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# Some of the Differing Responses of Peach Rootstocks to Root Temperatures

*By Peter Malcolm*

Peter Malcolm, NSW DPI, Locked Bag 4, Richmond, NSW 2753, Australia.

**Abstract.**

This paper examines the hypothesis that low root zone temperatures (RZT) affect growth, dry matter distribution and leaf development in stone fruit plants and secondly, that rootstocks differ in their growth, dry matter distribution and leaf development in response to changes in RZT. This hypothesis was tested by growing plants of five *Prunus* rootstocks at constant (5º, 12º, 19ºC) or at diurnally (29/20ºC) variable RZTs. These trials demonstrate that RZTs, independently of air temperature and light intensity, influence growth, dry matter partitioning and leaf development. From 5 to 19ºC RZT there was a positive correlation between RZTs and, both leaf development and growth. It was also found that rootstocks differed significantly in their leaf development and growth responses to RZTs and also, in their distribution of that growth among roots, stems and leaves. These results suggest the possibility that some of the documented, rootstock induced changes in tree growth may be due to differences in rootstock responses to RZTs. Such results also suggest that in the future, knowledge of rootstock RZT responses maybe useful in assisting in the selection of the most appropriate rootstock(s) for a specific location(s).

## Introduction

Despite evidence that rootstocks differentially influence *Prunus* tree growth and vigour (Layne and Ward, 1978; Dozier et al., 1984; Rom and Carlson, 1987; Layne, 1994; Moreno et al., 1994), dry matter partitioning (Salvatierra et al., 1988; Glenn and Scorza, 1992; Massai et al., 1993; Caruso et al., 1997; Pace and DeJong, 2000) and leaf area development (Yadava et al., 1980, 1989) few studies examining the comparative growth, partitioning and leaf development responses of different, actively growing *Prunus* rootstocks to RZTs, have been reported.

In order to examine the hypotheses that root temperatures influence growth, dry matter partitioning and leaf development and, that there are differences in these parameters among different rootstocks in response to changes in RZTs, two trials using actively growing plants of five different *Prunus* rootstocks were undertaken. Examined were the effects of constant 5, 13 and 19ºC RZTs, as well as diurnally variable 29 / 20ºC RZTs, on growth [also referred to as dry matter increment (DMI)] and, its partitioning among roots, stems and leaves. Also examined were the potential effects of RZT on leaf development.

**Materials and methods**

Actively growing plants of the rootstocks, Fay Elberta (FE), Green Leaf Nemaguard (GLN), Golden Queen (GQ), Okinawa (OK) and Flordaguard (FG) were grown for 6 weeks at constant RZTs of 5, 12 and 19° C and also at diurnally variable 29/20ºC RZTs. The plants were harvested and the leaves, stems and roots were washed and dried. The reported growth of the component parts of the plants were calculated as the differences between the masses at the start and end of the experiment. The experiment was repeated twice.

Leaf numbers were measured at the beginning of each trial and subsequently at weekly intervals. The daily rate of leaf expansion was measured for seven consecutive days in the week prior to harvest. At harvest, six weeks after the start of the trials, the plants were removed from the cabinets. The leaves were detached from each plant, counted and the leaf area measured using a Leaf Area Measurement System (I.C.T. Technologies, Narrabri, NSW).

Since the treatments and rootstocks were arranged in a split-plot design within trials, the response variables such as dry matter increment were fitted with a linear mixed model as follows: Data = *Trial* +Treatment + *Trial: Treatment* + Rootstock + Treatment: Rootstock + *Trial : Treatment : Rootstock + error* where the italicised terms were assumed to have random effects and the colon (:) denoted interaction. The errors were assumed to follow a normal distribution. Variance parameters were estimated using a residual maximum likelihood (REML) method (Patterson and Thompson, 1971). Pair-wise treatment differences were separated using the least significant difference (LSD) at 5% level. The analysis was run on Genstat for Windows version (VSN International Ltd, 2003).

**Results**

Root zone temperatures (RZT), independently of air temperatures and light levels, had a significant impact on the growth (DMI) of each of the five rootstocks examined (Figure 1). The pooled data for all rootstocks, demonstrated that the growth of plants exposed to a RZT regime of 19°C was approximately 250% larger than for those plants whose RZT was 12°C and they in turn, were approximately 240% larger than plants kept at a RZT of 5°C (See treatment means in Figure 1). Additionally, the growth (DMI) for those plants where RZTs were kept constant at 19°C, was approximately 20% larger than for similar plants where the RZT treatment alternated diurnally between 29º and 20ºC and for which, the mean daily RZT was 24.2°C (Figure 1).

Regarding the comparative response of the different varieties, at each RZT there were significant differences among individual rootstocks in the magnitude of the growth response (Figure 1). At RZTs of 5°C and 12°C, OK and FG rootstocks grew most vigorously and the increase in growth in these rootstocks was considerably greater than for GLN and GQ. For example, at 12°C RZTs, the growth for OK and FG was more than double that of GQ. In contrast, at a constant RZT of 19°C and also for the diurnally variable RZT treatments, GLN and GQ rootstocks grew most vigorously. These differences were reflected in the relationships between RZT and growth for the different rootstocks (Table 1).

**Table 1**. *Relationship (Regression) between RZT (5 - 19°C) and total growth for each of five varieties of peach rootstock seedlings subjected to various RZT treatments for six weeks.*

| Variety | Growth Stage | Relationship |
|---------|--------------|--------------|
| FE | Actively growing | TDMI = -2.89 + 1.02 RZT ($r^2 = 0.90$) |
| FG | Actively growing | TDMI = 3.11 + 0.55 RZT ($r^2 = 0.79$) |
| GL | Actively growing | TDMI = -10.47 + 1.91 RZT ($r^2 = 0.79$) |
| GQ | Actively growing | TDMI = -12.84 + 2.16 RZT ($r^2 = 0.84$) |
| OK | Actively growing | TDMI = 0.35 + 1.26 RZT ($r^2 = 0.88$) |

**Figure 1.** *The effects of 6 weeks exposure to 5º, 12º, 19º and diurnally variable 29 /20ºC RZT, on the dry matter increment (growth) of 5 varieties (n=4) of stone fruit rootstocks. Also included are the treatment means for the pooled data (n=20) for all rootstocks at each individual RZT. The plants were actively growing prior to the RZT treatments being applied. Error bars represent the least significant difference (5%) among means.*
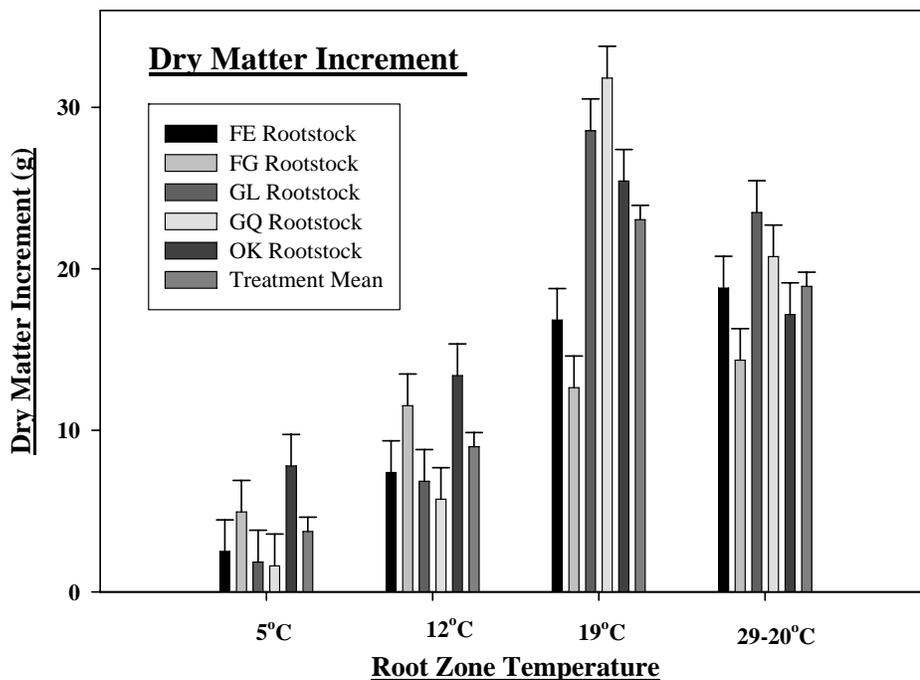


RZTs also affected the distribution of growth among roots, stems and leaves (Figure 2). For the pooled data, the percentage of growth assigned to the roots (Root mass ratio - RMR) rose as RZTs increased from 5 to 19°C while that apportioned to the stem (Stem mass ratio - StMR) fell over the same temperature range (Figure 2). As regards the proportion of growth allocated to leaves (Leaf mass ratio - LMR), differences among RZT treatments (5 to 19°C) were less obvious (Figure 2). In percentage terms, at a RZT of 5°C, root growth constituted 24% of the total growth

increment (RMR = 0.241), while at 19°C RZTs root growth made up 49% (RMR = 0.495) of the increase in growth. Correspondingly, in the 5°C RZT treatment, stem growth constituted 57% of total growth (StMR = 0.572) while at a 19°C RZT stem growth constituted only 30% of the total growth increment.

**Figure 2.** *The effects of 6 weeks exposure to 5º, 12º, 19º and, diurnally variable 29/20ºC RZT, on the mean leaf mass, stem mass and root mass ratios (n=20) for the pooled data for 5 stone fruit rootstock varieties. The plants were actively growing prior to the RZT treatments being applied. Error bars represent the least significant difference (5%) among means.*
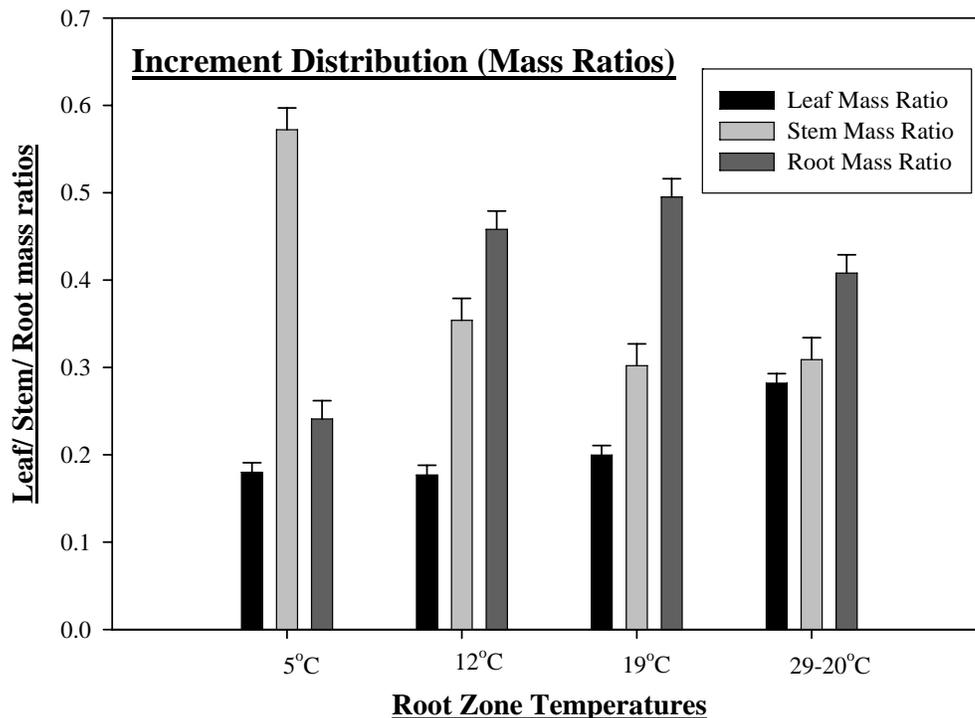


Compared with 19ºC plants, exposure to diurnally variable 29/20°C RZTs, led overall, to an 17% fall in RMR and a 41% increase in LMR (Figure 2). Also, in the 29/20°C RZT treatment, leaf growth constituted 28% of total growth compared with 20.0% at 19°C, 17.7% at 12°C and 18% at 5°C.

There were significant differences among varieties in the distribution of growth among leaves, stems and roots, in response to different RZTs (Data not shown). At 5°C RZT, Okinawa and Flordaguard apportioned ~40% of their growth increment to their roots, whilst FE and GQ apportioned only 14–23%. In contrast, at this temperature, GLN apportioned less than 0.5% of its growth increment to roots (Data not shown). As RZTs increased, differences in root growth among varieties became less. Even so, at 12 and 19°C RZTs, there were still significant differences among the varieties, in the proportion of their growth apportioned to the roots. These varietal differences in the apportioning of biomass resulted in considerable variation in the

mathematical relationships/ regression curves between RZT and, respectively LMR, StMR and RMR among the different varieties (Data not shown). For example the mathematical relationships between RMR and RZT (5 to 19°C) for the varieties GQ and GL were RMR (GQ) = -7.66 + 1.21 RZT ($r^2$ = 0.84) and, RMR (GL) = -1.34 + 0.035 RZT ($r^2$ = 0.85) respectively.

RZT also affected the daily rate of leaf expansion, which consequently affected leaf numbers and final leaf area (Figure 3). For the pooled data (See treatment means in Figure 3), final leaf area for plants whose roots were at 19°C was 340% greater than for those plants whose roots were at 12°C and they in turn had 184% more leaf area than plants whose roots were at 5°C.

For the pooled data as well as for each individual variety, there was also a positive correlation between constant RZT (5 to 19°C) and respectively, the daily rate of leaf expansion, leaf numbers and final leaf area (Data not shown). Regarding the comparative response of the different varieties, there were significant differences among individual rootstocks in the magnitude of their daily leaf expansion rates and final leaf numbers in response to RZTs (Data not shown). This was reflected in the final leaf area for the individual varieties (Figure 3). For example, at RZTs of 12°C, the leaf area for OK and FG rootstocks at experiments end, was double that of GQ. In contrast, at a RZT of 19°C and also in the diurnally variable treatment, GLN and GQ rootstocks grew most vigorously and the leaf area of GQ at 19°C RZT was, respectively, 215%, 177% and 152% greater than for FE, FG and OK rootstocks.

**Discussion**

These trials demonstrated that RZTs, independently of air temperatures strongly influence the growth of stone fruit. They also showed that there were significant differences among individual rootstocks in the comparative rates of growth at different RZTs. For example, at 5°C and 12°C RZTs, the varieties GQ and GLN had the lowest increase in growth, while at 19°C and 29/20°C RZT, they had the highest. Although in lettuce (Lee and Cheong, 1996), varietal differences in sensitivity to RZT were found, in stone fruit there appears to be little documentation of research examining the differential responses of Prunus rootstocks to RZT.

**Figure 3.** *The effects of 6 weeks treatment at 5º, 12º, 19º and diurnally variable 29/20ºC RZT on the final leaf area (cm$^{-2}$) of five varieties of stone fruit rootstocks. Also included, for each individual RZT, are the treatment means for the combined data for all rootstocks. The plants were actively growing prior to the RZT treatments being applied. Error bars represent the least significant difference (5%) among means.*
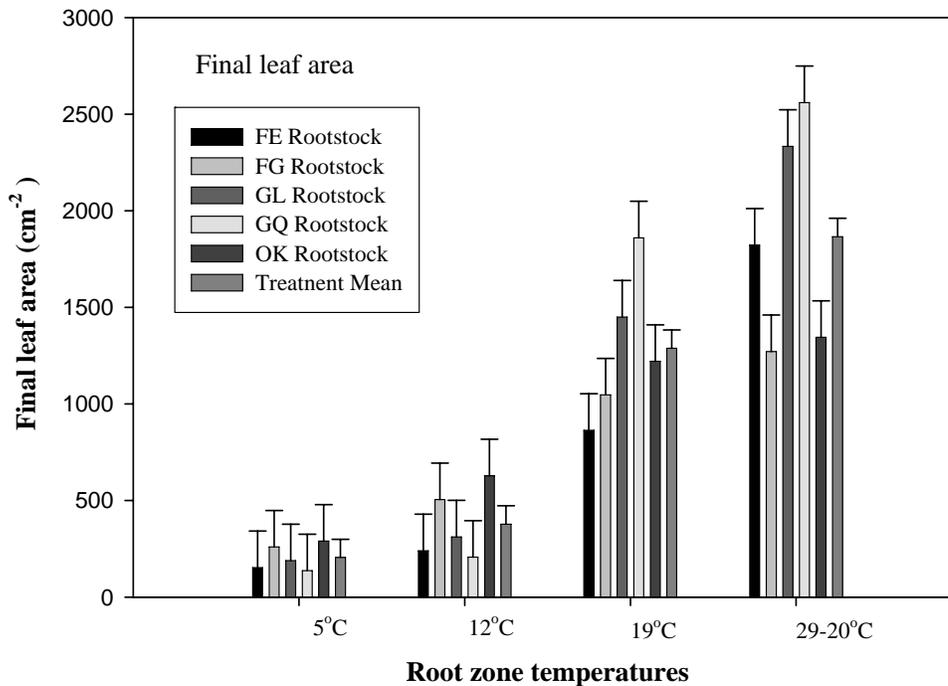
The sensitivity of the growth response of peach rootstocks to RZT is illustrated by the finding that in these trials, for the combined data over the RZT range 5–19°C, there was a strong positive correlation between RZT and growth [-4.63 + 1.38 RZT ($r^2$ = 0.66)]. A similar, positive correlation between RZT and growth of the rootstock Green Leaf Nemaguard, has been previously documented [Malcolm et al. 2006].

For the combined data, as well as for the individual varieties OK, GLN, and GQ, the reduced growth in the diurnally variable 29/20°C RZT treatments, compared to those exposed to constant 19°C RZTs, may possibly be due to the 29°C temperatures experienced daily by the roots of those plants; such high root temperatures may well be detrimental to growth.  Malcolm et al. (2006) also reported a similar detrimental effect in GLN peach rootstocks exposed to diurnally variable 26/15°C RZTs compared to those plants whose RZTs were maintained at a constant temperature of 20°C. This was despite the average daily RZTs for both treatments being almost identical (Malcolm et al., 2006). In peppers (Dodd et al., 2000), it has been shown that high RZTs have an unfavourable effect on growth and in lettuce (Lee and Cheong, 1996), there are varietal differences in sensitivity to high RZTs.

These trials also demonstrated that RZT had a significant impact on the distribution of growth among roots, stems and leaves as reflected in the leaf mass, stem mass and root mass ratios.  Not only were there significant differences among the different RZT treatments, but also among rootstocks in their individual responses to differing RZTs. As an informed generalization, at RZTs that were unfavourable for optimal growth, root growth as reflected in RMRs was reduced and instead, proportionally more of the dry matter increment (growth) was diverted into stems (at low RZTs), or leaves (at high RZTs). However, there were considerable differences among the individual rootstock varieties in their distribution of growth among the various plant factions, in response to RZTs.

In *Prunus* spp., it has been shown that rootstocks influence seasonal dry matter production and distribution (Caruso et al., 1997; Glenn et al., 1992; Salvatierra et al., 1998), that there are seasonal changes in carbohydrate fractions of peach trees (Stassen et al., 1981) and that there are seasonal shifts in the growth of various plant factions, such as roots and shoots (DeJong et al., 1987; DeJong and Scott Johnson, 1989; DeJong T., 1999). Whether these observations are related to seasonal changes in soil temperatures is unknown, as apart from a paper by Malcolm et al. (2006), there seems to be little documented work examining the general and seasonal influence of RZTs on the distribution of growth among various plant factions, let alone examining the responses of individual rootstocks or rootstock/scion combinations to RZTs. In lettuce (Lee and Cheong, 1996; He and Lee, 1998a) and maples (Wilkins et al., 1995), RZTs have been shown to affect dry matter distribution within the plant. Furthermore, in apples, there were varietal differences among rootstocks in such RZT induced distribution patterns (Gur et al., 1976).

Stems are a storage organ for many deciduous perennial crops, including peaches (Priestley 1962; Richards and Rowe 1977; Stassen *et al.* 1981). The storage of carbohydrates in autumn is necessary to support early growth and plant development in spring, until such time as the newly formed leaves become photosynthetically self-sufficient (Hansen 1967, 1971; Stassen *et al.* 1981). In apple, Hansen and Grausland (1973) estimated that more than 75% of the plant reserves located in the stems are used for respiration during the spring development of leaves, flowers and shoots. Our trials demonstrated that RZT can play a role in the distribution of dry matter to stems. The finding that for actively growing peach plants, lower RZTs which are normally associated with autumn, can influence the distribution of dry matter to the stems, raises the possibility that falling RZTs may prepare plants for dormancy in that they influence the distribution of nutrient to stems and, may possibly play a role in inducing dormancy, along with the triggering of the "chill clock". Little information on the influence of RZT on the distribution of dry matter increment to the stems of perennial crops is available; however, Delucia (1986) noted that low RZT induced changes in the starch and soluble sugar concentrations in the stems of Engelmann spruce.

These trials demonstrated a strong positive correlation between RZT and daily rates of leaf expansion and leaf numbers and consequently, total leaf area. In stone fruit, apart from a paper by Malcolm et al. (2006) there have been few studies examining the relationship between RZT and leaf development. These trials not only established that there was a strong positive correlation between RZT and rates of leaf expansion, leaf numbers and leaf area for each individual variety, but that there also existed, considerable varietal differences among rootstocks in their relationships between RZT and these parameters. Although Weinberger (1931) demonstrated a strong positive relationship between leaf area and, both fruit size and quality and, it has been shown that there are varietal differences among peach rootstocks in their effect on leaf area and leaf development (Yadava and Doud 1980; Yadava et al. 1989; Massai et al, 1993), particularly in the spring (Caruso et al. 1997; Malcolm et al. 1999), there has been little research examining the effects of RZT on leaf development in peaches, let alone examining the effects of RZT on comparative leaf development among different peach rootstocks.

These trials have demonstrated, that for the varieties examined and independently of air temperatures that;

(a) RZT affects growth in all the rootstock varieties examined and, that there exist significant differences among rootstocks in their growth responses to RZT.

(b) RZT affects the partitioning of growth among roots, stems and leaves and that there are significant differences among varieties in their partitioning responses to RZTs.

(c) RZT affects the rate of leaf development and, that there are significant differences among varieties in their rates of leaf development in response to changes in RZTs.

While there is still much work to be done examining the effects of RZT on the growth and performance of stone fruit, the results of these initial trials support the hypothesis that rootstocks differ in their growth, partitioning and leaf development responses to RZT, thus influencing the performance of the whole tree. These findings may also offer an explanation for the reported differences in the comparative performance of the same scion-rootstock combinations at different localities (Dozier et al., 1984). It also raises the possibility of developing more accurate tree performance models, taking into account RZTs at specific sites, in the individual fruit growing regions. In the future, detailed knowledge of RZT responses of individual rootstocks combined with site specific knowledge of soil temperatures may be useful in assisting in the selection of the most appropriate rootstock(s) for a specific location(s) and, in the development of more accurate tree performance models.

## References

Caruso, T., Inglese, P., Sidari, M., Sottile, F., (1997). Rootstock influences seasonal dry matter and carbohydrate content and partitioning in above ground components of "Flordaprince" peach trees. J. of the American Society of Horticultural Science 122, 673–679.

De Jong T.M., Day K.R. (1991) Relationship between shoot productivity and leaf characteristics in peach canopies. HortScience 26 (10):1271-1273

De Jong, T., Scott Johnson, R. (1989). Growth and development. In: LaRue, J.H., Johnson, R.S. (Eds). Peaches, Plums and Nectarines: Growing, Handling for the Fresh Market, Publication No 3331 University of California Division of Agriculture and Natural Resources, Oakland, pp. 35–37.

De Jong, T.M., (1999). Developmental and environmental control of dry matter partitioning in peach. HortScience 34, 1037–1040.

De Jong, T.M., Doyle, J.F., Day, K.R., (1987). Seasonal patterns of reproductive and vegetative sink activity in early and late maturing peach (*Prunus persica*) cultivars. Physiologia Plantarum 71, 83–88.

Delucia E.H. (1986) Effect of low root temperature on net photosynthesis, stomatal conductance and carbohydrate concentration in Engelmann Spruce (*Picea eigelmannii Parry Ex Engelm*) Seedlings. Tree Physiology 2 : 143-154.

Dodd, I., He, J., Turnbull, C.G., Lee, S.K., Critchley, C., (2000). The influence of supra-optimal root zone temperatures on growth and stomatal conductance in *Capsicum annuum L.* J. Experimental Botany 51, 239–248.

Dozier Jr. W.A., Knowles J.W., Carlton C.C., Rom R.C., Arrington E.H., Wehunt E.J., Yadava U.L., Doud S.L., Ritchie D.F., Clayton C.N., Zehr E.I., Gambrell C.E., Briton J.A. and Lockwood D.W., (1984). Survival, growth, and yield of peach trees as affected by rootstocks. HortScience, 19: 26-30.

Dozier W.A. (1984) Survival, growth and yield of peach trees as affected by rootstocks. HortScience, 19: 26-30.

Glenn, D.M., Scorza, R., (1992). Reciprocal grafts of standard and dwarf peach alter dry matter partitioning and root physiology. HortScience 27, 241–243.

Gur, A., Mizrahi, Y., Samish, R.H., (1976). The influence of root temperature in apple trees II: Clonal differences in susceptibility to supra-optimal root temperatures. J. Horticultural Science 51, 195–202.

Hansen P. (1967) [14] C- studies on apple trees. I. The effect of fruit on the translocation and distribution of photosynthates.  Physiologia Pl., 20 : 382-391

Hansen P. (1971) [14] C - studies on apple trees. VII. The early seasonal growth in leaves, flowers and shoots as dependant upon current photosynthates and existing reserves. Physiologia Pl., 25 : 469-473

Hansen P. and Grausland J. (1973) [14] C - studies on apple trees. VIII. The seasonal variation and nature of reserves. Physiologia Pl., 28 : 24-32

He, J., Lee, S.K., (1998). Growth and photosynthesis responses of three aeroponically grown lettuce cultivars (*Lactuca sativa L.*) to different root zone temperatures and growth irradiances under tropical aerial conditions. Journal of Horticultural Science and Biotechnology 73, 173–180.

Layne R.E.C., Ward G.M. (1978). Rootstock and seasonal influences on carbohydrate levels and cold hardiness of "Redhaven" peach. J.Amer.Soc.Hort.Sci., 103 (3) : 408-413.

Layne, R.E.C., (1994). Prunus rootstocks affect long-term orchard performance of Redhaven peach on Brookston clay loam. HortScience 29, 167–171.

Lee, S., Cheong, S. (1996). Inducing head formation of iceberg lettuce (*Lactuca sativa L.*) in the tropics through root zone temperature control. Tropical Agriculture 73, 34–42.

MacKay J.M.L., Neal A.M. (1993). Harvesting, recording weight, area and length. In:  Hendry, G., Grime, J. (Eds) Methods of comparative plant ecology – a laboratory manual. Chapman and Hall, London, pp. 25 – 26.

Malcolm P., Holford P., McGlasson B., Newman S., Richards G., Topp B. (1999) Growing low chill peaches and nectarines on high chill rootstocks causes Spring Shock Syndrome. Australian Fresh Stone Fruit Quarterly, 1 (1) : 11-12.

Root temperatures and the growth of Summerfruit. P. Malcolm, P. Holford, W.B. McGlasson, J.P. Conroy. Summerfruit Australia Quarterly, 6 (2), Winter, pp 19.

Leaf mineral concentrations in stone fruit are affected by both root temperatures and phenology. P.Malcolm. Fruitwise, N[o] 56, Summer 2004/05

Malcolm P., Holford P., McGlasson B., Conroy J. (2006) Root zone temperature influences growth, partitioning, leaf morphology and physiology of the peach rootstock, Green Leaf Nemaguard. Australian J. of Experimental Agriculture 46, 1-8 (In Press)

Malcolm P.J., Holford P., McGlasson W.B., Newman S. (2003) Temperature and seed weight affect the germination of peach rootstock seeds and the growth of rootstock seedlings. Scientia Horticulturae 98 : 247 - 256

Massai, R., Yiloyannis, C., Piccotino, D., Baroni, G. (1993). Root system growth and conformation of peach grafted on two rootstocks in high-density orchards. Acta Horticulturae 349, 163–166.

Moreno, M.A., Tabuenca, M.C., Cambra, R., (1994). Performance of Adafuel and Adarcias as peach rootstocks. HortScience 29, 1271–1273.

Pace, L., De Jong, T.M., (2000). Relationship between canopy growth and root growth in young peach trees. ISHS, 7th International Symposium on Orchard and Plantation Systems, p. 14.

Patterson, H.D., Thompson, R., (1971). Recovery of interblock information when block sizes are unequal. Biometrika 31, 100–109.

Priestley C.A. (1962) Carbohydrate resources within the perennial plant. Comm. Agric. Bur.Tech. Bull. 27, 116pp

Richards D., Rowe R.N. (1977). Effects of root restriction, root pruning and 6-benzylaminopurine on the growth of peach seedlings. Ann.Bot., 41 : 729-740

Salvatierra, A.M.G., Gemma, H., Iwahori, S., (1998). Partitioning of carbohydrates and development of tissues in the graft union of peaches grafted on *Prunus tormentosa Thumb*. Rootstock. J. Japanese Society of Horticultural Science 67, 475–482.

Stassen P.J.C., Strydom D.K., Stindt H.W. (1981). Seasonal changes in carbohydrate fractions of young Kakamas peach trees. Agroplantae, 13: 47-53.

Weinberger J.H. (1931). The relation of leaf area to size and quality of peaches. Proceedings of the American Society of Horticultural Science. 28: 18 -22.

Wilkins, L.C., Graves, W.R., Townsend, A.M. (1995). Responses to high root zone temperatures among cultivars of red maple and Freeman maple. Journal of Environmental Horticulture 13, 82–85.

Yadava U.L, Doud S.L. (1989). Rootstock and scion influence growth, productivity, survival and short-life related performance of peach trees. J. of the American Society of Horticultural Science 114 (6) : 875-880.

Yadava U.L., Doud S.L., Bird D.M., McCrary D. (1980). The effect of peach seedling rootstocks on tree performance of four peach cultivars on a non-short-life site without soil fumigation. Hort.Science, 15 : 283 - 284