SEASONAL PATTERNS OF ROOT GROWTH POTENTIAL (RGP) OF 2 CONTAINERIZED CHERRY ROOTSTOCKS, PRUNUS MAHALEB L. AND P. AVIUM L. CV. MAZZARD.

By

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ABSTRACT

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Root Growth Potential (RGP), measured as capacity to regenerate new roots during a test period under optimal conditions following transplanting, was evaluated in 2 seedling cherry rootstocks, *Prunus mahaleb* L. and *P. avium* L. cv. Mazzard at six different shoot developmental stages. Highest RGPs were recorded in the Spring with active buds present. Both rootstocks displayed a marked reduction in RGP during first leaf expansion but recovered when a mean of 10 fully expanded leaves were present. Mazzard was superior in production of total numbers of new roots per 100 g total plant dry weight and in the replacement of pruned-off roots, at bud swell and first leaf expansion. In a separate experiment performed at bud swell, presence of *P. cerasus* cv. Montmorency as scion on Mazzard stocks significantly increased new root production when compared to unbudded Mazzard stocks. No comparable effect was seen when Montmorency was budded on Mahaleb stocks.

To the memory of my father

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SECTION I

INTRODUCTION.

Research into the factors controlling root growth, initiation, extension, etc. in woody perennials could be considered a relatively underexplored field when compared to the large volume of literature extant concerning the physiology of the above ground portion of the same plants. The technical and physical difficulties of data collection have been a major dilemma to research. Nevertheless, horticulturists, pathologists, nurserymen and growers alike are keenly interested in this area for a variety of reasons.

The capacity of a tree's root system to initiate and elongate new roots following transplanting is almost universally recognized as being crucial to its survival and subsequent growth. Indeed, its importance is underscored by the numerous reports from forestry researchers evaluating this ability in a large number of species (10,11,12,17,25,26,27,30). This regrowth ability has been described as Root Growth Potential (RGP); usually defined as the capacity to regenerate new roots during a test period under optimal conditions following transplanting (18).

RGP displays a marked seasonal periodicity; conifers, which constitute the majority of species tested, generally display a single peak sometime around mid-Winter (18). However, this is not always the case and there appear to be some consistent differences between gymnosperms and angiosperms (3,18,25). Most temperate deciduous species tested have displayed a peak RGP just prior to normal spring bud break (3,30,31).

There is a correlation between increasing RGP and the accumulation of chilling hours (28,31,30). These same studies have demonstrated that RGP peaks with the fulfillment of a specie's chilling requirement. In addition, physiologically active buds are necessary for high RGP (6,13). This would seem to suggest a linkage between RGP periodicity and plant dormancy.

RGP has been found to be subject to manipulation by many of the same factors that alter intensity of annual root growth of undisturbed plants. These include: soil moisture, soil temperature (5,11,12,17) and shoot pruning or defoliation (9,10,13).

The effects of the rootstock on the growth and morphology of the scion in a 2-piece tree are well documented (1,19,20,29,33), but there is relatively little information which describes the influence of the scion or of the graft union on the morphology or performance of the rootstock rootsystem, particularly its Root Growth Potential (RGP).

Current opinion concludes that the rootstock retains its own distinct morphology regardless of scion or presence/absence of rootstock stempiece (20,29,34). Additionally it has been noted that a tree's shoot/root ratio remains remarkably constant for a given soil type and scion across a broad range of size controlling rootstocks (7,20,29), indicating an integrated control over total tree growth by both scion and rootstock.

Scion influence on Root Growth Potential has been documented in *Quercus* spp. (13) and in *Rosa* spp. (15). The mechanism of this effect was inconclusive, but there appeared to be evidence that control is associated with translocatable factors from the scion.

Containerized studies for root growth have serious limitations (2,14,22). Some researchers have utilized aeroponic or hydroponic methods. Advantages of these systems include ease of monitoring ongoing root growth and retention of entire rootsystem. However, these techniques suffer from the criticism that experimental conditions differ so extremely from those in the field that results are difficult to compare (16,23).

Short term studies using media systems, typically require some initial pruning of the root system in order to facilitate the identification of new growth at the completion of the experiment. This results in the removal of all fibrous roots (4,14), all white roots (24,25,35) or only the tips of white roots (8,26,27,35). Such practices might actually confound an experiment since it is known that root tipping and injury can cause striking increases in root initiation, branching and growth rates (21,32).

Relatively little work has been done evaluating root growth potential and the various factors that modify its expression in temperate fruit species. We have taken some preliminary steps to fill this void through the research conducted over the past 2 years and reported on in this thesis.

Literature Cited.

1. Beakbane, A.B. and W.S. Rogers. 1956. The relative importance of stem and root in determining rootstock influence in apples. J. Hort. Sci. 31:99-110.

2. Boehm, W. 1979. Methods of studying root systems, Springer-Verlag, Berlin.

3. Farmer, R.E., et al 1975a. Effects of chilling and pruning in forcing dormant black cherry, Can. J. For. Res. 5:160-162.

4. Farmer, R.E. 1975b. Dormancy and rot regeneration of northern red oak, Can. J. For. Res. 5:176-185.

5. Heningen, R.L. and D.P. White 1974. Tree seedling growth at different soil temperatures, For. Sci. 10:142-147.

6. Heth, D. 1980. Root and shoot water potentials in stressed pine seedlings, N. Z. J. For. Sci. 10:142-147.

7. Knight, R.C. 1934. The influence of winter stem pruning on subsequent stem and root development in the apple. J. Pomol. Hort. Sci. 12:1-14.

8. Krugman, S.L. and E.C. Stone 1966. Effect of cold nights on the root regenerating potential of ponderosa pine seedlings, For. Sci. 12:451-459.

9. Larson, M.M. 1978. Effects of late season defoliation and dark periods on initial growth of planted northern red oak seedlings, Can. J. For. Res. 8:67-72.

10. Larson, M.M. 1975. Pruning northern red oak nursery seedlings: effects on root regeneration and early growth, Can. J. For. Res. 5:381-386.

11. Larson, M.M. 1970. Root regeneration and early growth of red oak seedlings: influence of soil temperature, For. Sci. 16:442-446.

12. Larson, M.M. and F.W. Whitmore 1970. Moisture stress effects root regeneration and early growth of red oak seedlings, For. Sci. 16:495-498.

13. Lee, C.I., et al 1974. Root regeneration of transplanted pin and scarlet oak, The New Horizons, The Hort. Res. Inst., Washington, DC pp 10-14.

14. Lee, C.I. and W.P Hackett 1976. Root regeneration of transplanted *Pistachia cheninsis* Bunge seedlings at different growth stages, J. Amer. Soc. Hort. Sci. 101:236-240.

15. Lee, C.I. and N. Zieslin. 1978. Root regeneration of Manetti rootstocks grafted with different scion cultivars of rose. HortScience. 13:665-666.

16. MacKey, J. 1973. The wheat root, 4th Int. Wheat Genet. Symp., Missouri Agric. Exp. Stat., Columbia Mo. pp 827-842.

17. Nambiar, E.K.S., et al 1979. Root regeneration and plant water status of *Pinus radiata* seedlings transplanted to different soil temperatures, J. Exp. Bot. 30:1119-1131.

18. Ritchie, G.A. and J.R. Dunlap 1981. Root growth potential: Its development and expression in forest tree seedlings, N. Z. J. For. Sci. 10:218-248.

19. Rogers, W.S. and A.B. Beakbane. 1957. Stock and scion relations. Ann. Rev. Plant Physiol. 8:217-236.

20. Rogers, W.S. and M.C. Vyvyan. 1934. Root studies. V. Rootstock and soil effects on apple root systems. J. Pomol. Hort. Sci. 12:110-150.

21. Rook, D.A. 1971. Effect of undercutting and wrenching on growth of *Pinus radiata* seedlings, J. Applied Ecol. 8:477-490.

22. Schumacher, T.E. et al 1983. Measurement of short term root growth by prestaining with neutral red, Crops Sci. (in press).

23. Schuurman, J.J. and M.A.J. Goediwangen 1971. Methods for the examination of root systems and roots, Wageningen, Pudoc.

24. Stone, E.C. and J.L. Jenkinson 1971. Physiological grading of ponderosa pine nursery stock, J. For. 69:31-33.

25. Stone, E.C. and J.L. Jenkinson 1970. Influence of soil water on root growth capacity of ponderosa pine transplants, For. Sci. 16:230-239.

26. Stone, E.C. and G.H. Shubert 1959. Root regeneration by ponderosa pine seedlings lifted at the different times of the year, For. Sci. 5:322-332.

27. Stone, E.C., et al 1962. Root regeneration potential of douglas-fir seedlings lifted at different times of the year, For. Sci. 8:288-297.

28. Taylor, J.S. and E.B. Dumbroff 1975. Bud, root and growth regulator activity in *Acer saccharum* during the dormant season, Can. J. Bot. 53:321-331.

29. Tubbs, F.R. 1980. Growth relations of rootstock and scion in apples. J. Hort. Sci. 55:181-189.

30. Webb, D.P. 1977. Root regeneration and bud dormancy of sugar maple, silver maple and white ash seedlings: effects of chilling, For. Sci. 23:474-483.

31. Webb, D.P. 1976. Effects of cold storage duration on bud dormancy and root regeneration of white ash, *Fraxinus americana* L., seedlings, HortScience 11:155-157.

32. Wightman, F. and K.V. Thimann 1980. Hormonal factors controlling the initiation and development of lateral roots. I. Sources of primordia inducing substances in the primary root of pea seedlings, Physiol. Plant. 49:13-20.

33. Vyvyan, M.C. 1955. Inter-relation of scion and rootstock in fruit trees. Ann. Bot. 19:401-423.

34. Vyvyan, M.C. 1930. The effect of scion on root. III. Comparison of stem and root-worked trees. J. Pomol. Hort. Sci. 8:259-282.

35. Zaerr, J.B. 1967. Auxin and the root regeneration potential in ponderosa pine seedlings, For. Sci. 13:258-264.

SECTION I.

SHOOT DEVELOPMENTAL STAGE AND WATER-STRESS EFFECTS ON ROOT GROWTH POTENTIAL (RGP) OF 2 CONTAINERIZED, SEEDLING CHERRY ROOTSTOCKS, MAHALEB AND MAZZARD.

ABSTRACT

Root growth potential (RGP) was evaluated in 2 seedling cherry rootstocks, Prunus mahaleb L. and P. avium L. cv. Mazzard, at 6 shoot developmental stages. Highest RGP's were recorded in the spring with active buds present. Both rootstocks displayed a marked reduction in RGP during first leaf expansion but recovered when 10 leaves had fully expanded. Mazzard markedly outperformed Mahaleb in the production of total numbers of new roots per 100 g total tree dw and in percent rootsystem dw regenerated at spring bud swell and at first leaf expansion. Mazzard was also superior in the production of new roots along the shank during first leaf expansion. Water stress imposed prior to RGP evaluation enhanced RGP in both rootstocks.

Literature Review

There is a strong positive association between capacity to survive transplanting and root growth potential (29,30,33) where the latter term is defined as the capacity to regenerate new roots during a test period under optimal conditions following transplanting (25).

RGP displays a marked seasonal periodicity; conifers, which constitute the majority of species tested, generally display a single peak sometime around mid-Winter (25). However, this is not always the case and there appear to be some consistent differences between gymnosperms and angiosperms (5,18,25,28). Most temperate deciduous species tested have displayed a peak RGP just prior to normal spring bud break (5,35,36). Other investigators working with different species have noted a small additional peak in the Fall (17) or, in one instance, the main peak during rapid summer shoot elongation (16). One study which evaluated the RGP of several *Vitis* species, during the summer and fall months only, noted a general increase in RGP in the Fall although the various species did differ in their pattern of RGP throughout this period (22).

There is a correlation between increasing RGP and the accumulation of chilling hours (32,35,36). These same studies have demonstrated that RGP peaks with the fulfillment of a specie's chilling requirement. In addition, physiologically active buds are necessary for high RGP (9,17). This would seem to suggest a linkage between RGP periodicity and plant dormancy.

RGP has been found to be subject to manipulation by many of the same factors that alter intensity of annual root growth of undisturbed

plants. These include: soil moisture, soil temperature (8,12,15,21) and shoot pruning or defoliation (13,14,17). Some studies have shown that water stress prior to transplanting improves subsequent RGP for a considerable time period (10,26,27), while other investigators have suggested a decline in RGP following drought conditions under certain circumstances (22,25).

The purpose of this experiment is twofold: first, to quantify the seasonal periodicity of root growth potential of two twice transplanted cherry rootstocks and secondly, to delineate the effects of prior drought stress on the RGP of these species.

Materials and Methods.

During the first 2 weeks of June, 1982, two-year-old, dormant seedlings of Prunus mahaleb L. and P. avium L. cv. Mazzard were pruned to 30-35 buds and planted in 10 liter containers. Containers were filled with an equal quantity of a 3:1 mineral soil:sand mix. Plants were placed in a field at the Horticultural Research Center, MSU, E. Lansing, MI 30x55 cm apart. Container grown trees were protected on the perimeter by a guard row of containerized trees or 1.5 m high snow fence. Containers were initially set in the sandy soil up to their rims (approximately 25 cm) to avoid possibly excessive root temperatures due to exposure of the black plastic pots to the sun.

Trees were watered via a trickle irrigation system regularly with 1.5 l of water every 2-3 days until the start of water stress treatments on July 12, 1982. On July 11, trees were fertilized with 20-20-20 soluble fertilizer (Peter's Fertilizer Products, W.R. Grace and Co., Fogelsville, PA) diluted to 400 ppm N. Fertilization was repeated during the experiment on August 16 with 200 ppm N. Trees were sprayed as needed for pest control.

Trunk circumference was measured at 5 cm from the soil at start of irrigation treatments and every 4 weeks thereafter. Five soil samples were collected randomly from each of 4 treatments (Mahaleb or Mazzard, each with and without irrigation) every 3 days including before and after rehydration of water-stress treatments. Samples were dried for at least 7 days at 105°C in a forced air oven and soil moisture determined gravimetrically. Soil moisture tension was measured by use of a "Quick-Draw" soil moisture probe (Soil Moisture Equipment Corp., Santa Barbara, CA) at a depth of approximately 10 cm.

Plastic shrouds were placed around each of the water-stress treatments prior to precipitation periods. Water-stress treatments were watered to saturation whenever average soil moisture tension exceeded 65 KiloPascals (KPa) during periodic sample described above. Check treatments were watered via a trickle system as needed to keep soil moisture tension less than 20 KPa.

Weeds were controlled initially by hand and later by 2 applications of Paraquat herbicide at recommended rates during the treatment period.

On July 28 it was discovered that substantial rooting into the soil surrounding the sunken containers had taken place. Prior to July 11, random observations had shown no roots exiting the container's drainage holes. Rooting was, no doubt, encouraged by over 10 cm of rainfall received between the 2 dates. All containers were extracted from the soil and all protruding roots removed (Table 1.). Containers were then reset in their original positions, this time on the soil surface. Subsequently, soil temperature was measured (Figure 2.) at approximately 10 cm depth, halfway between the pot rim and tree stem; measurements were made between 11 am and 3 pm on each occasion. Overhead irrigation was provided for a period of 5 days before the water-stress treatments were restarted in order to minimize apparent stress (wilting) evident in many trees due to the root trimming procedure. Containers were tipped and checked regularly to prevent any further rooting into the field soil.

On September 5, irrigation treatments were concluded and the entire plot watered. Trees were subsequently watered whenever average soil moisture tension exceeded 35 KPa among 10 trees randomly sampled until

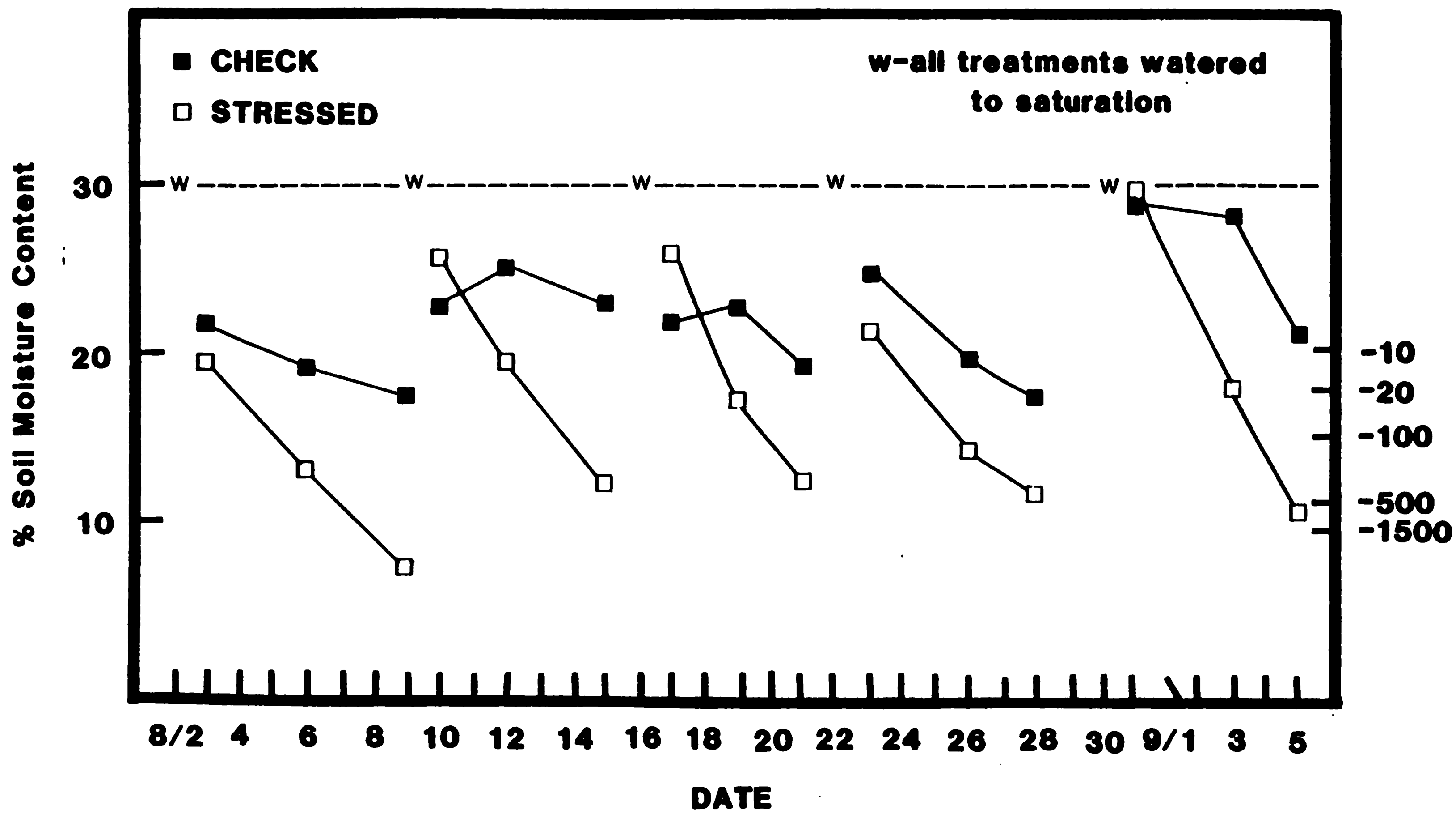

Figure 1. Percent soil moisture content during imposition of water-stress treatments.

Table 1. Mean dry weight of roots removed from sunken pots (July 29, 1982).

Rootstock	Water-stress treatment	Mean DW (g)^z
Mahaleb	Check	38.2
	Water-stressed	36.2
Mazzard	Check	49.9
	Water-stressed	48.1

^{z}Mean of 10 pots

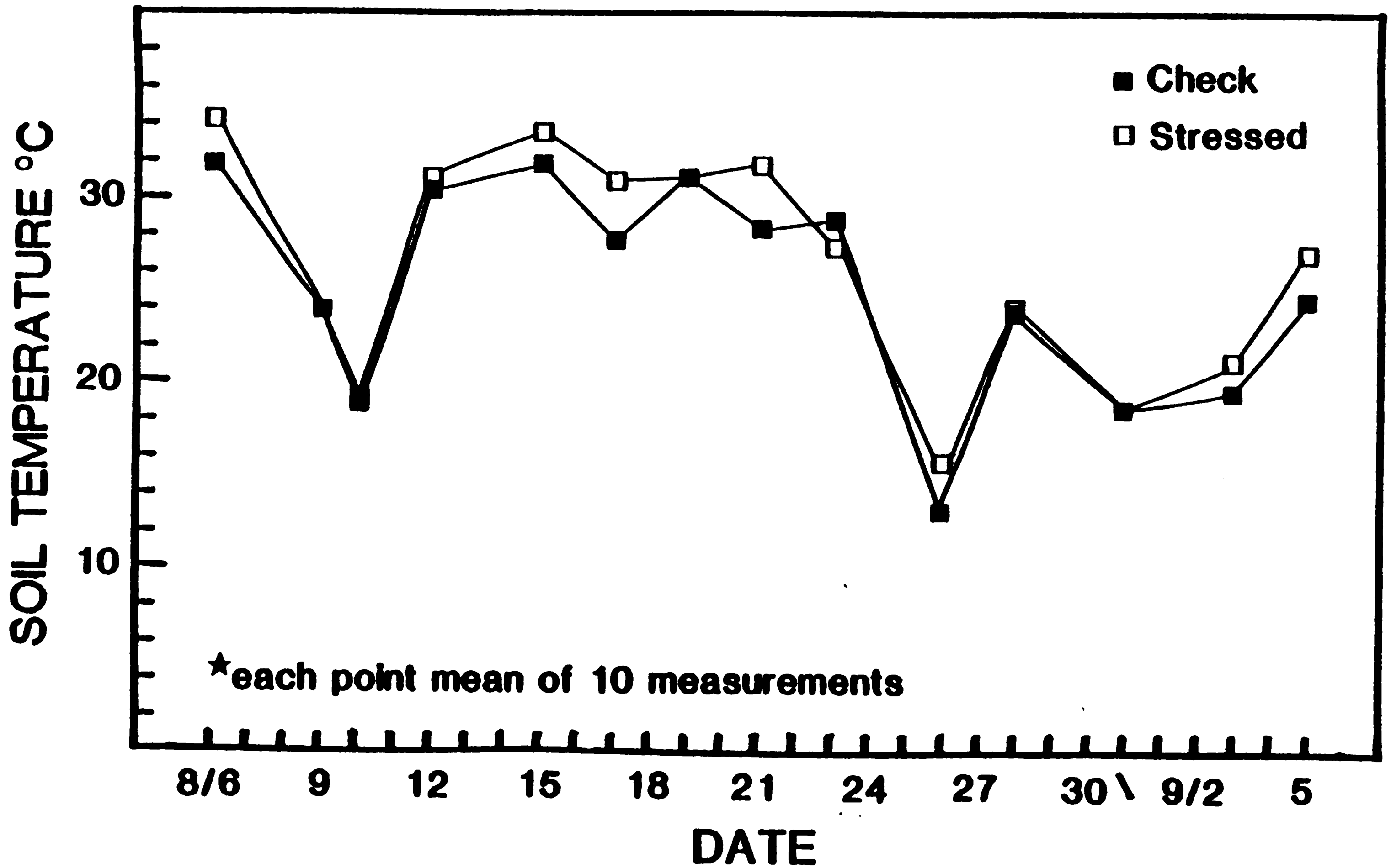

Figure 2. Soil temperature during imposition of water stress treatments.

all trees defoliated in the Autumn.

In view of the fact that RGP seems to be at least correlated with accumulation of chilling hours and bud activity, we chose to evaluate the regenerative capacity of these stocks at points in the yearly growth cycle where past research has found both maxima and minima. Thus, trees from each rootstock/water-stress combination were randomly divided into 6 groups for RGP evaluation at different growth stages (Table 2). Trees selected for Winter and Spring occurring stages remained in field location but were mulched with straw for Winter protection.

Procedure for RGP evaluation:

Trees removed to the greenhouse for RGP evaluations were sprayed with a fungicide (Ferbam at 7 g per l) to help protect the canopy from possible fungal attack while in the Ventilated High Humidity Propagator, Model 520 (Agritech, Inc., Raleigh, NC) and subsequent mist bench.

Trees were depotted and all roots smaller than 2 mm diameter were removed in order to facilitate later evaluation of RGP. The trimmings were dried and then weighed. These and all subsequent shoots, leaves, roots, etc., were dried for at least 1 week at 75^{o}C in a forced air oven. Trees were weighed, repotted in 10 liter containers filled with coarse sand. Trees were watered and placed in humidity propagator. Trunk circumference was measured at the start and end of the evaluation period. Trees removed for evaluation #6 had one shoot tagged and it's growth during the evaluation period measured to the last fully expanded leaf.

After one week in the humidity propagator, trees were moved to an overhead mist bench. After another week, trees were moved to the

Table 2. Morphological characteristics of seedling rootstocks at start of RGP evaluations.

Growth stage	Status of shoot system	Date^{z}
1	Shoot elongation completed Inception of term. bud scales	10-6
2	Dev. of fall coloration Dev. of bud scales Onset of shoot dormancy	10-29
3	Shoot in deep dormancy (rest)	1-11
4	Terminal bud swell	4-13
5	Terminal buds broken First leaf expansion	4-28
6	Some leaves full size Rapid shoot elongation	6-13

^{z}At start of 30 day RGP evaluation period.

greenhouse floor for the remainder of the 30 day RGP evaluation period. Environmental conditions at the 3 locations are summarized in Table 3.

While on the greenhouse floor all trees received approximately 100 $\mu mols^{-1}m^{-2}$ PAR supplemental lighting from Metal Halide HID lamps for 16 hours each day. These trees also received a daily irrigation with 1 liter of quarter strength Hoagland's solution (Epstein, E. 1972. Mineral nutrition of plants, Wiley, p 39).

At the end of the 30 day RGP evaluation period, sand was gently washed from the roots. All new white roots originating on the shank (vertical axis of the root system from the soil line to the first lateral root) were counted and removed. All new white roots originating on the remainder of the root scaffold were then counted and removed. In this experiment, roots were counted at their point of origin. Therefore, a large new root with multiple branches still counted as one root. The remainder of the tree was partitioned into root axis and scaffold, 2 year-old wood and previous season's shoot growth as depicted in Figure 3. for dry weight determinations. Trees of evaluation #6 were further partitioned into current season's shoot growth and leaf canopy. Leaf area was measured with a Li-Cor Portable Area Meter, Model LI-3000 (Lambda Instruments Corp., Lincoln, NE).

A randomized, complete block design was utilized with growth stage split on rootstock and irrigation treatments. Four replications were used with 3 samples of each treatment combination. All variables expressed as percentages were analyzed as arcsin $\sqrt{y}$.

Table 3. Summary of environmental conditions (temperature and % relative humidity-RH) during RGP evaluations.

		Temperature[z]				
		Root zone[y]		Canopy zone[x]		
Growth stage	Location[w]	Mean min.	Mean max.	Mean min.	Mean max.	Mean % RH
1	HP	-	-	14.7	19.9	99.5
	MB	-	-	15.3	25.7	79.2
	GR	19.3	29.1	20.6	33.7	53.5
2	HP	-	-	17.6	23.8	99.3
	MB	16.1	21.3	15.1	23.6	68.6
	GR	19.6	26.3	20.7	28.9	47.7
3	HP	-	-	14.1	23.1	96.0
	MB	15.2	23.3	14.4	25.7	63.4
	GR	18.8	25.8	19.3	27.9	46.1
4	HP	-	-	15.7	24.7	91.3
	MB	13.3	25.8	11.7	28.2	62.5
	GR	17.4	30.6	17.8	32.6	46.3
5	HP	-	-	16.6	24.5	91.7
	MB	12.8	25.3	11.7	23.7	67.5
	GR	16.9	31.2	17.3	31.9	50.1
6	HP	-	-	18.8	28.1	92.7

[z]°C.
[y]Measured 25 cm from floor.
[x]Measured 1 m from floor.
[w]HP=Humidity propagator, MB=Mist bench, GR=Greenhouse floor.

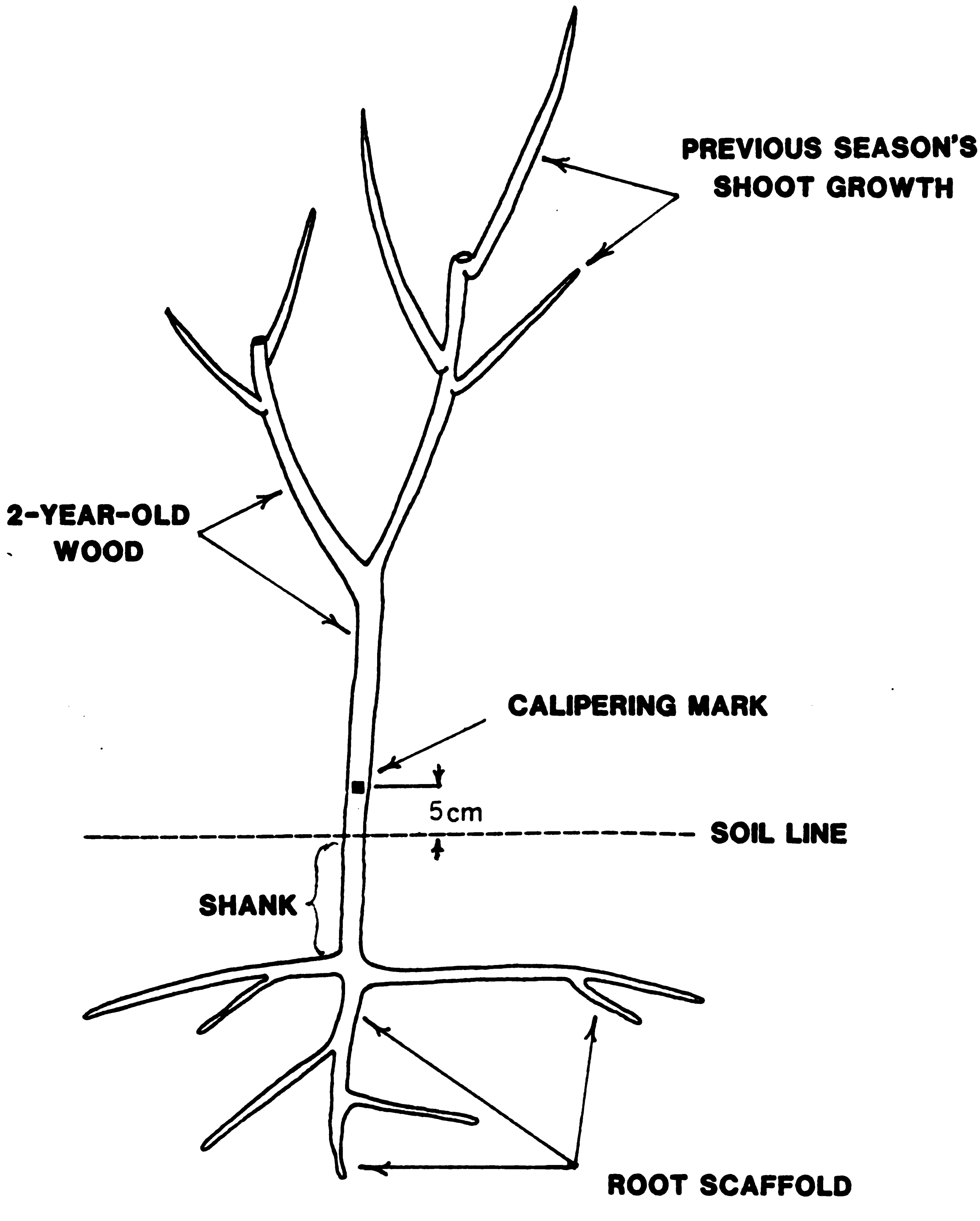

Figure 3. Dry weight (dw) partition categories for harvest at end of RGP evaluations.

Results.

Growth stage effects.

When measured as total number of new roots per tree, there were significant differences between the various growth stages with the spring evaluations (#4-#6) generally being much better than the fall evaluations (#1-#3) as shown in Table 4. However, a growth stage x rootstock interaction at the 1% level was present. As a group, all 3 spring evaluations of Mazzard were significantly better than the fall evaluations. Mahaleb was not so consistent in that it performed best at bud swell and during rapid shoot elongation (stages #4 and #6), poorest during stages #1 and #2 and at an intermediary level during stages #3 and #5 as depicted in Figure 4.

Maximum RGP occurred at bud swell for Mazzard, while for Mahaleb peak RGP occurred during rapid shoot elongation with some leaves fully expanded. Both species displayed marked drop-off's in RGP at first leaf expansion and minimum RGP's during growth stage #2.

When measured as total number of new roots per 100 g total plant dw, the same pattern was seen as above. Again a stock x growth stage interaction at the 1% level was present in that Mazzard displayed significantly greater new root production than Mahaleb during bud swell and first leaf expansion as shown in Figure 5.

Number of shank roots produced per tree (i.e. roots produced along the vertical axis of the rootstock from the first lateral root to the soil line) was markedly better during first leaf expansion and rapid shoot extension as shown in Table 5. A growth stage x rootstock interaction at the 5% level was present in that Mazzard was markedly

Table 4. Total number of new roots produced per tree at 6 growth stages, averaged over rootstock and water-stress treatments.

	Growth stage					
	1	2	3	4	5	6
Total # new roots per 100 g total plant dw	73.5c^{z}	47.5c	93.5ab	285.7a	172.9b	306.3a

^{z}Values followed by same letter not significant different at 5% level, DMR test.

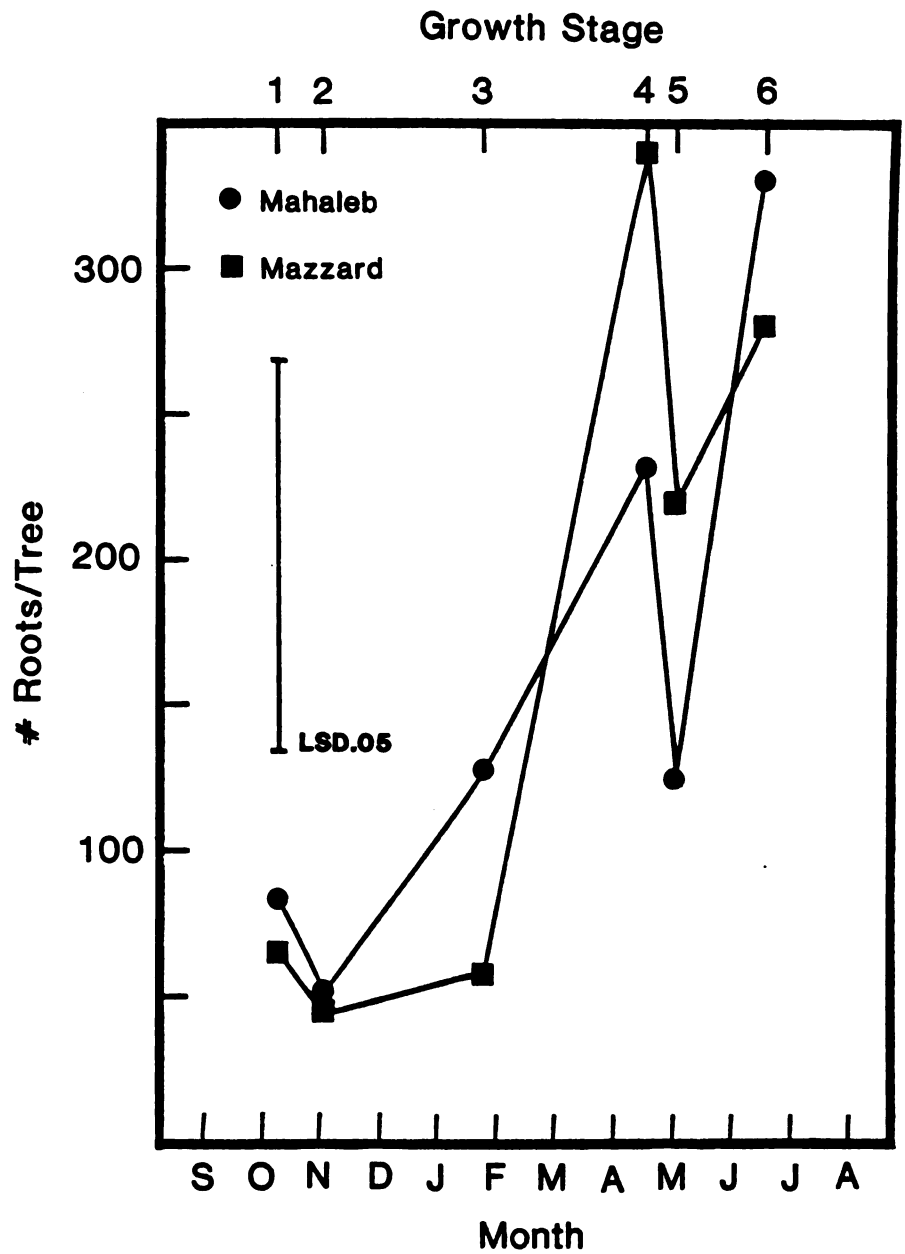

Figure 4. Rootstock and growth stage effects on total numbers of new roots produced per tree, averaged over water-stress treatments.

Roots/100 g DW

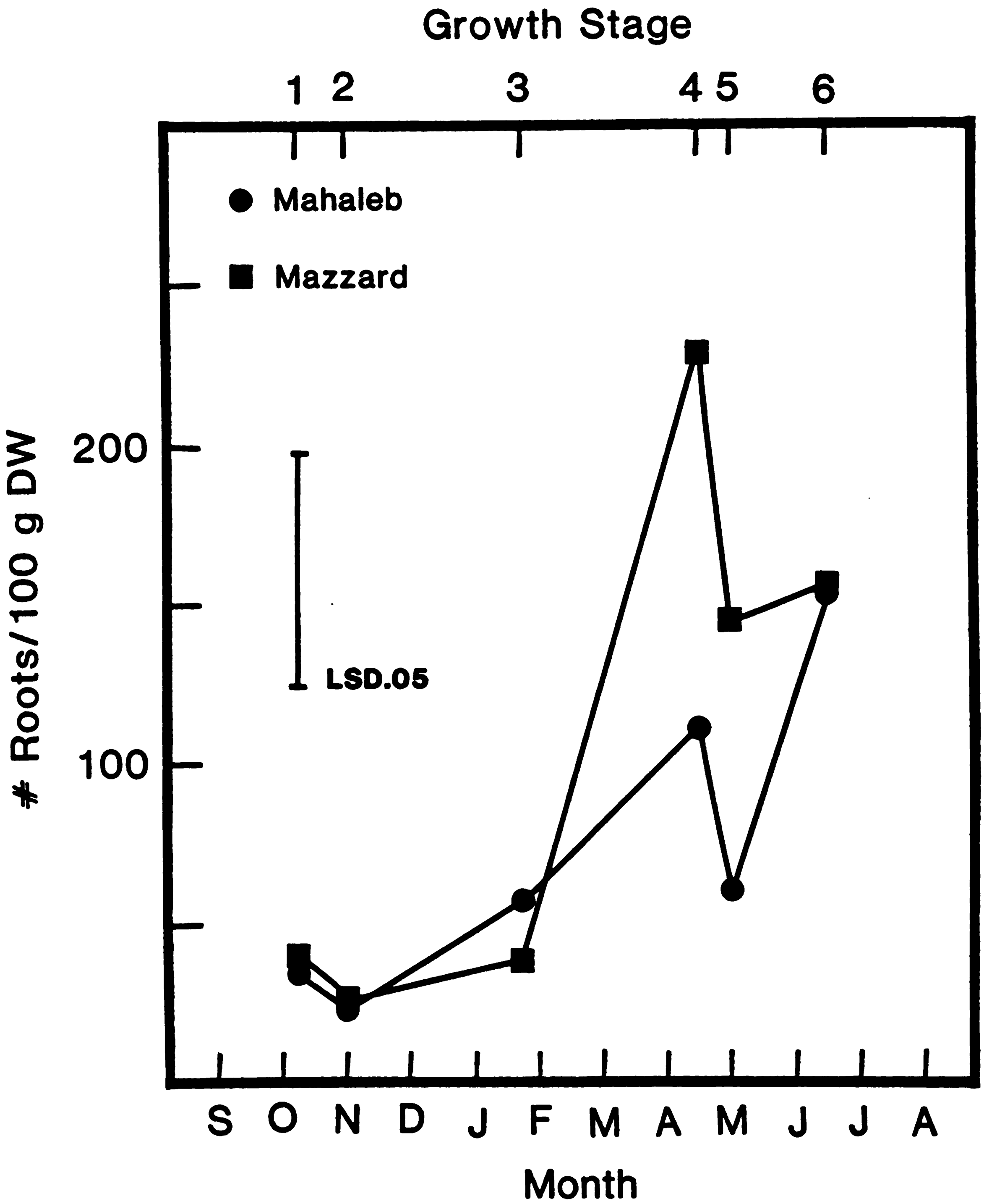

Figure 5. Rootstock and growth stage effects on total numbers of new roots produced per 100 g total plant dw, averaged over water-stress treatments.

Table 5. Growth stage effects on number of shank roots produced per tree, averaged over rootstock and water-stress treatments.

	Growth stage					
	1	2	3	4	5	6
# shank roots per tree	0.8B[z]	0.1B	0.9AB	1.5AB	4.0A	5.9A

[z]Values followed by same letter not significantly different at 1% level, DMR test.

superior to Mahaleb at first leaf expansion while no significant difference was noted at any other evaluation as shown in Figure 6.

Capacity to replace pruned-off roots, i.e. roots less than 2 mm diameter removed during preparation for RGP evaluations, was markedly better during all spring growth stages than any fall evaluations as shown in Table 6. A rootstock x growth stage interaction at the 1% level was present in that Mazzard performed markedly better in all 3 spring evaluations while Mahaleb showed significant improvement only during the last evaluation (rapid shoot elongation) as depicted in Figure 7.

Total new root dw per plant was significantly different throughout the 6 evaluations. However, a rootstock x growth stage interaction at the 1% level was present in that although all spring evaluations of Mazzard were significantly better than any fall evaluations, only the growth stage 6 evaluation (rapid shoot elongation) of Mahaleb was a significant improvement over any other evaluation. There were no significant differences between Mazzard and Mahaleb except at bud swell as shown in Table 7.

New root dw per 100 g total tree dw (or trunk cross-sectional area) displayed much the same pattern as new root dw per plant (data not shown).

Rootstock effects.

Mazzard was significantly better than Mahaleb in capacity to produce shank roots and replace pruned-off roots as shown in Table 8. In both cases, a significant rootstock x growth stage interaction has been previously described.

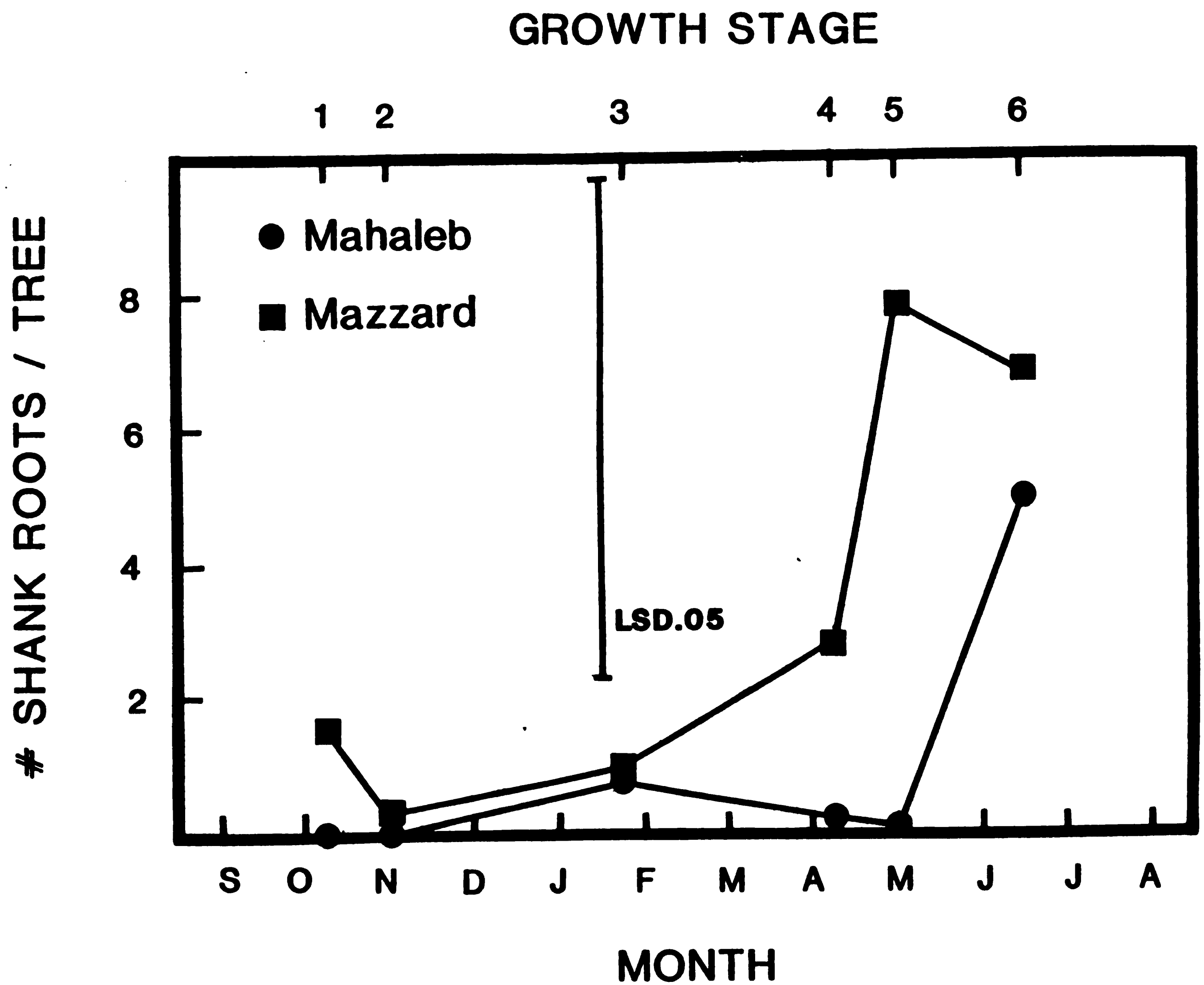

Figure 6. Rootstock and growth stage effects on total numbers of shank roots produced per tree, averaged over water-stress treatments.

Table 6. % rootsystem dw regenerated[z] at 6 growth stages averaged over rootstock and water-stress treatments.

	Growth stage					
	1	2	3	4	5	6
% root dw regenerated	2.9B[y]	2.1B	2.9B	11.6A	9.9A	13.4A

[z]Calculated as 100 times total new root dw divided by trimmed root dw, i.e. dw of roots, less than 2 mm in diameter, removed during preparation for RGP evaluation.
[y]Values followed by same letter not significantly different at 1% level, DMR test.

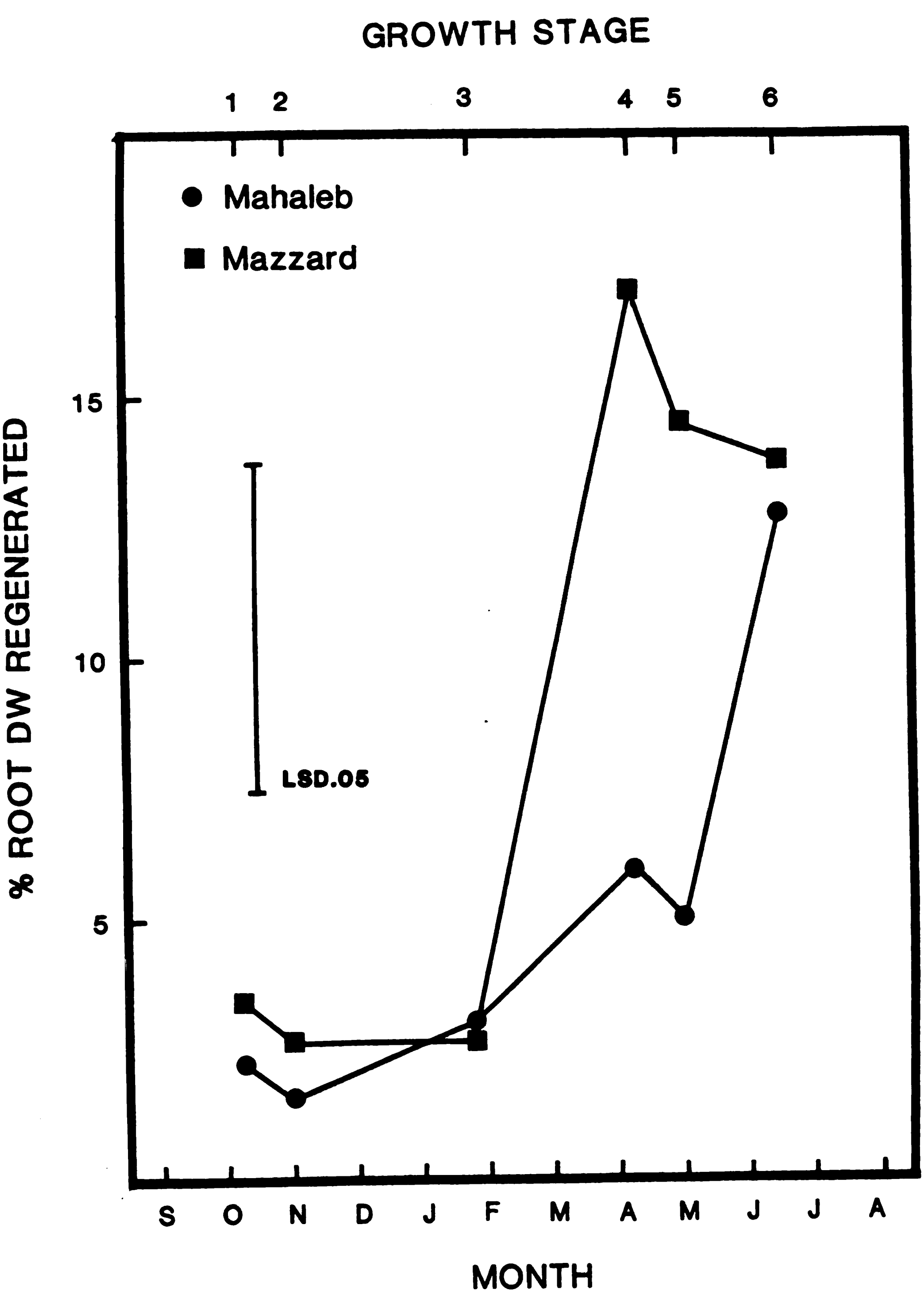

Figure 7. Rootstock and growth stage effects on percent root dw regenerated during RGP evaluations, averaged over water-stress treatments.

Table 7. Total new root dw produced per tree[z] by 2 seedling cherry rootstocks, Mahaleb and Mazzard at 6 growth stages, averaged over water-stress treatments.

	Growth stage					
Rootstock	1	2	3	4	5	6
Mahaleb	396aB[y]	273aB	483aB	986bB	661aB	2546aA
Mazzard	374aB	288aB	318aB	1948aA	1430aA	1590bA

[z]Reported as mg per tree.
[y]Values in same column followed by same lower case letter not significantly different at 5% level, LSD test.
Values in same row followed by same upper case letter not significantly different at 5% level, DMR test.

Table 8. Comparison of 2 seedling cherry rootstocks, Mahaleb and Mazzard, in capacity to produce shank roots and replace pruned-off roots, averaged over water-stress and growth stage treatments.

Rootstock	# shank roots per tree	% root dw regenerated[z]
Mahaleb	1.0b[y]	5.2b
Mazzard	3.4a	9.1a

[z]Calculated as 100 times total new root dw divided by trimmed root dw, i.e. total dw of roots, less than 2 mm diameter, removed during preparation for RGP evaluations.
[y]Values in same column followed by same letter not sig. different at 5% level, LSD test.

RGP expressed as new root dw (or total numbers) per 100 g total plant dw showed Mazzard to be superior to Mahaleb as shown in Table 9 A significant interaction between rootstock and growth stage has been previously described.

Overall, Mazzard was a smaller tree than Mahaleb when compared on a fresh weight (fw), dry weight (dw) or trunk cross-sectional area basis throughout the experiment as shown in Table 10.

Water-stress effects.

In spite of significant water-stress effects on total plant dw and cross-sectional area, there were no significant water-stress treatment effects on RGP except on replacement of pruned-off roots as shown in Table 11.

Relative pruning intensity during preparation for RGP evaluations varied with water-stress treatments. A rootstock x water-stress interaction at the 1% level was present in that control Mahaleb treatments were much more heavily pruned than water-stressed Mahaleb treatments when compared with check Mazzard treatments and their water-stressed counterparts as shown in Table 12. This was inadvertent; apparently small diameter roots, i.e. less than 2 mm, made up a substantially larger proportion of the rootsystem in check water-stress Mahaleb treatments.

Table 9. Total new root dw and numbers of new roots per 100 g total plant dw by 2 seedling cherry rootstocks, Mahaleb and Mazzard, averaged over water-stress and growth stage treatments.

Rootstock	New root dw (g) per 100 g total tree dw	Total # new roots per 100 g total tree dw
Mahaleb	0.42b[z]	73.5b
Mazzard	0.62a	106.3a

[z]Values in same column followed by same letter not significantly different at 5% level, LSD test.

Table 10. Comparison of 2 seedling cherry rootstocks, Mahaleb and Mazzard, in total plant dw and cross-sectional area, averaged over water stress and growth stage treatments.

Rootstock	Total plant fw(g)^z	Total plant dw(g)	Trunk x-sectional area (cm^2)^y
Mahaleb	206.7A^x	221.5A	3.5A
Mazzard	167.2B	158.7B	2.9B

^{z}As measured at time of initial containerization (1982).
^{y}As measured at end of RGP evaluations
^{x}Values in same column followed by same letter not sig. different 1% level, LSD test.

Table 11. Water-stress effects on total tree dw, trunk cross sectional area and % root dw regenerated, averaged over rootstock and growth stage treatments.

Water stress treatment	Total tree dw (g)	Trunk cross sectional area (cm^2)	Root dw regenerated (%)[z]
Check	209.8a[y]	3.4A[x]	6.0b
Stressed	170.4b	3.0B	8.3a

[z]Calculated as 100 times total new root dw divided by trimmed root dw, i.e. total dw of roots, less than 2 mm in diameter, removed during preparation for RGP evaluation.
[y]Values in same column followed by same lower case letter not significantly different at 5% level, LSD test.
[x]Values in same column followed by same upper case letter not significantly different at 1% level, LSD test.

Table 12. % rootsystem dw[z] removed from various rootstock/water-stress treatment combinations, averaged over all growth stages.

Water stress treatment	Rootstock treatment: Mahaleb	Mazzard	Combined
Check	21.6A[y]	15.4A	18.5A
Stressed	15.9B	13.9A	14.9B

[z]Calculated as 100 times trimmed root dw, i.e. total dw of roots, less than 2 mm in diameter, removed during preparation for RGP evaluation, divided by root scaffold dw (at end of experiment).
[y]Values in same column followed by same letter not sig. different at 1% level, LSD test.

Discussion.

Growth stage effects.

Numerous authors working with various temperate deciduous species have noted the need for physiologically non-dormant buds as a prequisite for high RGP (12,14,17,24,35,36). While root growth may occur all year long in undisturbed conifers and some hardwoods if soil temperatures are mild, root activity as a rule remains low until the buds are physiologically non-dormant (11,37). This would also seem to be the case in this experiment as RGP was consistently higher in Spring (i.e. active buds) evaluations.

The pronounced depression of RGP in both species at growth stage 5 (first leaf expansion) is most likely due to competition between the shoot and root systems for stored reserves. Such an effect has been noted in many woody species studied (4,16,28,34). Hansen (8) suggests that early growth of apple shoots is largely supported by internal reserves, at least until the shoot has 5-6 fully expanded leaves at which time the shoot becomes a net exporter of photosynthates. Presumably, at this time competition for stored reserves would lessen, indeed, be supplanted by current photosynthates and high RGP would again be possible. This seems to be the case with growth stage 6 trees (rapid shoot elongation) which had an average of 10 fully expanded leaves at the start of the RGP evaluation period and which subsequently displayed some of the highest RGP's observed.

Many researchers working with deciduous hardwoods have noted a minima in RGP during winter rest (2,16,32,35,36) presumably due to bud dormancy. Webb (35,36) demonstrated a strong correlation between chilling hours received and RGP in Acer saccharum Marsh, A. saccharinum L. and Fraxinus americana L. Based on these investigations one would expect a RGP minimum in growth stage 3 trees (trees defoliated, shoots in deep dormancy) which appears contrary to the results obtained. Due to the unusually mild winter of 1982-1983, these trees received approximately 750 chilling units when calculated according to Swartz and Gray's (31) modification of Richardson's, et al (23) method. This is within the low end of the range of chilling hours reported for flower buds of various P. avium cvs., i.e. 600-1400 hours (1). However, work with apples and peaches has shown that vegetative buds typically have a higher chilling requirement than flower buds (3,38).

An additional factor needs to be considered. All trees in this experiment were maintained under high humidity during the first 2 weeks of the RGP evaluation period, often with wet stem and bud surfaces. Rainfall or water soaking has been shown to be effective in reducing the chilling requirement in apple and pear flower buds (38). The fact that 63% and 83% of the Mahaleb and Mazzard rootstocks, respectively, broke dormancy during this evaluation would seem to indicate that these trees were, in fact, not at rest but actually quiescent.

In contrast, growth stage 2 trees experienced less than 200 chilling units prior to their RGP evaluations and, subsequently, no trees broke dormancy in this group which displayed the minimum RGP observed in the experiment. Therefore, it would appear that the RGP of these 2 species is responsive to the accumulation of chilling units as noted in other temperate deciduous species.

Rootstock effects.

Mazzard's significant advantage over Mahaleb in new root dw (and numbers) per 100 g total plant dw, capacity to replace pruned-off roots and production of shank roots during early spring growth stages, is interesting in light of Mazzard's noted superiority in resisting various root rots when compared to Mahaleb (19,20). Perry (22) noted an association between propensity for adventitious rooting at the crown and high RGP with resistance to Phymatotrichum root rot in grapes. Garrett (6) found the ability to generate crown roots important to wheat resistance to "take-all" disease. Thus, Mazzard may physically escape root rot organisms. This area clearly deserves more investigation.

Mazzard's apparent superiority over Mahaleb in capacity to replace pruned-off roots requires cautious interpretation in view of corresponding differences in severity of root pruning during preparation for RGP evaluations. Mazzard suffered the loss of only 11.6 g (dw) of roots compared to 21.5 g for Mahaleb, representing 17.1%** and 23.8%** of the root system, respectively (**significantly different at 1% level, LSD test). Larson (13) has shown that severe pruning of Quercus rubra L. root systems, i.e. 48% (dw basis), significantly reduced new root dw. However, in the same study, less severe pruning of 14% and 33% resulted in non-significant reductions in new root dw. In our experiment, there were no significant differences between pruning intensities at any growth stage (data not shown) that would correspond with the spring growth stage differences between Mahaleb and Mazzard in replacement of pruned-off roots. This area deserves more investigation before a firm conclusion can be drawn.

Water stress effects.

Rook (27) demonstrated that subjecting pine seedlings to water stress prior to transplanting improved their subsequent RGP. However, this effect was transitory, disappearing after 40 days. In this experiment, the effect appeared to last for 9 months albeit to a lesser extent during the later trials (data not shown). Drought treatments significantly reduced trimmed root dw removed during preparation for RGP evaluations from 20.7 g per plant to 12.3 g representing 23.5%** and 17.6%** of the root system, respectively (**significantly different at the 1% level, LSD test). Therefore, these presumed drought effects may be attributable to relative pruning intensity and will require further experimentation in order to comment confidently on their cause.

Literature Cited.

1. Chandler, W.H., et al 1937. Chilling requirements for opening of buds on deciduous orchard trees and some other plants in California, Calif. Agr. Exp. Sta. Bull. 611.

2. Dumbroff, E.B. and D.C.W. Brown 1976. Cytokinin and inhibitor activity in roots and stems of sugar maple seedlings through the dormant season, Can. J. Bot. 54:191-197.

3. Eggert, F.P. 1951. A study of rest in several varieties of apple and in other fruit species grown in New York State, Proc. Amer. Soc. Hort. Sci. 57:169-178.

4. Eliasson, L. 1971. Adverse effects of shoot growth on root growth in rooted cuttings of aspen, Physiol. Plant. 25:268-272.

5. Farmer, R.E., et al 1975. Effects of chilling and pruning in forcing dormant black cherry, Can. J. For. Res. 5:160-162.

6. Garrett, S.D. 1948. Soil conditions and the "take-all" disease of wheat, In: IX Interaction between host plant nutrition, disease escape and disease resistance, Ann. Appl. Biol. 35:14-17.

7. Hansen, P. 1971. ^{14}C studies on apple trees. VII The early seasonal growth in leaves, flowers and shoots as dependent upon current photosynthates and existing reserves, Physiol. Plant. 25:469-473.

8. Heningen, R.L. and D.P. White 1974. Tree seedling growth at different soil temperatures, For. Sci. 10:142-147.

9. Heth, D. 1980. Root and shoot water potentials in stressed pine seedlings, N. Z. J. For. Sci. 10:142-147.

10. Kelly, O.J., et al 1945. The effect of moisture stress on nursery-grown guayle with respect to the amount and type of growth and growth response on transplanting, Amer. Soc. Agron. J. 37:194-216.

11. Kreuger, K.W. and J.M Trappe. 1967. Food reserves and seasonal growth of Douglas-fir seedlings. For. Sci. 13:192-202.

12. Larson, M.M. 1970. Root regeneration and early growth of red oak seedlings: influence of soil temperature, For. Sci. 16:442-446.

13. Larson, M.M. 1975. Pruning northern red oak nursery seedlings: effects on root regeneration and early growth, Can. J. For. Res. 5:381-386.

14. Larson, M.M. 1978. Effects of late season defoliation and dark periods on initial growth of planted northern red oak seedlings, Can. J. For. Res. 8:67-72.

15. Larson, M.M. and F.W. Whitmore 1970. Moisture stress effects root regeneration and early growth of red oak seedlings, For. Sci. 16:495-498.

16. Lee, C.I. and W.P. Hackett 1976. Root regeneration of transplanted Pistacia chinensis Bunge. seedlings at different growth stages, J. Amer. Soc. Hort. Sci. 101:236-240.

17. Lee, C.I., et al 1974. Root regeneration of transplanted pin and scarlet oak, The New Horizons, The Hort. Res. Inst., Washington, DC pp 10-14.

18. Lyr, H. and G. Hoffman 1967. Growth rates and growth periodicity of tree roots, Int. Rev. For. Res. 2:181-236.

19. Mircetich, S.M. and M.E. Matheron 1976. Phytophthora root and crown rot of cherry trees, Phytopathology 66:549-558.

20. Mircetich, S.M., et al 1976. Root and crown rot of cherry trees, Calif. Agr. 30(8):10-11.

21. Nambiar, E.K.S., et al 1979. Root regeneration and plant water status of Pinus radiata seedlings transplanted to different soil temperatures, J. Exp. Bot. 30:1119-1131.

22. Perry, R.L. 1980. Anatomy and morphology of Vitis roots in relation to pathogenesis caused by Phymatotrichum omnivorum, Ph.D. Diss., Texas A & M, College Station, Texas, USA.

23. Richardson, E.A. and S.D. Seeley 1974. A model for estimating the completion of rest for "Redhaven" and "Elberta" peach trees, HortScience 9:331-332.

24. Richardson, S.D. 1958. Bud dormancy and root development in Acer saccharinum, In: K.V. Thimann (ed) The physiology of forest trees, pp 409-425.

25. Ritchie, G.A. and J.R. Dunlap 1981. Root growth potential: Its development and expression in forest tree seedlings, N. Z. J. For. Sci. 10:218-248.

26. Rook, D.A. 1971. Effect of undercutting and wrenching on growth of Pinus radiata seedlings, J. Applied Ecol. 8:477-490.

27. Rook, D.A. 1973. Conditioning radiata pine seedlings to transplanting by restricted watering, N. Z. J. For. Sci. 3:54-69.

28. Stone, E.C. and J.L. Jenkinson 1970. Influence of soil water on root growth capacity of ponderosa pine transplants, For. Sci. 16:230-239.

29. Stone, E.C., et al 1962. Root regeneration potential of douglas-fir seedlings lifted at different times of the year, For. Sci. 8:288-297.

30. Stone, E.C. and G.H. Shubert 1959. Root regeneration by ponderosa pine seedlings lifted at the different times of the year, For. Sci. 5:322-332.

31. Swartz, H.J. and S.E. Gray 1982. Annual chill unit accumulation in the United States, Fruit Var. J. 36:80-83.

32. Taylor, J.S. and E.B. Dumbroff 1975. Bud, root and growth regulator activity in Acer saccharum during the dormant season, Can. J. Bot. 53:321-331.

33. Wakeley, P.C. 1948. Physiological grades of southern pine nursery stock, Soc. Amer. For. Proc. 43:311-322.

34. Webb, D.P. 1976a. Root growth in Acer saccharum Marsh. seedlings: effects of light intensity and photoperiod on root elongation rates, Bot. Gaz. 137: 211-217.

35. Webb, D.P. 1976b. Effects of cold storage duration on bud dormancy and root regeneration of white ash, Fraxinus americana L., seedlings, HortScience 11:155-157.

36. Webb, D.P. 1977. Root regeneration and bud dormancy of sugar maple, silver maple and white ash seedlings: effects of chilling, For. Sci. 23:474-483.

37. Webb, D.P. and E.B. Dumbroff. 1978. Root growth in seedlings of Acer saccharum. Proc. IUFRO symp. on root physiol. and symbiosis. Nancy, France.

38. Weinberger, J.H. 1950. Prolonged dormancy of peaches, Proc. Amer. Soc. Hort. Sci. 56:129-133.

SECTION II.

SCION AND GRAFT UNION EFFECTS ON ROOT GROWTH POTENTIAL (RGP) OF CONTAINERIZED, SEEDLING CHERRY ROOTSTOCKS, MAHALEB AND MAZZARD.

ABSTRACT

Root growth potential (RGP) was evaluated in two seedling cherry rootstocks, *Prunus mahaleb* L. and *P. avium* L. cv. Mazzard at bud swell following 2 growth cycles. Each of these stocks was budded in three combinations: unbudded, budded with *P. cerasus* cv. Montmorency, and with itself, i.e. Mazzard F12/1 on Mazzard stocks and Mahaleb (single bud source) on Mahaleb stocks. Mazzard rootstocks displayed a significantly higher RGP than Mahaleb rootstocks when measured as total numbers of new roots per tree or per 100 g total plant dry weight. Presence of Montmorency as a scion on Mazzard rootstocks significantly increased new root production compared to unbudded stocks and those budded with Mazzard F12/1. No comparable effect was seen when Montmorency was budded on Mahaleb stocks.

Literature Review

The effects of the rootstock on the growth and morphology of the scion in a 2-piece tree are well documented (1,20,21,25,27), but there is relatively little information which describes the influence of the scion or of the graft union on the morphology or performance of the rootstock rootsystem, particularly its Root Growth Potential (RGP).

Early studies noted striking scion effects on seedling rootstock morphology particularly branching, extensiveness and direction of growth (16,17,18,24). The investigators of these studies concluded that the seat of this influence resides in the stempiece and, therefore, if the scion was grafted directly onto a rootpiece the scion will dominate the rootstock in control of tree growth.

Later researchers studying clonal apple rootstocks, refuted this theory and instead concluded that the rootstock retained its own distinct morphology regardless of scion or presence/absence of rootstock stempiece (21,25,26). It has been noted that a tree's shoot/root ratio remains remarkably constant for a given soil type and scion across a broad range of size controlling rootstocks (10,21,25), indicating an integrated control over total tree growth by both scion and rootstock.

Scion influence on Root Growth Potential has been documented in *Quercus* spp. (13) and in *Rosa* spp. (14). The mechanism of this effect was inconclusive, but there appeared to be evidence that control is associated with translocatable factors from the scion.

Studies of the effects of graft unions on xylem sap composition have noted significant differences,in sap dw above and below the union of apple cvs (8) and apparent restrictions in acropetal movement of major and secondary nutrients through the graft union (2,7,8). Differences were generally in proportion to the dwarfing influence of the the apple stocks. A comparison of own rooted peach cvs with the same cvs budded to various seedling rootstocks demonstrated a reduction in canopy content of N, Mg and Ca in the budded treatments (3). Impact of these apparent restrictions in nutrient movement on root growth was not determined.

The purpose of this research was to investigate the effects of scion and presence/absence of a graft union on the Root Growth Potential of 2 seedling cherry rootstocks.

Materials and Methods.

One year-old seedlings of Mahaleb and Mazzard were planted in early April, 1982, in 7 liter containers using a 3:1 soil:sand mix.

During the first week of June, these trees were budded 8-9 cm above the soil line in the following combinations:

1. Mahaleb unbudded (suppressed lateral bud forced)
2. Montmorency/Mahaleb
3. Mahaleb/Mahaleb (all buds from single source tree)
4. Mazzard unbudded
5. Montmorency/Mahaleb
6. Mazzard F12-1/Mazzard

All stocks were cut just above the bud a week later and buds forced within 4-5 days. Unbudded stocks were cut at approximately 10 cm in order to force a suppressed lateral bud into vigorous growth. Trees were grown under lathe (estimated at 50% shade) and watered regularly. Fertilization consisted of 20-20-20 NPK (Peter's Fertilizer Products, W.R. Grace and Co., Fogelsville, PA) diluted to 400 ppm N and applied in mid-July. Fertilization was repeated in mid-August at 200 ppm N. Trees were sprayed as needed for pests.

Trees were allowed to defoliate naturally in the Fall and chilling requirement was satisfied by 10 weeks at $2^{o}C$ in cold storage. Trees were then moved to a greenhouse for a second growing period under supplemental lighting (16 hours/day, 100 $\mu mol s^{-1} m^{-2}$ PAR) from January 21 to March 31. Mean minimum/maximum temperature during this period was $19.1/27.4^{o}C$ (measured at canopy height). At the end of the growing period trees were defoliated manually and returned to $2^{o}C$ cold storage for 2 months. In June, 1983 trees were heeled-in at the nursery. At bud swell (6/27), 6 trees of each budding combination were taken to the greenhouse and prepared for RGP evaluations as follows:

1. Canopy, shoots and stems were sprayed with a fungicide (Ferbam at 7 g/l) to help protect the canopy from fungal attack while in the Ventilated High Humidity Propagator (Model 520, Agritech, Inc., Raleigh, NC).
2. Trees were depotted and all roots less than 2 mm in diameter were removed in order to facilitate later evaluation of RGP. These and all subsequent shoots, leaves, roots, etc. were dried for at least 1 week at 75^{o}C in a forced air oven before weighing.
3. Trees were weighed and repotted in 7 liter containers filled with coarse sand.

Trees were maintained for the entire 31 day regeneration period in the high humidity propagator under a mean minimum/maximum temperature of 19.6/28.6^{o}C and a mean % relative humidity of 92.2% (all measured at canopy height). At the end of the regeneration period the trees were depotted and the rootsystem gently washed free of sand. All roots arising from the rootstock shank (i.e. vertical axis of the rootsystem from the first lateral to the soil line) were counted and removed. All remaining roots were counted and removed. Tree was then partitioned into leaves, shoots and stem above the graft union (or its equivalent in unbudded treatments), stem from graft union to soil line, and root scaffold, i.e. vertical axis and laterals left after removal of all the fleshy new roots. Leaf area was measured with a Li-Cor Portable Area Meter, Model LI-3000.

A completely randomized design was used with 6 replications of the 6 treatments.

Results.

Statistical analysis was in the manner of orthogonal planned comparisons as described in Table 1. F-test are reported in Table 2 and means of the different variables measured are reported in Table 3.

Rootstock effects.

Mazzard appeared to be superior to Mahaleb in production of total numbers of new roots per tree or per 100 g total plant dry weight (dw). Shoot/root ratio and mean dw per 100 new roots was significantly higher for Mahaleb rootstocks than for Mazzard.

Graft union effects.

Within Mahaleb rootstocks. Presence of a graft union (Mahaleb/Mahaleb) coincided with a larger shoot/root ratio and a larger loss in rootsystem dw (due to removal of roots less than 2 mm diameter during preparation) when compared to unbudded Mahaleb rootstocks.

Within Mazzard rootstocks. Total plant fresh weight (fw), as measured at start of regeneration period, was greater on self-budded Mazzard rootstocks (Mazzard F12-1/Mazzard) when compared to unbudded Mazzard rootstocks.

Scion effects.

Within Mahaleb rootstocks. Total leaf dw was greater when Montmorency was present as scion when compared to unbudded and self-budded Mahaleb rootstocks.

<u>Within Mazzard rootstocks</u>. Montmorency, when present as scion, significantly increased total numbers of new roots per tree (or 100 g total plant dw) and numbers of shank roots per tree when compared to unbudded and self-budded Mazzard rootstocks.

No significant differences were noted in any comparisons of total new root dw per tree, % rootsystem replaced per tree, total leaf area per tree, specific leaf weight, total shoot dw per tree or total root scaffold dw per tree.

Table 1. Planned comparisons and coefficients for analysis of variance.

	Scion/stock combination[z]					
Comparison[y]	MB	MB/MB	MT/MB	MZ	F12/MZ	MT/MZ
C1	1	1	1	-1	-1	-1
C2	1	-1	0	0	0	0
C3	1	1	-2	0	0	0
C4	0	0	0	1	-1	0
C5	0	0	0	1	1	-2

[z]MB=Mahaleb seedling (single source tree when used as scion), MT=Montmorency, MZ=Mazzard seedling, F12=Mazzard F12/1

[y]C1=Mahaleb vs Mazzard rootstocks.
C2=Unbudded (MB) vs budded (MB/MB) within Mahaleb rootstocks.
C3=Montmorency (MT/MB) vs Mahaleb scion (MB and MB/MB combined).
C4=Unbudded (MZ) vs budded (F12/MZ) within Mazzard rootstocks.
C5=Montmorency (MT/MZ) vs Mazzard scion (MZ and F12/MZ combined).

Table 2. Analysis of variance.

	F value[z]							
	Variable[y]							
Source[x]	1	2	3	4	5	6[w]	7[w]	8
C1	5.75*	10.16**	3.77	1.29	4.65*	0.62	0.46	0.31
C2	0.93	0.70	0.66	0.53	0.04	7.65*	0.49	0.57
C3	0.14	0.04	2.63	0.46	0.14	0.64	0.01	4.38*
C4	0.22	0.64	2.54	0.11	2.48	0.26	0.90	1.01
C5	7.75**	9.81**	11.68**	3.67	0.20	3.45	0.80	2.75
EMS	1052	18160	33.22	0.018	0.699	0.004	0.024	0.233
EMS df[v]	27(3)	26(4)	27(3)	27(3)	23(7)	26(4)	26(4)	27(3)

[z]Significant at the 5% (*) and 1% (**) levels, otherwise nonsignificant.
[y]For descriptions of variables see Table 3.
[x]C1=Mahaleb vs Mazzard rootstocks.
C2=Graft union effects within Mahaleb rootstocks (MB vs MB/MB).
C3=Scion effects within Mahaleb rootstocks (MT/MB vs MB and MB/MB combined).
C4=Graft union effects within Mazzard rootstocks (MZ vs F12/MZ).
C5=Scion effects within Mazzard rootstocks (MT/MZ vs MZ and F12/MZ combined).
[w]Analysis performed on transformed data: arcsin $\sqrt{y}$
[v]Planned comparisons (C1-C5) df=1.

Table 2. (cont'd).

	F value[z]							
	Variable[y]							
Source[x]	9	10	11	12	13	14	15	16
C1	0.23	0.13	1.24	2.70	0.57	15.76**	0.06	10.49**
C2	0.65	3.56	0.29	0.78	3.19	0.00	2.91	9.93**
C3	0.00	0.29	0.96	0.94	0.00	0.67	1.18	0.99
C4	1.64	0.19	4.74*	7.63*	2.38	0.40	0.84	0.27
C5	0.05	1.76	0.96	3.20	3.34	0.00	0.04	2.22
EMS	23844	4.045	75.26	15.31	8.92	3.36	1.41	0.37
EMS DF[w]	27(3)	27(3)	27(3)	26(4)	27(3)	27(3)	27(3)	27(3)

[z]Significant at the 5% (*) and 1% (**) levels, otherwise nonsignificant.

[y]For descriptions of variables see Table 3.

[x]C1=Mahaleb vs Mazzard rootstocks.
C2=Graft union effects within Mahaleb rootstocks (MB vs MB/MB).
C3=Scion effects within Mahaleb rootstocks (MT/MB vs MB and MB/MB combined).
C4=Graft union effects within Mazzard rootstocks (MZ vs F12/MZ).
C5=Scion effects within Mazzard rootstocks (MT/MZ vs MZ and F12/MZ combined).

[w]Planned comparisons (C1-C5) df=1.

Table 3. Effects of rootstock, scion and presence/absence of graft union on RGP and component dry weights (dw) of 2 seedling cherry rootstocks, Mahaleb and Mazzard, each in 3 budding combinations.

	Scion/stock combination[z]					
Variable	MB	MB/MB	MT/MB	MZ	F12/MZ	MT/MZ
1. Total # roots/tree	14.3	32.4	17.2	36.5	27.8	77.3
2. Total # roots/100 g total dw[y]	51.0	116.0	70.0	183.0	121.0	363.0
3. # shank roots/tree	3.5	0.8	6.8	1.5	6.8	14.0
4. Total new root dw/tree	0.06	0.12	0.11	0.15	0.06	0.23
5. Mean dw/100 new roots	0.97	0.87	1.13	0.62	0.26	0.29
6. % rootsystem removed[x]	19.9	28.9	26.5	23.9	25.4	30.1
7. % rootsystem replaced[w]	4.0	8.0	4.5	10.6	3.2	8.7
8. Total leaf dw/tree	0.74	0.95	1.35	1.11	0.83	1.37
9. Total leaf area (cm^2)/tree	215.0	287.0	253.0	278.0	164.0	239.0
10. Specific leaf weight mg/cm^2	5.97	3.78	5.38	4.59	5.10	6.18
11. Total fw/tree[v]	48.0	50.7	53.6	43.5	54.4	44.7
12. Total dw/tree[u]	22.87	24.93	25.84	20.45	26.69	20.07
13. Total shoot dw/tree	10.52	13.60	12.10	10.90	13.56	9.50
14. Total trunk dw/tree[t]	5.33	5.27	6.05	2.79	3.46	3.11
15. Total root scaffold dw/tree[s]	6.28	5.11	6.34	5.65	6.28	6.09
16. Shoot/root ratio[r]	2.63	3.73	2.88	2.49	2.67	2.13

[z]MB=Mahaleb seedling (single source tree when used as scion), MT=Montmorency, MZ=Mazzard seedling, F12=Mazzard F12/1.

[y]All dry weights (dw) and fresh weights (fw) expressed in grams.

[x]Calculated as 100 x total dw of roots less than 2 mm diameter removed during preparation for RGP evaluation (root trimmings) divided by total root trimmings dw and total dw of root scaffold after removal of all new roots at end of experiment.

[w]Calculated as 100 x total dw of new roots divided by total dw of root less than 2 mm diameter removed during preparation for RGP evaluation.

[v]As measured as start of RGP evaluation less total dw of roots less than 2 mm diameter removed during preparation for RGP evaluation.

[u]As measured at end of experiment less new root dw.

[t]Stem tissue from the soil line to bud union (or equivalent in unbudded treatments.

[s]Root axis and laterals minus all new roots.

[r]Calculated as leaf dw + shoot dw + trunk dw divided by root scaffold dw.

Discussion.

Rootstock effects.

Increased shoot/root ratio of Mahaleb rootstocks over Mazzard rootstocks is most likely a direct result of the higher trunk dw/tree for the Mahaleb rootstocks. Shoot/root ratio at time of initial potting was not determined. However, random sampling of the rootstock liners at that time showed that the Mahaleb stocks were generally heavier and of a larger caliper, i.e. 33.8 $\pm$6.9 g and 0.73 $\pm$0.10 cm for Mahaleb stocks vs. 29.1 $\pm$6.1 g and 0.66 $\pm$0.15 cm for the Mazzard stocks (means of 50 samples each). If we were to presume that these seedlings had a similar shoot/root ratio in the seedbed which was disturbed at time of harvest, then, the Mahaleb seedling should have had ample time to restore the ratio during the 2 growth cycles prior to RGP evaluation. Perhaps the different ratios are a result of inherent differences in dw partitioning of the various combinations of scion/stock material. Alternatively, research has shown that the shoot/root ratio of a given scion/stock combination generally varies with relative soil fertility (19,21). Differences between the 2 stocks might simply represent a differential response to the highly artificial conditions of containerization.

Mazzard's apparent superiority over Mahaleb in capacity to produce total numbers of new roots per tree or 100 g total tree dw must be viewed cautiously due to the inordinately large production of new roots by the Montmorency/Mazzard combination. Mahaleb budded with Montmorency showed no similar increase in new root production, (i.e. a rootstock x scion interaction is present). Mahaleb appeared to produce fewer and larger roots than Mazzard, yet total new root dw was similar. This would seem to indicate that Mahaleb may be limited in it's ability to initiate lateral roots and not in it's capacity to increase the mass of a root once initiated.

Studies have demonstrated that root initiation and root elongation are different processes mediated by different factors (11,15). Auxins appear to be of primary importance in root initiation (22), however, other co-factors may be involved also (22). Zaerr (28) has demonstrated that high auxin concentrations seem to stimulate root initiation while lower concentrations tend to favor root elongation. Relative levels of auxins and auxin inhibitors (apparently originating in buds) have also been implicated as a control mechanism (11,12). Partial disbudding experiments and quantification of the relative levels of auxins and co-factors might prove helpful in explaining the RGP differences of these 2 rootstocks.

Highly branched rootsystems have been found to be related to high root regeneration and transplant success in pin and scarlet oaks (13,23). Pin oak with its more fibrous root system produced far more new roots than the "hard to transplant" scarlet oak which possesses a relatively unbranched rootsystem. Mazzard's rootsystem is generally considered to be rather fibrous and branching compared to that of Mahaleb (23). While no statistical analysis of branching patterns and relative populations of root diameter classes was undertaken in this experiment, our casual observations would seem to agree with these descriptions. Preparation of trees for RGP evaluations often left little more than the vertical root axis on Mahaleb stocks while Mazzard stocks usually retained several short laterals. Zieslin (14) has demonstrated with excised root segments of _Rosa_ x _noisettiana_ cv.

Manetti that the largest numbers of new roots are produced by segments with a diameter of 1-2 mm and the least by segments greater than 4 mm or less than 0.5 mm. Whether this means that Mahalebs low root regeneration capacity is due to water stress imposed by an inadequate rootsystem, lack of a framework with latent primordia or suitable sites for root initiation, or some other cause remains for future experimentation to determine.

The promotive effects of various scions on RGP has been demonstrated in Quercus and Rosa spp (13,14). In this experiment Montmorency improved RGP of Mazzard stocks when compared to unbudded and self-budded Mazzard rootstocks. This is most likely due to transmission of substances promoting root initiation. If the scion effect exerted by Montmorency on Mazzard were due to an increased carbohydrate supply, a corresponding increase in root mass might have been expected, but was not evident in this experiment. Alternatively, a differential responsiveness of the rootstocks to whatever rooting promoters Montmorency might supply or a differential transport of the promoters thru the graft union of the various scion/stock combinations cannot be ruled out.

Because Montmorency tended to exaggerate differences in RGP between the 2 rootstocks, e.g. providing a significant promotion on Mazzard stocks while having no effect on Mahaleb stocks, the most meaningful work on relative performance of these 2 cherry rootstocks will be with grafted material.

Further experimentation with reciprocal grafts, monitoring of known rooting promoters and cofactors above and below the graft union, disbudding, etc. would be helpful in elucidating the mechanisms involved in scion influence on RGP.

Literature cited.

1. Beakbane, A.B. and W.S. Rogers. 1956. The relative importance of stem and root in determining rootstock influence in apples. J. Hort. Sci. 31:99-110.

2. Bukovac, M.J., et al. 1958. Effect of stock-scion interrelationships on the transport of ^{32}P and ^{45}Ca in apple. J. Hort. Sci. 33:145-152.

3. Couvillon, G.A. 1982. Leaf elemental content comparisons of scion-rooted peach cvs. to the same cvs. on several peach seedling rootstocks. J. Amer. Soc. Hort. Sci. 107:555-558.

4. Day, L.H. 1951. Cherry rootstocks in CA. Ca. Agric. Exp. Stat. Bul. #725.

5. Head, G.C. 1966. Estimating seasonal changes in the quantity of white unsubersized root on fruit trees. J. Hort. Sci. 41:197-206.

6. Jones, O.P. 1971. Effects of rootstocks and interstocks on the xylem sap composition in apple trees. Effects on N, P and K content. Ann. Bot. 35:825-836.

7. Jones, O.P. 1974. Xylem sap composition in apple trees, effect of the graft union. Ann. Bot. 38:463-467.

8. Jones, O.P. 1976. Effect of dwarfing interstocks on xylem sap composition in apple trees: effect on N, K, P, Ca and Mg content. Ann. Bot. 40:1231-1235.

9. Jones, O.P. and J.S. Pate. 1976. Effect of M 9 dwarfing interstocks on the amino compounds of apple xylem sap. Ann. Bot. 40:1237.

10. Knight, R.C. 1934. The influence of winter stem pruning on subsequent stem and root development in the apple. J. Pomol. Hort. Sci. 12:1-14.

11. Larsen, M.M. 1975. Pruning northern red oak nursery seedlings: effects on root regeneration and early growth. Can. J. For. Res. 5:381-386.

12. Lavender, D.P., et al. 1970. Growth potential of Douglas-fir seedlings during dormancy. In: L.C. Luckwill and C.V. Cuttings (eds) The physiology of tree crops pp 209-222 Academic Press, NY.

13. Lee, C.I., et al. 1974. Root regeneration of transplanted pin and scarlet oak. The new horizons, The Hort. Res. Inst., Wash., DC pp 10-14.

14. Lee, C.I. and N. Zieslin. 1978. Root regeneration of Manetti rootstocks grafted with different scion cultivars of rose. HortScience. 13:665-666.

15. Richardson, S.D. 1958. Bud dormancy and root development in Acer saccharinum. In: W.J. Whittington (ed), Root Growth. Plenum Press, NY. pp 20-41.

16. Roberts, R.H. 1929. Some stock and scion observations on apple trees. Agric. Exp. Stat. Univ. Wisc., Madison, Res. Bull. 94:1-39.

17. Roberts, R.H. 1931. Two more season's notes upon stock and scion relations. Proc. Amer. Soc. Hort. Sci. 27:102-105.

18. Roberts, R.H. 1932. Notes upon stock and scion relations in 1931. Proc. Amer. Soc. Hort. Sci. 28:470-472.

19. Rogers, W.S. 1933. Root studies III. Pears, gooseberry and black currant root systems under different soil fertility conditions with some observations on rootstock and scion effects on pears. J. Pomol. Hort. Sci. 11:1-18.

20. Rogers, W.S. and A.B. Beakbane. 1957. Stock and scion relations. Ann. Rev. Plant Physiol. 8:217-236.

21. Rogers, W.S. and M.C. Vyvyan. 1934. Root studies. V. Rootstock and soil effects on apple root systems. J. Pomol. Hort. Sci. 12:110-150.

22. Street, H.E. 1969. Factors influencing the initiation and activity of meristems. In: W.J. Whittington (ed), Root Growth, Plenum Press, NY. pp 20-41.

23. Struve, D.K. and B.C. Moser. 1984. Root system and root regeneration characteristics of pin and scarlet oak. HortScience 19:123-125.

24. Swarbrick, T. and R.H. Roberts. 1927. The relation of scion variety to character of root growth in apple trees. Agric. Exp. Stat. Univ. Wisc., Madison, Res. Bull. 78:1-23.

25. Tubbs, F.R. 1980. Growth relations of rootstock and scion in apples. J. Hort. Sci. 55:181-189.

26. Vyvyan, M.C. 1930. The effect of scion on root. III. Comparison of stem and root-worked trees. J. Pomol. Hort. Sci. 8:259-282.

27. Vyvyan, M.C. 1955. Inter-relation of scion and rootstock in fruit trees. Ann. Bot. 19:401-423.

28. Zaerr, J.B. 1967. Auxin and the root-regenerating potential in ponderosa pine seedlings. For. Sci. 13:258-264.

SECTION III.

ROOT PRUNING EFFECTS ON ROOT GROWTH POTENTIAL (RGP) OF 2 CONTAINERIZED CHERRY ROOTSTOCKS, MAHALEB AND MAZZARD, EACH BUDDED WITH MONTMORENCY SOUR CHERRY.

ABSTRACT

Two cherry rootstocks, Prunus mahaleb L. and P. avium L. cv. Mazzard, both budded with P. cerasus L. cv. Montmorency, were subjected to a root pruning treatment consisting of the removal of all roots smaller than 2 mm in diameter. Staining of all stocks with a solution of Neutral Red allowed separation of new root growth from old in all treatments. Mazzard produced a significantly greater number of new roots per 100 g total plant dry weight and replace pruned-off roots to a greater degree than Mahaleb. Root pruning caused a significant reduction in total and component dry weights and root numbers per plant.

Literature Review

Containerized studies for root growth have serious limitations (1,7,12). Some researchers have utilized aeroponic or hydroponic methods. Advantages of these systems include ease of monitoring ongoing root growth and retention of entire rootsystem. However, these techniques suffer from the criticism that experimental conditions differ so extremely from those in the field that results are difficult to compare (8,13). Other investigators have employed window boxes (1,13), but this method is limited in that only a small portion of the root system can be monitored.

Short term studies using media systems, typically require some initial pruning of the root system in order to facilitate the identification of new growth at the completion of the experiment. This results in the removal of all fibrous roots (3,7), all white roots (6,11,14,15,20) or only the tips of white roots (4,16,17,20).

Inasmuch as root tipping and injury have been shown to cause striking increases in root initiation, branching and growth rates (10,18), it would seem advisable to ascertain the potentially confounding effects of this pruning on RGP and tree growth.

The purpose of this experiment was to utilize a root staining technique previously shown to have no deleterious effects on root growth and physiology (2,12) in the study of the effects of root pruning treatments on the Root Growth Potential of cherry rootstocks.

Materials and Methods.

Twelve trees each of Montmorency/Mahaleb and Montmorency/Mazzard were removed from cold storage on January 14, 1983 and placed in a greenhouse mean minimum/maximum temperature of 19/27 ^{o}C. On February 3, 1983, plants in bud swell were prepared for RGP evaluations. Procedure as follows:

1. Trees are depotted and all soil removed from rootsystem by washing.
2. All roots smaller than 2 mm in diameter are removed from half the trees.
3. The rootsystem of all trees was stained for 5 minutes in a 0.5 gram per liter solution of Neutral Red (pH adjusted to 5.0 with sulfuric acid) then rinsed 4 times for 1 minute each in clear water followed by 2 minutes in quarter strength Hoagland's solution (Epstein, E. 1972. Mineral nutrition of plants, Wiley p 39.).
4. Plants were repotted in containers refilled with coarse sand and placed in the humidity propagator for 12 days.
5. Trees were then moved to a mist bench for 7 days and finally to the greenhouse floor for 10 days. During this final phase, trees received supplemental lighting from HID lamps for 16 hours each day (100 $\mu mol s^{-1} m^{-2}$ PAR) and a daily irrigation with quarter strength Hoagland's solution. Environmental conditions during the regeneration period are described in Table 1.

Table 1. Summary of environmental conditions, temperature and percent relative humidity (% RH), during RGP evaluation.

	Air temperature^z				
	Root zone^y		Canopy zone^x		
Location^w	Mean min.	Mean max.	Mean min.	Mean max.	Mean % RH
HP	-	-	15.4	24.0	86.4
MB	13.4	21.7	13.7	23.9	73.4
GR	17.1	28.2	18.0	30.4	36.4

^{z}°C.
^{y}As measured 25 cm from floor.
^{x}As measured 0.5 m from floor.
^{w}HP=humidity propagator, MB=mist bench, GR=greenhouse floor.

6. Trees were then harvested by gently pouring them from their pots and washing the roots free of sand.
7. All new roots were counted and removed from the root pruned treatments while the new roots on the unpruned treatments were counted and removed with razor blades; the new unstained growth being easily distinguishable.
8. Remaining tree was partitioned into leaves, shoots and stem above the graft union, stem from graft union to soil line, and root scaffold, i.e. vertical axis and all laterals remaining after removal of all the fleshy new roots.

A randomized complete block design was utilized with 6 replications of the 4 treatments.

All variables expressed as percentages were analyzed as the arcsin of the square root of y.

Results.

Rootstock Effects.

Montmorency on Mahaleb caused a significantly larger plant in total plant dry weight, and in stem and root scaffold dry weights than Montmorency on Mazzard as shown in Table 2. Montmorency on Mazzard outperformed Montmorency on Mahaleb in numbers of new roots per 100 grams total plant dry weight and % root dry weight regenerated, although these differences were significant at only the 10% level (Table 3). Average dry weight per 100 new roots was larger for Mahaleb as was shoot/root dry weight ratio as shown in Table 3 and 2 respectively. There were no significant differences between the 2 rootstocks in new shoot length, total numbers of new roots per plant and % root scaffold dry weight removed during preparation for evaluation (Table 3.).

Root Pruning Effects.

Plants with roots pruned exhibited significantly lower total plant dry weight, new leaf dry weight, new shoot length, total dry weight of new roots, total numbers of new roots per plant (or 100 grams total plant dry weight) as depicted in Tables 4 and 5 which also show that mean dry weight per 100 new roots was significantly higher in the root pruned treatments.

Table 2. Component and total dry weight of two seedling cherry rootstocks, Mahaleb and Mazzard, each budded with Montmorency sour cherry, averaged over root pruning treatments.

	Rootstock			
	Mahaleb		Mazzard	
Component	Mean	% total	Mean	% total
Leaves	1.57[z]	11.8A	1.10	12.9A
Shoots	1.17	8.9A	0.58	6.8A
Stem	4.43	34.9A	1.88	22.4B
Root Scaffold[y]	5.29	40.8B	4.22	50.5A
New roots	0.48	3.6B	0.41	7.4A
Total[y]	12.94A	100.0	8.41B	100.0
Shoot/root ratio[x]	1.29A		0.76B	

[z]Values in same row followed by same letter not significantly different at 1% level, LSD test.
[y]Includes vertical axis and lateral roots remaining after removal of all new roots.
[x]As measured at end of experiment; calculated as leaf dw plus shoot dw plus stem dw all divided by root scaffold dw plus total new root dw.

Table 3. Shoot growth and root production by two seedling cherry rootstocks, Mahaleb and Mazzard, each budded with Montmorency sour cherry, averaged over root pruning treatments.

	Rootstock	
	Mahaleb	Mazzard
New shoot length (cm)[z]	5.82a[y]	6.49a
# new roots/plant	116.8a	114.0a
# new roots/100 g total dw	1023b	1599a
% rootsystem dw removed[x]	11a	11a
% root dw regenerated[w]	32b	89a
Mean root dw/100 new roots	3.75a	1.29b

[z]Total new growth of one selected shoot during RGP evaluation period.

[y]Values in same row followed by same letter not significantly different at 10% level, LSD test.

[x]Calculated as 100 times total dw of all roots less than 2 mm diameter removed during preparation for RGP evaluation divided by total root scaffold dw at end of experiment.

[w]Calculated as total new root dw times 100, divided by total dw of all root less than 2 mm in diameter removed prior to RGP evaluation.

Table 4. Root pruning effects on component and total dry weight of two seedling cherry rootstocks, Mahaleb and Mazzard, each budded with Montmorency sour cherry, averaged over rootstock treatments.

	Root pruning treatment			
	Pruned		Non-pruned	
Component	Mean	% total	Mean	% total
Leaves	0.85[z]	9.6B	1.82	15.0A
Shoots	0.75	7.7A	1.00	8.1A
Stem	3.06	31.2A	3.25	26.1B
Root Scaffold[y]	4.12	46.3A	5.39	45.0A
New roots	0.43	5.2B	0.68	5.8A
Total[y]	9.20B	100.0	12.15A	100.0
Shoot/root ratio[x]	1.04A		1.02A	

[z]Values in same row followed by same letter not significantly different at 1% level, LSD test.
[y]Includes vertical axis and lateral rootsystem after removal of all new roots.
[x]As measured at end of experiment; calculated as leaf dw plus shoot dw plus stem dw all divided by root scaffold dw plus total new root dw.

Table 5. Root pruning effects on shoot and root production of two seedling cherry rootstocks, Mahaleb and Mazzard, each budded with Montmorency sour cherry, averaged over rootstock treatment.

	Root pruning treatment	
	Pruned	Not-pruned
New shoot length (cm)[z]	3.66B[y]	8.66A
Total # of new roots/plant	24B	206A
# new roots/100 g plant dw	374B	2249A
Mean dw (g)/100 new roots	4.68A	0.36B

[z]Total new growth of one selected shoot during RGP evaluation period.

[y]Values in same row followed by same letter not significantly different at 1% level, LSD test.

Discussion.

Total and component dry weight and shoot/root ratio advantage of Mahaleb over Mazzard stocks is most likely a direct result of the higher stem dw per tree for Mahaleb stocks. Shoot/root ratios and component dry weights were not determined at time of initial potting. However, random sampling of the rootstock liners at that time showed that the Mahaleb stocks were generally larger, i.e. 33.8 $\pm$ 6.9 g vs. 29.1 $\pm$ 6.1 g for the Mahaleb and Mazzard stocks respectively. If one were to presume that these seedlings had similar shoot/root ratios and component dry weights in the seedbed which were disturbed at time of harvest, then, the 2 stocks should have had ample time to restore the ratios during the growth cycle following budding. Perhaps the different ratios are a result of inherent differences in dw partitioning of the 2 combinations of scion/stock material. Alternatively, the differences between the 2 stocks might simply represent a differential response to the highly artificial conditions of containerization.

Mahaleb stocks appeared to produce fewer and larger roots than Mazzard stocks, yet total new root dw was similar (though representing a relative larger percentage of total dw for Mazzard). This would seem to indicate that Mahaleb may be limited in it's ability to initiate lateral roots and not in it's capacity to increase the mass of a root once initiated.

Mahaleb's difficulties might be related to its rootsystem's morphology. We observed that due to its finely divided nature, root pruning during preparation often left little more than a vertical axis, whereas the coarser Mazzard stocks usually retained 1 or 2 short laterals greater than 2 mm in diameter. This meant that pruned Mahaleb stocks had to rely upon 2-3 year-old tissue that was likely to be less permeable to water flow than the younger laterals present on pruned Mazzard stocks (9). Whether this means that Mahaleb's low root regeneration capacity is due to water stress imposed by an inadequate rootsystem, lack of a framework with latent primordia or suitable sites for root initiation, or some other cause remains for future experimentation to determine.

Overall, the results of the pruning treatments are similar to those of Larson's (5) more extreme treatments in which he removed a much larger percentage of the root system dw than was done in the present experiment. However, in the aforementioned experiment, pruning was not performed on a certain size class of roots as in the present experiment. Instead, the laterals were merely shortened, resulting in only a partial loss of the small branchlet roots, whereas most if not all were removed in the present experiment. Thus, the results of this experiment suggest that root fibrosity is more important that previously supposed by Williams (17), who demonstrated that increasing root fibrosity (via root pruning) in black walnut seedlings conferred no survival or growth benefits upon subsequent transplanting.

Nevertheless, lack of any significant interaction between rootstock and pruning treatments would seem to indicate that pruning of cherry rootstock seedlings as practiced in this experiment does not necessarily confound an experiment. Therefore, such a practice may be permissible as a means of facilitating data collection.

Literature Cited.

1. Boehm, W. 1979. Methods of studying root systems, Springer-Verlag, Berlin.

2. Carman, J.G. 1981. A nondestructive stain technique for investigating root systems, Agron. Abstracts, 73rd Ann. Meeting, p 81.

3. Farmer, R.E. 1975. Dormancy and rot regeneration of northern red oak, Can. J. For. Res. 5:176-185.

4. Krugman, S.L. and E.C. Stone 1966. Effect of cold nights on the root regenerating potential of ponderosa pine seedlings, For. Sci. 12:451-459.

5. Larson, M.M. 1975. Pruning northern red oak nursery seedlings: effects on root regeneration and early growth. Can. J. For. Res. 5:381-386.

6. Lathrop, J.K. and R.A. Mecklenburg 1971. Root regeneration and root dormancy in Taxus spp., J. Amer. Soc. Hort. Sci. 96:111-114.

7. Lee, C.I. and W.P Hackett 1976. Root regeneration of transplanted Pistachia cheninsis Bunge seedlings at different growth stages, J. Amer. Soc. Hort. Sci. 101:236-240.

8. MacKey, J. 1973. The wheat root, 4th Int. Wheat Genet. Symp., Missouri Agric. Exp. Stat., Columbia Mo. pp 827-842.

9. Queen, W.H. 1967. Radial movement of water and ^{32}P through suberized and unsuberized roots of grape, Ph.D. Diss., Duke Univ., Durham, NC.

10. Rook, D.A. 1971. Effect of undercutting and wrenching on growth of Pinus radiata seedlings, J. Applied Ecol. 8:477-490.

11. Rook, D.A. 1973. Conditioning radiata pine seedlings to transplanting by restricted watering, N. Zealand J. For. Sci. 3:54-69.

12. Schumacher, T.E. et al 1983. Measurement of short term root growth by prestaining with neutral red, Crops Sci. (in press).

13. Schuurman, J.J. and M.A.J. Goediwangen 1971. Methods for the examination of root systems and roots, Wageningen, Pudoc.

14. Stone, E.C. and J.L. Jenkinson 1970. Influence of soil water on root growth capacity of ponderosa pine transplants, For. Sci. 16:230-239.

15. Stone, E.C. and J.L. Jenkinson 1971. Physiological grading of ponderosa pine nursery stock, J. For. 69:31-33.

16. Stone, E.C., et al. 1962. Root regenerating potential of Douglas-fir seedlings lifted at different times of the year, For. Sci. 8:288-297.

17. Stone, E.C. and G.H. Shubert 1959. Root regeneration by ponderosa pine seedlings lifted at different times of the year, For. Sci. 5:322-332.

18. Wightman, F. and K.V. Thimann 1980. Hormonal factors controlling the initiation and development of lateral roots. I. Sources of primordia inducing substances in the primary root of pea seedlings, Physiol. Plant. 49:13-20.

19. Williams, R.D. 1972. Root fibrosity proves insignificant in survival and growth of black walnut seedlings, Tree Planter's Notes 23:22-25.

20. Zaerr, J.B. 1967. Auxin and the root regeneration potential in ponderosa pine seedlings, For. Sci. 13:258-264.

APPENDIX

Table A1. Mean number of new roots per excised root segment[z] in 3 cherry rootstocks[y], Prunus mahaleb L., P.avium L. cv. Mazzard and P. avium x P. pseudocerasus cv. Colt, each grafted with P. avium L. cv. Hedelfingen, and one rose rootstock[x], Rosa x noisettiana cv. Manetti.

Scion/rootstock combination	Mean # of new roots per segment
Hedelfingen/Colt	0.85A[w]
Hedelfingen/Mazzard	0.04B
Hedelfingen/Mahaleb	0.02B
Manetti	1.08 ± 1.50

[z]Prepared by surface sterilization in 0.5% hypochlorite (v/v) for 15 s, rinsed in tap water for 30 s, buried 2 cm deep in steam sterilized perlite, covered with aluminum foil and plastic, and held 30 days under mean min/max temperature: 18.3/29.0°C.

[y]Averaged over size class, i.e. 10 cm x 1-2 mm or 4-5 mm diameter, and collection date, i.e. April 21 (bud swell) or May 5 (first leaf expansion). No signiicant differences between root diameter or collection date treatments, nor any interactions between treatments. Design was a randomized complete block with collection date split on rootstock and root diameter treatments. Six replications were utilized with 2 subsamples of each treatment combination.

[x]Included as check on procedure; mean number of roots per segment comparable to that reported by Lee, C.I. and N. Zieslin. 1978. HortScience. 13:665. Most cherry root pieces failing to produce new roots during 30 day regeneration period were also invaded by an unidentified fungal pathogen; this represented 98%, 90% and 38% of the Mahaleb, Mazzard and Colt samples respectively. Virtually no rose root pieces displayed any fungal infection indicating sterilization procedure was probably inadequate for cherry rootstocks and results were possibly confounded by infection.

[w]Values followed by same letter not significantly different at 1% level, DMR test.