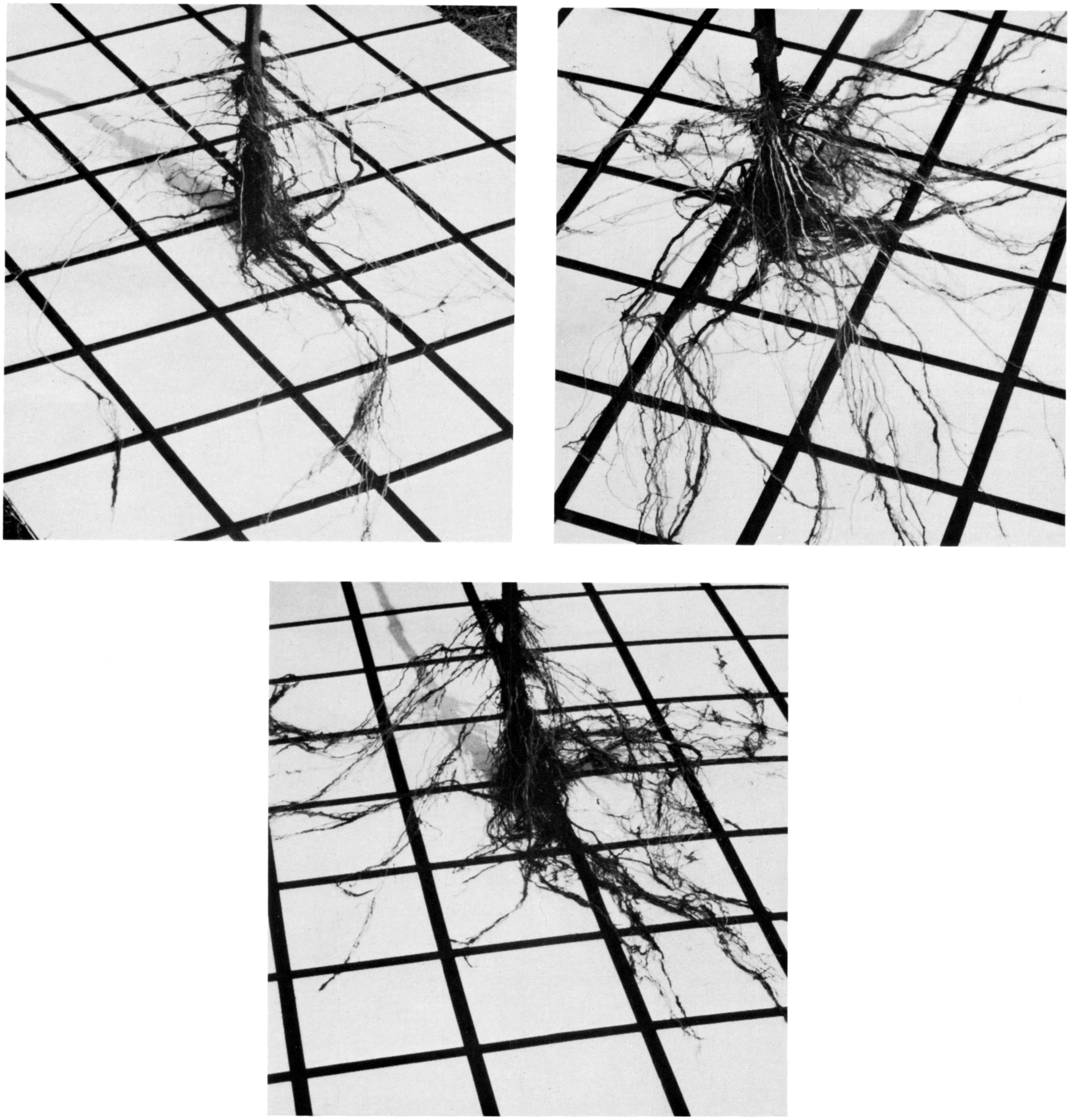

Fig. 2. Root systems of representative Rome/MM 111 planted by modified auger (top left), tree planter (top right), and conventional auger (bottom). Planted May 8, 1978 and excavated March 8, 1979. (Each division on background represents 20 cm).

auger drills the planting hole remains evident over time, inhibiting root penetration beyond the area of the backfill soil. Roots often circle the interface before finally pushing through to the undisturbed soil. This clay-pot effect of the auger-drilled hole causes stunting of tree growth and inferior anchorage. In addition to roots being mechanically inhibited, other pathways may be blocked. It is possible that the impervious hole wall acts as a vertical fragipan that impedes gaseous and aqueous exchange. If this is true, certain irrigation, nematocide application, fertilization, and soil testing practices may be ineffective on trees planted using an auger.

The results of the tree planting comparison support a number of alternatives to the conventional auger method, depending on local soil characteristics and orchard design. The large numbers of trees required in high density systems can be planted quickly and efficiently with a commercial or home-built continuous mechanical planter. Speed is important, as tree roots do not have a chance to dry out, and during a wet

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-09-01 via Open Access. This is an open access article distributed under the CC BY-NC-ND license (https://creativecommons.org/licenses/by-nc-nd/4.0/). https://creativecommons.org/licenses/by-nc-nd/4.0/

spring only a few days may be suitable for working the soil. Continuous planting is 6 to 8 times faster than planting with the auger, and 1 worker can be eliminated. In a continuous furrow, roots are not confined to a hole environment. Instead, a mole hole system permits free movement of water and roots. Small family orchards could be planted with the aid of a ditch trencher, since it's use requires comparatively little operational skill. The ditch trencher was associated with better tree performance than the auger, but whether or not it was comparable to the tree planter was debatable. The blades on the trencher chain cut a smooth-sided ditch, a problem that could possibly be alleviated by reversing the blades on the chain. Tukey has tried this in Pennsylvania and reports that glazing is reduced. On orchards with shallow soils, heavy soils, stratified sands, or man-made compaction problems, it would be prudent to conduct personal tests. The subsoiler on the tree planter may be the solution in some cases, but there will probably be sites where backhoe renovation is needed. Although the backhoe is slow, a number of researchers have reported great success with this method, even on problem soils (3, 6). Finally, the fact cannot be ignored that tractor-mounted augers are established orchard equipment. The burnishing action of the auger could be reduced by modifying the side flange of the auger, or the sides of the auger-drilled hole could be broken up with a shovel. In this study, trees planted by the modified auger demonstrated growth comparable to the tree planter, but anchorage was inferior. Perhaps a better modification could be engineered.

Literature Cited

1. Card, F. W. 1898. Methods of tree planting. *Neb. Agr. Expt. Sta. Bul.* 56.
2. Chandler, W. H. 1965. Deciduous orchards. Lea and Febiger, Philadelphia.
3. Childers, N. F. 1976. Modern fruit science. Horticultural Publications, Rutgers Univ., New Brunswick, N.J.
4. Pickering, S. U. 1908. Woburn Expt. Fruit Farm Rpt. 9:1-95. London, U.K.
5. Preston, A. P. 1972. Apple rootstock studies: growth of trees on three clonal rootstocks planted with or without roots. *J. Hort. Sci.* 47:329-335.
6. Ross, N. W. and J. L. Meyer. 1975. Orchard preplant land preparation new and replant. *Cal. Agr.* 6(6):12-14.
7. Stringfellow, H. M. 1896. The new horticulture. Farm and Ranch, Galveston, Texas.
8. Tennes, B. R. 1976. 500 trees per hour. *Agr. Res.* 25(4):3-4.
9. __________ and C. L. Burton. 1978. A rapid planting method for fruit trees and bushes. Amer. Soc. Agr. Eng. Tech. Paper 78-1020.
10. Teskey, B. J. and J. S. Shoemaker. 1972. Tree fruit production. AVI, Westport, Conn.
11. Tukey, H. B. 1964. Dwarfed fruit trees. Macmillan, New York.
12. Van Der Slikke, L. B. H. 1952. De Stringfellow methods van wortelsnoei. *Fruiteelt* 42:896.
13. Westwood, M. N. 1978. Temperate-zone pomology. W. H. Freeman, San Francisco.
14. Wilkinson, A. E. 1915. The apple. Ginn, New York.

J. Amer. Soc. Hort. Sci. 105(3):472–475. 1980.

Growth Responses and Leaf Nutrient Concentrations of 'Fordhook 242' Lima Beans as Affected by Fertilizer Treatment and Plant Stand[1]

Cyril B. Smith[2]

Department of Horticulture, Pennsylvania State University, University Park, PA 16802

Additional index words. Phaseolus lunatus, maturity, nitrogen source

Abstract. **'Fordhook 242' lima beans (*Phaseolus lunatus* L.) were grown in 1973-1974 with 16 fertilizer treatments and 2 plant stands (11 and 16 plants/m) at 0.96 m row width. Soils used were low in P and Mg, medium in K and high in Ca. Banded fertilizer treatments were 28 or 56 kg/ha of N, P, K, and Mg in various combinations, 5 N sources compared at 56-56-0 kg/ha, and 2 commercial fertilizers, 18-46-0 and 8-24-8. With an increase in plant stand from 11 to 16 plants/m of row, vine growth was increased and maturity was delayed but yield of marketable beans was not influenced. Yields were increased an average of 74% by 6 treatments at or close to 56-56-0 kg/ha with and without K when compared to check. N sources, P and K all affected maturity. Urea, $(NH_4)_2SO_4$, and NH_4NO_3 resulted in higher yields than $Ca(NO_3)_2$ and $NaNO_3$ primarily by hastening maturity. Leaf concentrations of Ca and Mg were enhanced by P and all N sources while leaf K was lowered. Applied K depressed leaf Mg. Thus when both K and Mg were added to NP treatment, Mg leaf concentration was not changed.**

The 'Fordhook 242' lima bean, the most common of the large seeded type, is widely grown in Pennsylvania for fresh market and freezing. There have been few spacing studies and little is known about its specific nutrient requirements.

Odland (6) showed that spacing in the row of 7.5 cm resulted in higher yields than either 15 or 30 cm spacing but results were not consistent. Larson and Peng-Fi (4) and McGillivray et al. (5) also showed that closer spacing in the row of 5-10 cm resulted in higher yields.

There have been few reports on fertilizer needs. Increased yields were obtained with an increase in 4-12-4 fertilizer from 392 to 784 kg/ha at 7.5 cm plant spacing by Odland (6). Dallyn and Sawyer (2) reported good yield responses to 112 and 224 kg/ha of N and P, respectively, but no response to K. Parker (7) showed that 1120 kg/ha of 6-12-5 fertilizer placed in bands 5 cm below and 5 cm to each side of the seed gave the highest yields when compared with 4 other placements. Only a few experiments have included plant analysis (3).

These experiments were carried out to determine more precisely the nutritional requirements using a wide range of

[1]Received for publication on November 26, 1979. Paper No. 5872 in the Journal Series of the Pennsylvania Agricultural Experiment Station.

The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper must therefore be hereby marked *advertisement* solely to indicate this fact.

[2]Professor of Plant Nutrition.

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-09-01 via Open Access. This is an open access article distributed under the CC BY-NC-ND license (https://creativecommons.org/licenses/by-nc-nd/4.0/). https://creativecommons.org/licenses/by-nc-nd/4.0/