ABSTRACT

BUCKELEW, JULIANA KIRSTEN. Orchard Floor Management in Young Peach [*Prunus persica* (L.) Batsch.]: Effects of Irrigation, Vegetation-free Width, and Certain PRE Herbicides. (Under the direction of David W. Monks).

A hindrance to peach culture in the southeastern U.S. is orchard floor vegetation in which weeds can compete for water and nutrients. Young orchards may take longer to come into production if infested with weeds. The common orchard floor management system in the southeastern U.S. is a 3.0 to 3.6 m wide vegetation-free strip in the tree row with an orchard cover of volunteer weedy vegetation. However, reduction of the strip width may be possible through the use of irrigation which could reduce herbicide use. Thus, the objective of this study was to determine the optimum vegetation-free strip for irrigated peach with a weedy groundcover. Research was conducted in 2006 to 2008 to determine the optimum vegetation-free strip for irrigated peach with a weedy groundcover, and to evaluate PRE-emergence directed control of weeds that infest peach in North Carolina.

The first experiment included two factors, vegetation-free widths (VFW) of 0, 0.6, 1.2, 2.4, 3, and 3.6 m and irrigation (either irrigated or nonirrigated). At Jackson Springs, NC, the irrigated VFW which would produce the same yield season total (kg/ha) as the grower standard (3.6 nonirrigated) is 1.16 m, based on results from regression. (For maximum season total, the VFW needed to be 3.6 m.) The irrigated VFWs which would produce the same tree cross-sectional area (TCSA) as the grower standard was 1.5, 1.3 and 0.8 m for trees aged one, two, and three years old, respectively. At Clayton, NC, TCSA in 2007 and 2008 and harvest season totals were not different by irrigation, but did increase linearly with VFW. At both locations, water and nitrogen were probably the limiting factors. Similar across locations, leaf nitrogen concentrations were lower but not deficient in the irrigated trees than

the nonirrigated trees, presumably due to leaching of NO_3 by irrigation. Foliar N, SPAD measurements, soil moisture, and growth responses were positively related to VFW at Jackson Springs therefore growth responses there were probably due to water and N competition with vegetation. In contrast, foliar N concentration was not different by VFW at Clayton. However, growth responses were positively related to VFW. SPAD measurements increased with VFW so vegetation had some effect on nitrogen. For the first two years of the study, VFW did have an effect on soil moisture at 30 cm depth. Data suggest that a 1.5 m VFW combined with proper irrigation and fertilization will produce tree growth and yield in volunteer weedy vegetation similar to the current grower standard.

The second set of experiments was conducted to determine newly planted peach tolerance to sulfentrazone herbicide applied PRE at various rates and to determine the effect of sequential sulfentrazone when tank mixed with other PRE herbicides (norflurazon, oryzalin, terbacil, rimsulfuron, or flumioxazin). Sulfentrazone PRE did not injure newly planted peach trees. Sulfentrazone alone controlled several broadleaf weeds however it did not adequately control large crabgrass and yellow foxtail. Control of these grasses increased with the addition of norflurazon or oryzalin.

The third set of experiments was conducted to determine tolerance to halosulfuron, mesotrione, and rimsulfuron applied at various rates on newly planted peach. No herbicide reduced TCSA or winter pruning weight relative to the nontreated check. In 2006, some foliar injury from halosulfuron occurred at the higher rates. No visual injury symptoms occurred in 2007 for any study.

Mesotrione, rimsulfuron, and sulfentrazone were safe to newly planted peach and likely would be useful to growers developing weed management programs for peach.

Orchard Floor Management in Young Peach [*Prunus persica* (L.) Batsch.]: Effects of Irrigation, Vegetation-free Width, and Certain PRE Herbicides

by
Juliana Kirsten Buckelew

A dissertation submitted to the Graduate Faculty of
North Carolina State University
in partial fulfillment of the
requirements for the Degree of
Doctor of Philosophy

Horticultural Science

Raleigh, North Carolina

2009

APPROVED BY:

Dr. Michael Parker	Dr. Randy Wells
Dr. David Monks Chair of Advisory Committee	Dr. Michael Burton

DEDICATION

For Lamar and Charles

BIOGRAPHY

Juliana Beiwel Buckelew is the third child of Ferenc and Marian Beiwel. She grew up in Davenport, Iowa and graduated from Davenport West High School in 1991. She graduated from Iowa State University in 1997 with a Bachelor of Science Degree in Horticultural Science. After graduation she was employed by Seed Savers Exchange in Decorah, Iowa. After marrying Lamar Buckelew in 1998, they moved to Milwaukie, Oregon. There she worked for Oregon State University as an ornamental nursery production research technician at North Willamette Research and Extension Center. In spring of 2002, she began her graduate studies under the direction of Dr. David Monks at North Carolina State University.

ACKNOWLEDGMENTS

I would like to thank Dr. David Monks for his advice and patience. I also thank Drs. Mike Burton, Michael Parker, and Randy Wells for serving on my graduate committee. I would like to thank Dr. Katie Jennings for her encouragement.

Thanks to Lamar and Charles for giving me encouragement and motivation.

TABLE OF CONTENTS

Page
LIST OF TABLES……………………………………………………………………. vii

LIST OF FIGURES…………………………………………………………………... ix

EFFECTS OF VEGETATION-FREE WIDTH AND IRRIGATION ON NEWLY PLANTED PEACH [*Prunus persica* (L.) Batsch.]
Abstract……………………………………………………………………. 1
Introduction………………………………………………………………... 2
Materials and Methods…………………………………………………….. 5
Results and Discussion…………………………………………………….. 11
Literature Cited…………………………………………………………….. 42

WEED CONTROL AND PEACH [*Prunus persica* (L.) Batsch.] RESPONSE TO SULFENTRAZONE HERBICIDE SYSTEMS
Abstract……………………………………………………………………. 78
Introduction………………………………………………………………... 79
Materials and Methods…………………………………………………….. 80
Results and Discussion…………………………………………………….. 82
Literature Cited…………………………………………………………….. 85

RESPONSE OF NEWLY PLANTED PEACH [*Prunus persica* (L.) Batsch.] TO CERTAIN PRE HERBICIDES
Abstract…………………………………………………………………….. 89
Introduction………………………………………………………………..... 90
Materials and Methods…………………………………………………….. 91
Results and Discussion…………………………………………………….. 92
Literature Cited…………………………………………………………….. 94

APPENDICES……………………………………………………………………... 96

Appendix Table 1. Precipitation and irrigation data, Clayton, NC, 2006 - 2008 ………………………………………………………………………………… 97

Appendix Table 2. Precipitation and irrigation data, Jackson Springs, NC, 2006 - 2008………………………………………………………………………… 98

Appendix Table 3. Elemental amount in vegetation by vegetation-free width (VFW) in irrigated (irr.) and nonirrigated (nonirr.) conditions, Clayton, NC, 2007 and 2008……………………….…………………………………………. 99

Table of Contents (Continued)

Appendix Table 4. Elemental amount in vegetation by vegetation-free width (VFW) in irrigated (irr.) and nonirrigated (nonirr.) conditions, Jackson Springs, NC, 2007 and 2008……………………….……………………………………………. 100

Appendix Figure 1. Effect of irrigation and vegetation-free width (VFW) on fruit soluble solids in fruit harvested July 24, 2008, Jackson Springs, NC........... 101

Appendix Figure 2. Effect of irrigation and vegetation-free width (VFW) on fruit firmness of fruit harvested July 24, 2008, Jackson Springs, NC.................. 102

Appendix Figure 3. Effect of irrigation and vegetation-free width (VFW) on fruit soluble solids in fruit harvested July 23, 2008, Clayton, NC....................... 103

Appendix Figure 4. Effect of irrigation and vegetation-free width (VFW) on fruit firmness of fruit harvested July 23, 2008, Clayton, NC............................... 104

LIST OF TABLES

Page

EFFECTS OF VEGETATION-FREE WIDTH AND IRRIGATION ON NEWLY PLANTED PEACH [*Prunus persica* (L.) Batsch.]

Table 1 Parameter estimates and equivalent irrigated VFW to 3.0 m nonirrigated for peach trunk cross sectional area as affected by vegetation - free area (VFW) and irrigation, Clayton and Jackson Springs, NC, 2006 to 2008.…………...... 48

Table 2 Comparisons of mean peach trunk cross-sectional area of various combinations of vegetation free widths (VFW) and irrigation levels (IRR) with the 3.6 m VFW, nonirrigated treatment, Clayton, NC……….……………………………... 55

Table 3 Comparisons of mean peach trunk cross-sectional area of various combinations of vegetation free widths (VFW) and irrigation levels (IRR) with the 3.6 m VFW, nonirrigated treatment, Jackson Springs, NC…….……………..………… 56

Table 4 Comparisons of peach trunk cross sectional areas of irrigation levels within vegetation free widths (VFW), Clayton, NC……………………………… 57

Table 5 Comparisons of peach trunk cross sectional areas of irrigation levels within vegetation free widths (VFW), Jackson Springs, NC…………………….. 58

Table 6 Parameter estimates and equivalent irrigated VFW to 3.0 m nonirrigated for peach tree winter prunings as affected by vegetation - free area (VFW) and irrigation, Clayton and Jackson Springs, NC, 2007 and 2008……..…………………... 59

Table 7 Parameter estimates for peach harvest as influenced by vegetation - free width (VFW) and irrigation, Jackson Springs, NC, 2008…………….……......... 62

Table 8 Regression analyses for peach harvest as influenced by vegetation - free width (VFW) and irrigation, Clayton, NC, 2008……………….…….…......... 63

Table 9 Regression analyses of total dry weight (kg ha^{-1}) of herbaceous vegetation as influenced by vegetation - free width (VFW) and irrigation for various sampling dates……………….….. 73

Table 10 Percent (averaged over three reps) of total dry weight of total herbaceous vegetation for winter grasses and forbs by irrigation and VFW, Clayton, NC, 2007 and 2008.……………….. 74

Table 11 Percent (averaged over three reps) of total dry weight of total vegetation for summer grasses and forbs by irrigation and VFW, Clayton, NC, 2007 and 2008 …………………..………... 75

Table 12 Percent (averaged over three reps) of total dry weight of total vegetation for winter grasses and forbs by irrigation and VFW, Jackson Springs, NC, 2007 and 2008.……..…………... 76

Table 13 Percent (averaged over three reps) of total dry weight of total vegetation for summer grasses and forbs by irrigation and VFW, Jackson Springs, NC, 2007 and 2008.…………..……….. 77

WEED CONTROL AND PEACH [*Prunus persica* (L.) Batsch.] RESPONSE TO SULFENTRAZONE HERBICIDE SYSTEMS

Table 1 Common name, trade name, formulation, and application rates of herbicides used in sulfentrazone systems study ……………………………………….......... 86

Table 2 The effect of various PRE herbicides on peach trees, weeds, and percent bareground, Vale, NC, 2007… ……………………………………….......... 87

Table 3 Precipitation records (cm) for Clayton and Vale, NC, 2006 and 2007.. 88

RESPONSE OF NEWLY PLANTED PEACH [*Prunus persica* (L.) Batsch.] TO CERTAIN PRE HERBICIDES

Table 1 The effect of various PRE herbicides on tree cross-sectional area (TCSA) and weight of winter prunings, Jackson Springs, NC, 2006 and 2007………… 95

LIST OF FIGURES

Page

EFFECTS OF VEGETATION-FREE WIDTH AND IRRIGATION ON NEWLY PLANTED PEACH [*Prunus persica* (L.) Batsch.]

Figure 1 Effect of irrigation and vegetation - free width (VFW) on trunk cross - sectional area (TCSA), Clayton, NC, December 30, 2006………………………….. 49

Figure 2 Effect of irrigation and vegetation - free width (VFW) on trunk cross - sectional area (TCSA), Clayton, NC, December 13, 2007……………………….…... 50

Figure 3 Effect of irrigation and vegetation - free width (VFW) on trunk cross - sectional area (TCSA), Clayton, NC, January 3, 2009………………………………. 51

Figure 4 Effect of irrigation and vegetation - free width (VFW) on trunk cross - sectional area (TCSA) of newly planted peach, Jackson Springs, NC, February 3, 2007 …………………………………………………….…………………. 52

Figure 5 Effect of irrigation and vegetation - free width (VFW) on trunk cross - sectional area (TCSA) of newly planted peach, Jackson Springs, NC, November 20, 2007 …………………………………………………….…………………. 53

Figure 6 Effect of irrigation and vegetation - free width (VFW) on trunk cross - sectional area (TCSA) of newly planted peach, Jackson Springs, NC, January 3, 2009 ………………………………………………………………………… 54

Figure 7 Effect of irrigation and vegetation - free width (VFW) on SPAD value of newly planted peach, averaged across four sampling dates, Clayton, NC………… 60

Figure 8. Effect of irrigation on SPAD value by vegetation - free width (VFW) at various sampling dates, Jackson Springs, NC.………………….......................... 61

Figure 9 Effect of irrigation and vegetation - free width on percent first harvest of season total, Jackson Springs, NC, 2008………………….......................... 64

Figure 10 Effect of irrigation and vegetation - free width on yield season total, Jackson Springs, NC, 2008………………….. 65

Figure 11 Effect of irrigation and vegetation - free width (VFW) on yield season total Clayton, NC, July, 2008……….. 66

Figure 12 Effect of irrigation and vegetation - free width (VFW) on soil water tension at various sampling dates, Jackson Springs, NC, 2006..................................... 67

Figure 13 Effect of irrigation and vegetation - free width (VFW) on soil water tension at various sampling dates, Jackson Springs, NC, 2007..................................... 68

Figure 14 Effect of irrigation and vegetation - free width (VFW) on soil water tension at various sampling dates, Jackson Springs, NC, 2008..................................... 69

Figure 15 Effect of irrigation and vegetation - free width (VFW) on soil water tension at various sampling dates, Clayton, NC, 2006……….................................... 70

Figure 16 Effect of irrigation and vegetation - free width (VFW) on soil water tension at various sampling dates, Clayton, NC, 2007……….................................... 71

Figure 17 Effect of irrigation and vegetation - free width (VFW) on soil water tension at various sampling dates, Clayton, NC, 2008……….................................... 72

Effects of vegetation - free width and irrigation on newly planted peach[1].

JULIANA K. BUCKELEW and DAVID W. MONKS[2]

Abstract: Field experiments were conducted to determine the optimum vegetation-free strip for irrigated peach with a weedy groundcover. The experiment included two factors, vegetation-free widths (VFW) of 0, 0.6, 1.2, 2.4, 3, and 3.6 m and irrigation (either irrigated or nonirrigated). At Jackson Springs, NC, the irrigated vegetation-free width (VFW) which would produce the same yield season total (kg/ha) as the grower standard (3.6 nonirrigated) is 1.16 m, based on results from regression. (For maximum season total, the VFW needed to be 3.6 m.) The irrigated VFWs which would produce the same tree cross-sectional area as the grower standard was 1.5, 1.3 and 0.8 m for trees aged one, two, and three years old, respectively. At Clayton, NC, trunk cross-sectional area in 2007 and 2008 and harvest season totals were not different by irrigation, but did increase linearly with VFW. At both locations, water and nitrogen were probably the limiting factors. Similar across locations, leaf nitrogen concentrations were lower but not deficient in the irrigated trees than the nonirrigated trees, presumably due to leaching of NO_3 by irrigation. Foliar N, SPAD measurements, soil moisture, and growth responses were positively related to VFW at Jackson Springs therefore growth responses there were probably due to water and N competition with vegetation. In contrast, foliar N concentration was not different by VFW at

---

[1] Received for publication date and in revised form date.

[2] Graduate student and professor, Department of Horticultural Science, North Carolina State University, Raleigh, NC 27695.

Clayton. However, growth responses were positively related to VFW. SPAD measurements increased with VFW so vegetation had some effect on nitrogen. For the first two years of the study, VFW did have an effect on soil moisture at 30 cm depth. Data suggest that a 1.5 m VFW combined with proper irrigation and fertilization will produce tree growth and yield in volunteer weedy vegetation similar to the current grower standard.

Nomenclature: paraquat, flumioxazin, *Prunus persica* (L.) Batsch. 'Contender'.

Additional index words: orchard floor management, *Prunus persica,* competition, vegetation, weed control, nutrition, irrigation.

Introduction

Peach production in North Carolina totaled 5090 metric tons and $5.6 million in crop value in 2008 on 486 ha (Anonymous 2009). A hindrance to peach culture in the southeastern U.S. is orchard floor vegetation in which weeds can compete for water and nutrients (Glenn and Welker 1991). Weeds can have the greatest impact on stone fruit trees during the first 3 to 4 yr after establishment (Anonymous 1999). Young orchards may take longer to come into production if infested with weeds. Orchards are also more likely to suffer frost damage if infested with weeds because their presence can reduce soil temperature by a few degrees, as compared with moist, vegetation-free soil. Weed suppression can increase resistance of bark and wood tissue on dormant scions to cold injury. Decreased available photosynthate related to reduced growth may contribute to lowered cold hardiness (Marriage and Quamme 1980). Removal of all vegetation with herbicides over the total orchard floor or only in tree rows significantly reduces vole and northern pocket gopher populations and their damage (Sullivan and Hogue 1987). Damage from these pests includes feeding on the bark and vascular tissues of stems, roots and underground bark. The weeds that make up an orchard ground cover, if not controlled, can harbor catfacing insects like tarnished plant bug and stink bugs (Meyer 1984; Killian and Meyer 1984). Likewise, spider mites may become problematic to the peach in midsummer when they migrate from senescing winter weeds (Meagher and Meyer 1990) Those trees grown in weedy or sod floor will have fewer total roots and fewer deep roots, with limited lateral spread as compared to bareground (Parker et. al 1993, Parker and Meyer 1996). Glen et al. (1996) found that a sod barrier restricted the growth of peach trees by reducing the size of the root system. Weller et al. (1985) found fewer fibrous peach tree roots in the top 15 cm of soil and reduced fibrous roots 15 to 30 cm deep when subjected to bermudagrass competition, compared to weed-free conditions.

To counter these negative effects of weeds, weed management methods target vegetation around tree trunks (basal weed control), vegetation in tree rows (strip weed control), or all vegetation on the orchard floor (total orchard floor control). Strip weed control involves maintaining a weed-free strip and causes minimum soil compaction by equipment used for cultivation because it eliminates mowing or cultivation between trees. This production system allows access to the orchard during wet weather and reduces erosion on sloped land, compared to total orchard floor control. Trees grown in a strip weed control pattern compared to a basal weed control pattern had greater TCSA (trunk cross sectional area) starting the third year after planting (Welker and Glenn 1991). The use of herbicides for vegetation control results in greater tree growth than when vegetation is controlled by cultivation or hand-hoeing (Daniell and Hardcastle 1972, Bussi et. al 1994).

Concerning timing of weed control, a critical weed- free period from bloom to 12 wk after bloom provides the largest fruit size, total yield and fruit number in peach (MacRae et. al 2007). Huffman (2006) found that the critical weed-free period for young fruit trees in Ontario is May to July to maintain trunk diameter growth, while for bearing fruit trees is from bud break to 30 d after bloom to maintain greatest yields.

Various studies have measured optimal strip width in peach. In studies with tall fescue as orchard floor cover in non-irrigated peach, tree growth and fruit yield was proportional to size of the vegetation free area but plateaued at 9 m^2 with soil nitrogen as the limiting factor (Welker and Glenn 1985, 1989).

The preferred orchard floor management system by growers in the southeastern U.S. is a 3.0 to 3.6 m wide vegetation-free strip in the tree row (Mitchem 2005). However, herbicide volume per acre for strip maintenance may be reduced if strips are narrowed. Reduction of the strip width may be possible through the use of irrigation. If irrigation can decrease the effect of peach/weed competition that occurs with narrow vegetation-free strips, herbicide active ingredient per acre could be reduced which would be cost saving to the grower and reduce potential impacts to the environment. Trickle irrigation was effective in overcoming the added competition imposed by permanent creeping red fescue sod strips in row middles (Layne and Tan 1988). Irrigation of newly planted peach trees maintained in a 3.0 m wide strip in a cover of crabgrass and brome, had larger TCSA than non-irrigated trees by the second growing season (Huslig et. al 1993). By reducing the strip width even lower, optimal tree growth can be determined at the narrowest strip possible under irrigation.

Competition studies involving vegetation-free area have primarily used fescue sod as an orchard ground cover (Belding et al. 2004; Welker and Glenn 1989; Welker and Glenn 1985). These studies were located in climates conducive for fescue growth. However, in South Carolina, Georgia, and central North Carolina, the orchard cover is often volunteer weedy vegetation as the climate is not conducive for fescue. Thus, the objective of our study was to determine the optimum vegetation-free strip for irrigated peach with a weedy groundcover.

Materials and Methods

Field experiments were conducted from 2006 to 2008 at two sites. The first site was Central Crops Research Station in Clayton, NC (35.65 degrees N, 78.46 degrees W). Soil was Norfolk loamy sand (fine-loamy, Kaolinitic, thermic Typic Kandiudults) with pH 6.1 and humic matter 0.41%. The second site was the Sandhills Research Station in Jackson Springs, NC (35.21 degrees N, 79.63 degrees W). Soil was Candor Sand (sandy, Kaolinitic, thermic Grossarenic Kandiudults) with pH 5.8 and humic matter 0.60%. Dolomitic lime was also applied at both locations pre-plant at 1123 kg ha^{-1}. At Jackson Springs, the field was fumigated with 331 kg ha^{-1} of 1,3-dichloropropene. At both sites, the tree row and swathes 90 degrees to the tree row where the trees would be planted were chisel plowed and then disked. In both studies for 2006 and 2007, fertilization schedules were followed as recommended by Georgia Cooperative Extension Service for newly planted trees (Lockwood et al. 2005). In 2008 (bearing year) fertilization was broadcast-applied with 45 kg each of N and K_2O ha^{-1} in mid-April, and 22 kg ha^{-1} of each again in early June and again after harvest.

Peach trees 61 to 76 cm tall were hand planted in April 2005 in Clayton and January 2006 in Jackson Springs. At planting the bottom 30 cm of each tree was painted with white latex paint for protection from contact herbicide. Plots were four tree plantings of 'Contender' (freestone fresh-market type) on 'Guardian'[3] rootstock. Plot size was 21.9 by 3.7 m. Tree spacing was 5.5 m in rows 6.1 m apart (298 trees ha^{-1}). Of the four plants per plot, the middle two were used for data measurements and the outer two on each end were buffer trees.

The experimental design was a randomized complete block design replicated six times at Jackson Springs and four times at Clayton. The experiment had two factors, vegetation-free widths (VFW) of 0, 0.6, 1.2, 2.4, 3, and 3.6 m and irrigation (either irrigated or nonirrigated) as factors. Strips were chemically maintained with flumioxazin at 213.3 g ha^{-1} active ingredient for PRE weed control, and paraquat at 0.67 to 1.0 kg ha^{-1} active ingredient with non-ionic surfactant[4] at 0.25% volume per volume for POST weed control. A graminicide (fluazifop, sethoxydim or clethodim) was used as needed for perennial grass control.

Application equipment was a CO_2 backpack sprayer pressurized at 220-234 kPa using a flat fan 8002XR nozzle to apply 187 L/ha spray volume. Single, double, and triple nozzle booms were used according to the strip width being sprayed. Orchard mowers maintained the floor vegetation between tree rows up to 0.6 m on each side of the trees by cutting to approximately 10 to 13 cm tall. Trees were pruned each spring in an open-center form (Lockwood and Myers 2005).

Soil moisture was measured twice weekly May through August (after harvest) with Watermark™ granular matrix sensors[5] set at 30.5 cm soil depth in every plot in four replications per study location. These sensors were set at the second tree in each plot 46 cm from the tree trunk. Microsprinklers were set 15 cm on the other side of the tree trunk and 76 to 91 cm from the sensor, so that the sensor, trunk and microsprinkler were in a triangular arrangement. The irrigated plots were watered when the soil moisture readings of the irrigated standard 3.0 m strip treatment was 20 centibars (cb) or above, as measured by the granular matrix sensors. (The exception was when the watering did not fit into station irrigation scheduling or sensors could not be read in time to request for irrigation, both of which were rare.) (Appendix Tables 1 and 2) Irrigation at Clayton did not begin until spring of 2006, one year after tree planting. The optimum soil water tension for a particular crop depends primarily on soil texture. Field capacity is 10 cb or less for a sand (Gary Grabow, personal communication) and the irrigation range for peach trees in the southeastern U.S. is 20 to 60 cb (Taylor and Rieger 2005), therefore 20 cb was chosen for the threshold. Inside the sensors is salt dissolved from gypsum that conducts an electrical current based on water amount present. As the soil dries out, soil resistance increases, and is converted to soil tension units (cb). The microsprinklers delivered 70 liters per hour in a 6.0 m diameter, 300 degree swathe pattern around the tree. Water in the amount of 2.54 cm was applied at each irrigation. Precipitation and irrigation records are listed in Appendix Tables 1 and 2.

Trunk cross-sectional area (TCSA) was measured 30 cm above the soil line during the dormant season. Winter prunings were cut and weighed on March 5 and 6, 2007, and March 3 and 10, 2008 in Clayton and Jackson Springs, respectively. Winter prunings from two trees per plot were weighed, then the total was divided by two to get winter pruning weight per tree. Average leaf size (cm^2) was measured May 8, 2008 at Clayton, and April 29, 2008 at

Jackson Springs by randomly selecting ten leaves per tree. Leaf area was measured with a LI-COR LI-3100 area meter.[6] SPAD measurements measurements were recorded on July 5, 2007, July 2 and 4, and August 22, 2008 in Clayton and July 5, 2007, July 1 and 3, and August 20, 2008 in Jackson Springs using a SPAD 502[7] meter. The average of five readings per tree was recorded from new, fully expanded leaves, approximately the sixth to eighth leaf from each shoot tip.

Peach leaves were sampled in late July of every year for determination of concentration of nitrogen, phosphorous, potassium, calcium, magnesium, manganese, iron, copper, sodium, sulfur, zinc, and boron.

Orchard floor vegetation was harvested May 21 and August 13, 2007, and April 22 and September 8, 2008 at Clayton, and May 16 and August 10, 2007, and May 22 and September 15, 2008 at Jackson Springs. One 0.37 m^2 quadrate was randomly sampled around one of each plot's buffer trees in three reps. Total vegetation per tree per 3.6 m swathe was extrapolated from these sample quadrates, with 3.6 m VFWs having values of zero, and therefore were excluded from statistical analyses. In plots with VFWs of 0 and 0.6 m, mowing left approximately a 0.6 m nonmowed swathe on each side of the tree, so these nonmowed areas were sampled additionally, and taken into account when calculating the total vegetation. From each quadrate, species were separated and dried at 60 C until weight was constant. Dry weight of each species was recorded. Species at each date and irrigation level were then tested for percent content of nitrogen, phosphorous, potassium, calcium, and magnesium.

Fruit were thinned on May 9, 2008 at Clayton and May 13, 2008 at Jackson Springs to one fruit per 18 cm of shoot. Hand harvest began when approximately 5% of total fruit were a yellow or gold background color. Harvestable fruit were those with this coloring. The final harvest consisted of all fruit regardless of color. Fruit were picked from each of the two data trees per plot. Harvests at Jackson Springs were July 17, 21, 24, and 29, 2008 and at Clayton were July 16, 21, 23, and 25, 2008. Ten random fruit (approximately five from each tree, when available) were weighed to obtain average weight per fruit. These ten were then laid on their sides, touching side to side in a row, with suture facing up. This measurement when divided by ten provided average fruit width. These ten were then turned 90 degrees, touching tip to tip, with suture facing up. This measurement when divided provided average fruit length. When ten were not available due to small harvests per plot, the smaller number was measured for each parameter. A weighted index of individual fruit weight, fruit width, and fruit length was created for each treatment combination by first figuring the percent weight of total season's harvest for each harvest date. This percent was then multiplied by each date's harvest parameter of weight, width or length, as mentioned above. The four figures (representing four harvest dates) were then added together. The third harvest of the four total harvests at each site was sampled to test for soluble solids (degree Brix) with a digital refractometer[8] and fruit firmness.

Data were subjected to ANOVA with VFW and irrigation as factors. Year, date, and location were tested using appropriate error terms for significant interaction with VFW and irrigation to see if data could be combined where appropriate. When VFW was significant at the 0.05 level or below, means were regressed to describe trends. The dependent variable was regressed separately on VFW for each irrigation level (if the irrigation factor was significant). In certain cases, the interaction of VFW and irrigation was not necessarily significant; however, separate regressions were still fit because intercepts were different and both irrigation conditions were of interest in this study. The ANOVA for testing of linear, lack of fit to linear, quadratic relationship, and cubic relationships (and interactions with irrigation for each of these) determined the type of regression or trend line. When linear relationships were significant, dependent variables as a function of VFW were described through regression with the REG procedure of SAS (SAS 1998). When cubic and quadratic relationships were significant, relationships were described with the NLIN procedure of SAS to fit a quadratic plateau model of the form:

$$\begin{aligned} & Y = a + bV + cV^2 && \text{if } V < w && [1] \\ \text{or} \quad & Y = P, && \text{if } V \geq w && \end{aligned}$$

where Y is the dependent variable, a is the y intercept, b and c are coefficients defining the slope of the line, and V = the width (m) of the vegetation-free strip. The constants a, b, and c are constrained so that the entire function is unique at all rates of V. The constant w is the join point (i.e. the VFW at which the quadratic and the plateau portions of the function are joined). The constant P is the plateau value of the dependent value (Wold 1974). The model is often used for growth responses to single nutrient fertilization doses (Bullock and Bullock 1994). When the estimate of w is higher than 3.6 m, the response is similar to linear because it has not leveled off at the highest VFW of 3.6 m. In this case, the w estimate is not reliable; but illustrates that the response had not leveled off at the highest VFW. When the estimate of w is within the scope of the data, the quadratic plateau has a better fit compared to the linear model (Cavell Brownie personal communication).

For TCSA, winter pruning, and harvest data, irrigated VFWs were computed that were equivalent to the nonirrigated 3.0 m VFW. For TCSA data, effect slices within VFW compared means of irrigated and nonirrigated plots, and the PDIFF option of PROC GLM in SAS compared means of each treatment with the 3.6 m nonirrigated treatment. Vegetation nutrient data were regressed on VFW by irrigation level where appropriate. These data were also analyzed by protected lsd comparisons across all dates (Appendix Tables 3 and 4).

Results and Discussion

Trunk cross sectional area. Strong interactions were found for study location and tree age, so studies and years were analyzed separately. (TCSA for two year old trees from each location could not be combined, and TCSA of three year old trees from each location could not be combined.) The drought conditions of 2007 and the trees being planted with one year difference made data combination not possible. The standard factorial ANOVA for TCSA showed the factors VFW and irrigation to be significant ($p \leq 0.05$), with the exception of Clayton 2007 and 2008. In Clayton 2007, irrigation was significant at level $p=0.0784$. At Clayton 2008, only VFW was significant (Table 1). Quadratic plateaus of TCSA on VFW were fit separately to each irrigation level at each of Clayton (Figure 1) and Sandhills locations (Figure 4 to 6), with the exception of Clayton 2007 (Figure 2), where simple linear regression described the data, and Clayton 2008 (Figure 3) where a linear fit described both irrigation levels combined. At Clayton, the irrigated data point for 3.6 m appears low (Figure

1 to 3), but was not an outlier when residuals were plotted. When dropped from the data set, TCSA response to VFW for the irrigated plots would be linear: Y = 13.1 + 6.7 VFW (R^2 = 0.93) for 2006, Y = 20.5 + 11.4 VFW (R^2 = 0.94) for 2007. TCSA for both irrigation levels combined for 2008 would be described by Y = 32.1 + 13.8 VFW (R^2 = 0.90). However, no justification was found for the dropping of this data point from the data set, therefore it was retained. The predicted join point 'w' for the irrigated fitted regressions, i.e. the predicted VFW at which the TCSA is maximized and starts to plateau, ranges from 2.28 to 4.12, smaller than their companion nonirrigated fitted regressions, ranging from 4.5 to 8.29 (Table 1).

Without regression and comparing means, at Clayton and Jackson Springs, the TCSA of trees in irrigated zero and 0.6 m VFWs were smaller than those in the nonirrigated 3.6 m VFW (Tables 2 and 3). Likewise, the irrigated 1.2 and 2.4 m VFW at both locations (with the exception of Clayton 2008 1.2 m) were not different from the 3.6 m, nonirrigated VFW. This observation can be interpreted that irrigation allows reduction of herbicide strip width down to 1.2 m without reduction in TCSA. Within nonirrigated plots, TCSA of trees in 0, 0.6, and 1.2 m VFWs were smaller than those in the 3.7 m VFW (Tables 2 and 3).

The nonirrigated regressions have smaller slopes (parameter b) than the irrigated regressions i.e. the benefit of irrigation is large due to the rapid increase in TCSA (Table 1). However, there is no difference between irrigated and nonirrigated plots at 0 VFW (Table 4 and 5). This observation means irrigation could not lessen the impact of weed competition at the most intense competitive impact of the 0 VFW treatment. At Jackson Springs in the latter two years, irrigated trees were actually larger than their nonirrigated counterparts of the same VFW in VFWs of 0.6 m and wider (Tables 5), but at Clayton, irrigated trees were not different from their nonirrigated counterpart of the same VFW, except for the 2007 3.0 m VFW (Table 4).

The effect of the drought may have slowed tree growth because for trees of the same age, the predicted join points (parameter w) are larger and tree size (represented by y - intercepts or parameter a) is smaller for the trees at the end of 2007. For example, the predicted join points are 4.12 and 8.29 and the y - intercepts are 10.9 and 7.64 (irrigated and nonirrigated) for Jackson Springs 2007 compared to 2.88 and 6.08 and the y - intercepts 12.09 and 12.57 (irrigated and nonirrigated) for Clayton 2006 (Table 1). Likewise, for the three year old trees, the y - intercepts are 26.93 and 23.69 (irrigated and nonirrigated) for Jackson Springs 2008 compared to 24.13 and 20.33 (irrigated and nonirrigated) for Clayton 2007 (Table 1). Interestingly, the equivalent irrigated VFWs to 3.0 m nonirrigated is the same for two year old trees: 1.32 m (Table 1). It ranges from 0.8 to 2.17 for all tree ages at both locations. The 0.8 m equivalent irrigated VFW for Jackson Springs 2008 was low because the slope of the irrigated trees was almost three times greater than that of the nonirrigated trees i.e. irrigation benefit was high in this case (Table 1). This difference in magnitude may be due to trees getting larger and water needs increasing. The Clayton 2007 and 2008 tree response was best described by a simple linear regression. TCSA at Jackson Springs seemed to increase more rapidly with VFW i.e. the benefit of weed control was great, resembling a quadratic fit rather than linear. Therefore, the effect of competition may have been greater at Jackson Springs because for all three years a quadratic trend fit the data. The point at which a linear response, or a quadratic plateau with a high predicted ‘w,’ would plateau corresponds to a large VFW, not tested in the scope of this data set. By 2008 in Clayton, there was no difference in irrigation levels (Table 1) which suggests another factor of influence.

Winter prunings. All data were subjected to ANOVA. At Jackson Springs, the standard factorial ANOVA for winter prunings showed the factors VFW and irrigation to be significant ($p \leq 0.05$). At Clayton, however, irrigation effect was not significant but the ANOVA testing linear and lack of fit to linear responses showed VFW*VFW*irrigation to be significant ($p = 0.0311$), so separate trends were fit. Winter prunings on VFW followed a quadratic plateau for irrigated plots, while nonirrigated increased linearly with VFW (Table 6) for Clayton 2007. By 2008, the trees were combined into one regression trend because they varied similarly with VFW. This trend is similar to results above for TCSA. At Jackson Springs, winter prunings displayed quadratic plateaus for both years and irrigation levels (Table 6), also similar to results for TCSA.

In 2007 the equivalent irrigated VFW to grower standard (3.0 m VFW, nonirrigated) was 2.17 m for Clayton (Table 6), and for TCSA 2006 was 1.32 (Table 1) (both reflect 2006 growing season). These figures are similar. In Jackson Springs for consecutive years 2007 and 2008, the equivalent irrigated VFW was 1.53 and 1.60 for winter prunings (Table 6) and 1.52 and 1.32 for TCSA (Table 1) (both reflect 2006 and 2007 growing season). These figures are also similar.

Individual leaf area. As mentioned above, leaf area was measured one time, in spring of 2008 when trees were three years old at Jackson Springs and four years old at Clayton. At Clayton, leaf area increased with VFW for irrigated and nonirrigated trees, and nonirrigated trees had larger leaves. The trends for irrigated and nonirrigated were $Y = 12.23 + 0.96$

VFW ($R^2 = 0.70$) and $Y = 15.18 + 1.24$ ($R^2 = 0.84$), respectively. The mean area of irrigated trees' leaves was 13.98 cm^2 while that of nonirrigated trees' leaves was 17.45 cm^2 ($p < 0.0001$). At Jackson Springs, leaf area displayed a quadratic relationship with VFW for irrigated trees, with no effect of VFW for the nonirrigated trees. Irrigated trees followed the trend $Y = 11.95 - 2.91VFW + 0.74\ VFW.^2$ The mean area of irrigated trees' leaves was 10.39 cm^2 while that of nonirrigated trees' leaves was 14.42 cm^2 ($p< 0.0001$). Visual observation of lighter green leaves of the irrigated trees compared to the nonirrigated trees was noted.

SPAD measurement. SPAD measurements reflect leaf chlorophyll nitrogen, and are used as a measure of relative foliar nitrogen content between treatments because leaf chlorophyll content and leaf nitrogen content are closely linked (Bullock 1994). The meter quickly measures nitrogen status by emission of wavelengths in the infrared and red ranges that transmit through the leaf according to the chlorophyll content, since chlorophyll transmits those in the infrared and absorbs those in the red ranges (Anonymous 2007). The readings allow for more "snapshots" of nitrogen status than the traditional annual foliar sample subjected to laboratory testing. Relatively higher chlorophyll nitrogen in leaves is reflected by darker leaves than those with relatively lower chlorophyll nitrogen, which have lighter leaves. For the purposes of the following discussion, leaves may be referred to as "darker or lighter" for brevity.

At Clayton, the ANOVA test of main effects, VFW and irrigation, were significant. Date * irrigation was also significant ($p < 0.0001$). Effect slices of irrigation at each date showed each date to be significant, and charting the trends for each date showed that the interaction significance was due to differences in magnitude. So, all dates were combined for analysis between irrigation levels, averaged across date. The average of irrigated plots (36.7) was lower than the average of nonirrigated plots (39.6) ($p < 0.0001$). Irrigation on July 3, 2008 did not change leaf color in irrigated plots, as shown by a contrast statement investigating mean value for irrigated plots, averaged over VFW, for July 2 and July 4, 2008 ($P=0.2327$). Separate regressions were fit for each irrigation level: quadratic plateaus of SPAD on VFW. The irrigated predicted parameters are: $a = 34.31$, $b = 2.38$, $w = 3.07$ ($R^2 = .99$). The nonirrigated predicted parameters are: $a=38.06$, $b=3.42$, $w=1.16$, ($R^2 = 0.82$) (Figure 7). The nonirrigated trees were darker at wider VFWs, therefore had reached maximal darkness at 1.16 m VFW, compared to maximal darkness for the irrigated at 3.07 m. On August 22, 2008, the fourth date, nonirrigated trees were still 1.2 units darker green than irrigated trees ($p = 0.0378$), but this difference is less than the average across all dates (3.1) as mentioned above. As the season progresses, the darkening of leaves is expected as leaves age (Michael Parker, personal communication). As the season progressed in 2008, the difference in color narrowed between irrigation levels, as irrigated leaves became darker with season progression, and nonirrigated leaves were already dark. Across all dates and only comparing means (without regression), SPAD means of all treatments were compared to the 3.6 m, nonirrigated treatment. Irrigated trees of 0 and 0.6 VFW were lighter green than the 3.6 m VFW, nonirrigated ($P=.0040$ and 0.0196, respectively), while other VFWs (1.2, 2.4, and 3.0 m) of both irrigation types were not different from the 3.6 m VFW, nonirrigated treatment.

At Jackson Springs, the ANOVA test of main effects, VFW and irrigation, with block*VFW*irrigation used as an error term, was significant. Interaction of irrigation with date, and the triple interaction between VFW, irrigation and date were significant, so irrigation was analyzed separately by date and VFW. Across all dates and VFWs, the average SPAD of irrigated plots (36.5) was lower than the average of nonirrigated plots (40.6) ($p<0.0001$), which are similar to results from Clayton.

When VFW 0 to 1.2 were combined, VFW*irrigation*date was not significant, however, VFW*irrigation, with block*VFW*irrigation used as the error term, was significant ($p=0.0086$), so these VFWs were not combined. For VFW 0, irrigated (41.96) and nonirrigated (40.93) were not different for the fourth date August 20, 2008 ($p=0.3577$) (Figure 8a). Similar to Clayton, the difference in color narrowed between irrigation levels later in the season. Here, stressed irrigated tree leaves appeared not to be darkening as much as those of wider VFWs (Figure 8b and 8c), and nonirrigated dark leaves actually appeared to be becoming lighter. Irrigation on July 2, 2008 did not affect leaf color as measured by a contrast statement comparing leaf color the day before irrigation to the day after irrigation ($p= 0.4620$).

For VFW 0.6 and 1.2 at date 4, however, the irrigated tree leaf color (43.35) had surpassed the nonirrigated tree leaf color (40.41) and was actually darker ($P=0.0001$) (Figure 8b). The irrigated tree leaves were darkening as expected while the nonirrigated leaves appear to be lightening from July to August 2008, and surpass the nonirrigated in darkness. Across VFW 0.6 to 1.2, leaf color did not change the day before to the day after an irrigation for irrigated or nonirrigated, as shown by contrast statements investigating mean value, averaged over VFW ($P = 0.0669$ and 0.5880, respectively).

VFW 2.4 to 3.6 were combined, because VFW*irrigation*date was not significant (P=0.6475). Leaf color was lighter in irrigated plots compared to nonirrigated plots for early July of 2007 and 2008 (P<0.0001) but by August 20, 2008, leaves were the same as nonirrigated plots (Figure 8c). The normal pattern of darkening leaves from July to August 2008 was seen for both irrigation levels to the point where they became the same color. Leaf color did not change in nonirrigated plots on July 1 to July 3, 2008, as shown by a contrast statement investigating mean value for nonirrigated plots, averaged over VFW (P=0.7127). However, leaf color did change from the day before to the day after an irrigation in irrigated plots, as shown by a contrast statement investigating mean spad value for irrigated plots, averaged over VFW (P=0.0341). However, the leaves became darker not lighter. Since nonirrigated leaves are darker than irrigated, one would expect irrigation to have a lightening effect if it were the cause. This phenomena is probably not due to the irrigation event, but because the leaves were darkening in color with season progression.

In summary, leaf color was darker in nonirrigated plots at both locations in July of 2007 and 2008, However as the season progressed in 2008, the difference in color narrowed between irrigation levels, as irrigated leaves became darker with season progression. At Jackson Springs in 2008 the nonirrigated trees in the 0, 0.6, and 1.2 m VFW appeared to getting lighter with season progression.

Harvest. None of the following fruit parameters had interactions between VFW and irrigation factors, but regressions were fit separately for irrigation level to answer the objective of this study which was to determine equivalent values for dependent variables between the irrigation levels. At Jackson Springs, stressed trees such as those in narrower

VFWs seemed to have ripe fruit sooner. This observation was magnified in the nonirrigated plots. The mean percent of first harvest of total harvest (a measure of earliness) of the irrigated plots (9%) was lower than that of the nonirrigated plots (19%) ($p < 0.0001$). Percent of first harvest of total harvest followed a quadratic plateau trend for the nonirrigated, with the predicted join point of 1.04 m VFW ($R^2 = .82$) (Table 7 and Figure 9). The irrigated plots showed no regression trend, but the irrigated 0 m VFW (33%) was higher than the average of the other irrigated VFWs (5%) ($p < 0.0001$). The y-intercept is larger for all parameters in the irrigated plots vs. nonirrigated plots (Table 7). Fruit length displayed quadratic plateau trends for both irrigated and nonirrigated. It was the largest at VFW 1.89 m (and above) in irrigated plots and 0.84 m (and above) in nonirrigated plots (Table 7). Mean fruit length was 7.15 cm and 6.68 cm for irrigated and nonirrigated respectively ($p < 0.0001$). Fruit width displayed quadratic plateau trends for irrigated, but nonirrigated displayed a quadratic trend. Irrigated tree fruit width was the widest at VFWs 2.33 m and above ($R^2 = .93$). Mean fruit width was 7.29 cm and 6.81 cm for irrigated and nonirrigated respectively ($p < 0.0001$). Individual fruit weight (g) on VFW displayed a quadratic plateau for both irrigated and nonirrigated. It was the largest at VFW 2.83 (and above) in irrigated plots and 1.96 (and above) in nonirrigated plots (Table 7). Mean individual fruit weight was 49.05 g and 41.43 g for irrigated and nonirrigated respectively ($p < 0.0001$). Harvest season totals (1000 kg ha^{-1}) displayed quadratic plateau trends for both irrigated and nonirrigated (Figure 10). The predicted join points (w) for the fitted regressions, i.e. the predicted VFW at which the yields are maximized and start to plateau is outside the scope of the data, but is higher for the nonirrigated (7.07) than irrigated (5.12) (Table 7 and Figure 10). Mean season total

(1000 kg ha^{-1}) was 4.39 and 3.03 for irrigated and nonirrigated respectively ($p = 0.0005$). Fruit soluble solids increased linearly with VFW for nonirrigated trees: $Y = 12.37 + 0.139$ VFW, $R^2 = 0.71$, and the mean soluble solids for irrigated trees was lower at 11.8 vs 12.6 for nonirrigated ($p < 0.0001$) (Appendix Figure 1). Treatment differences were not found for fruit firmness (Appendix Figure 2).

At Clayton, no treatment differences were found for percent of first harvest of total harvest. As with TCSA, winter pruning, and leaf area, harvest parameters followed linear responses. Nonirrigated trees produced longer fruit, wider fruit, heavier individual fruit, and greater yield (kg ha^{-1}), although the yield difference was only marginally significant. The y-intercept is smaller for all parameters in the irrigated plots vs. nonirrigated plots (Table 8). Fruit length increased linearly with VFW with separate trends for irrigated and nonirrigated plots (Table 8). The mean length for irrigated plots was 6.7 cm versus 7.0 cm for nonirrigated plots ($p < 0.0001$). Fruit width increased with VFW with separate trends for irrigated and nonirrigated. Fruit width displayed a quadratic plateau trend for irrigated, but nonirrigated displayed a linear trend. Irrigated tree fruit width was the widest at VFWs 3.6 ($R^2 = 0.78$). Mean fruit width for irrigated trees was 7.0 cm versus 7.3 cm for nonirrigated trees ($p = 0.0004$). Individual fruit weight (g) increased linearly with VFW with separate trends for irrigated and nonirrigated plots (Table 8). The mean individual fruit weight for irrigated plots was 43.5 g versus 49.5 g for nonirrigated plots ($p = 0.0002$). Harvest season totals (1000 kg ha^{-1}) on VFW displayed linear trends for each irrigation level but the difference in irrigation levels was marginally significant at $p = 0.0573$ (Table 8 and Figure 11). The mean season total (1000 kg ha^{-1}) for irrigated trees was 8.5 versus 10.2 for nonirrigated trees. Fruit soluble solids were not different by VFW, but irrigation factor was significant (P=0.0033), with the mean soluble solids of irrigated plots (11.99) being higher than nonirrigated plots (11.51) (Appendix Figure 3). Treatment differences were not found for fruit firmness (Appendix Figure 4).

Results for fruit quality were inconclusive. Soluble solids were greater in fruit of irrigated trees versus nonirrigated trees at Clayton, but the reverse was true at Jackson Springs with no consistent effect of VFW. Tworkoski et al. (1997) found similar results in a nonirrigated situation in that size of vegetation-free area within a cover of grasses had no effect on concentration of soluble solids in peach fruit.

Soil moisture. Plotting the residuals showed a square root transformation to correct for nonhomogeneity of variance. Repeated measures ANOVA was run on all data by location and year. The irrigation factor was very strong, so comparisons for VFW were by irrigated and nonirrigated. A test of effect slices by each day showed for which days soil moisture was different by VFW, and the maximum lsd was recorded.

Soil moisture was less among non-irrigated plots compared to irrigated plots, but there were few differences between VFWs within each irrigation level later in the season (Figures 12 to 14). In a few instances (Jackson Springs irrigated trees 2007 and nonirrigated trees 2008), the larger VFWs dried out faster than the other VFWs. These trees were larger with higher water demand. There was however, a trend of differences between VFWs within each irrigation level early in the season, from the start of measurement to days 144 to 163 (Figures 12 to 14), and to days 163 to 177 for Clayton (Figures 15 to 17): competition from vegetation in the smaller VFWs caused the soil to be dryer than soil in the wider VFWs. The trees were in full bloom stage on day 91 (April 1, 2008) at Clayton and on day 93 (April 3, 2008) at Jackson Springs. The cell division stage of fruit development would last until approximately day 143. On day 178 approximately, final swell would begin based on harvest beginning on day 199 (July 17, 2008). Based on these approximate periods of fruit development, the dryness caused by the vegetation would coincide with cell division and pit hardening, stages one and two of fruit development.

The *first* irrigation of each year was day 174, day 145, and day 154 for 2006, 2007, and 2008, respectively, at Jackson Springs, and was day 195, day 144, and day 158 for 2006, 2007, and 2008, respectively, at Clayton, which would miss these earlier soil moisture differences due to vegetation. As mentioned above, irrigation scheduling was based on the threshold for the 3.0 m irrigated so irrigation would not have occurred anyway if only the smaller VFWs were dry. From these data, the period of competition for water caused by the vegetation actually occurs before days 144 to 163 (Jackson Springs) and before days 163 to 177 (Clayton). These results agree with MacRae et al. who found that a weed-free interval of 12 wk after bloom (approximately day 177) resulted in the greatest fruit size, total yield, and fruit number in mature trees. In a study by Huslig et al., with trickle irrigation and 3.0 m VFW, peach trees were irrigated according to the following treatments: no irrigation, irrigation budbreak to October, budbreak to harvest, stage III fruit growth (final fruit swell) to October, and stage III fruit growth to harvest. Irrigation before stage III fruit growth did not affect fruit yield, size, or pruning weights compared to trees irrigated at the onset of stage III fruit growth. However, trees irrigated from budbreak until harvest produced more fruit 64 to 70 mm (large fruit) than non-irrigated. Earlier irrigation timing during cell division and pit hardening stages of fruit development may help mitigate the negative effects of floor vegetation. Current extension recommendations advise that dryness during the 4 to 6 wk preceding peach maturity is significantly detrimental to yield and fruit quality (North Carolina State University Cooperative Extension Service 1999) but results from this study suggest this period may start earlier. In 2006 and 2007, during the early non-bearing years, peach root growth may have been restricted by the vegetation. New white root growth occurs in young, nonbearing trees throughout the growing season, while mature trees produce new white roots only in March to June, and resume following fruit removal in August and persist through January (Glenn and Welker 1993a). In greenhouse studies, Glenn and Welker (1993b) showed that peach fine root development in sod is restricted when water is limiting and could account for differences in growth. However, in the oldest trees in our study (Clayton 2008) no differences in soil moisture were found within irrigated or nonirrigated trees. As the trees aged in our study, detecting soil moisture differences of VFW at the 30 cm depth (that was used in this study) may have become more difficult due to deeper root development. This idea is supported by the findings of Glenn and Welker (1993a) who found a lack of correlation between plant available water and peach root density within 1 m of the tree and to a depth of 90 cm, suggesting that deep roots help maintain the surface root system when the soil dries. This idea is also supported by the findings of Smith et al. (2002) who found that soil moisture differences due to vegetation-free area were greater at 60 cm deep than 30 cm deep in newly planted, irrigated pecans. Therefore, soil moisture differences in this study due to VFW were probably occurring deeper than 30 cm as trees became larger and deeper rooted.

Foliar element concentrations. Since 2007 (year 2) was a very dry year, there are many interactions by year. For nitrogen (%), at Jackson Springs, an interaction was present for year * VFW and year * irrigation, so years were analyzed separately. All years had significant irrigation effects, with nonirrigated trees (4.01, 3.46, and 3.94) having higher % N than irrigated (3.69, 2.78, and 3.44), ($p = 0.0021, < 0.0001, < 0.0001$), for 2006, 2007 and 2008, respectively. In 2006 and 2007, nitrogen of irrigated trees increased along a quadratic plateau with VFW. In 2006 the parameters were $a = 2.5$, $b = 1.99$, and $w = 1.54$ ($R^2 = 0.90$) and in 2007 were $a = 2.29$, $b = 1.01$, $w = 1.23$ ($R^2 = 0.96$). The increase of nitrogen with VFW was probably related to the competition for nitrogen with the vegetation. Similarly, Haynes (1980), and Welker and Glenn (1985, 1988) reported that foliar N concentration increased when trees were grown in bareground compared to grass sod and Welker and Glenn (1991) reported higher soil NO_3 and P when peaches were grown on bare soil compared to growing with a living fescue sod. The irrigated trees may have been more susceptible to vegetation effect if soil N was lower due to leaching caused by the additional water received through irrigation compared to the nonirrigated trees. In 2008, the nitrogen in nonirrigated trees decreased linearly with VFW: $Y = 4.49 - 0.30\ VFW$, ($R^2 = 0.96$). The negative trend in nonirrigated trees could be due to increased nitrogen cycling by the vegetation without leaching being as dominant a factor as the irrigated situation. Nitrogen cycling is centered in the relationship of the less bare ground, the more organic matter content of the soil. Organic matter provides carbon that supports higher populations of microbes that utilize nitrogen, reducing leachability of nitrogen. Soil microbes decompose organic matter (mineralization) releasing nutrients to the tree. Also the plants take up nitrogen, reducing the leachable nitrate nitrogen in the soil. (Edson 2003). At Clayton, the effect of irrigation on nitrogen (%) was different by years but VFW had no effect for any year. Leaf nitrogen concentration was not affected by VFW, indicating that tree competition for nitrogen with the vegetation was minimal. Percent nitrogen was not different among treatments in 2006, but it was higher in nonirrigated trees (3.34) than irrigated trees (3.01%) in 2007 and 2008 ($p < 0.0001$).

The common trend between locations is that nonirrigated trees had higher percent nitrogen. NO_3 is leachable and probably leached from the irrigated plots. However, nitrogen is deficient under 1.7% (Lockwood et al. 2005), so no deficiencies were present at the time of sampling. Warren (1986) postulated that seasonal oscillations with decreased NO_3 levels in the spring and elevated levels in the fall occured due to a rise in soil temperature (and in turn microbial activity) so it may be possible that deficiencies in the springtime would not have appeared in foliar testing of late July. Gupta and Rorison (1975) have confirmed the occurrence of seasonal flushes in the availability of nitrogen (and phosphorous) in noncultivated soil. Taiz and Zeiger (2002) describe nitrogen deficiency symptoms as chlorosis, especially of older leaves, which can become completely yellow and fall from the plant. Younger leaves can become light green in color while older leaves become yellow or tan. These symptoms were evident in this study. Symptoms of nitrogen differences may have been the lighter green leaves of the irrigated trees as measured by the SPAD meter (as mentioned previously). Visual evidence of deficiency was the yellowing and early defoliation of older leaves of the irrigated trees in October 2008 compared to the nonirrigated trees. Leaf size as measured after budbreak in spring 2008 showed smaller and lighter green leaves of irrigated trees compared to the nonirrigated (as mentioned previously). Companion research in this experiment studied the Jackson Springs site soils. The nonirrigated plots had higher soil available nitrogen compared to the irrigated, and the 0 m VFW had higher microbial carbon content compared to the 3.6 m VFW (which reflects microbial activity) (Wang Liang Ju personal communication). This finding would support these nitrogen foliar concentration findings.

For phosphorous (%) at Jackson Springs, interactions were present for VFW*year, irrigation*year, and VFW*irrigation*year. In 2006 and 2007, irrigated trees had higher phosphorous (0.26 and 0.19%) versus 0.18 and 0.15% in nonirrigated trees ($p<0.0001$ and $p = 0.0021$), respectively. However in 2008, irrigated trees had lower phosphorous (0.20%) versus 0.23% in nonirrigated trees ($p < 0.0001$). These levels are adequate based on deficiency ranges below 0.11% (Lockwood et al. 2005). In 2006 and 2008, phosphorous increased with VFW in irrigated trees: The trend for 2006 was $Y = 0.21 + 0.03$ VFW ($R^2 = 0.89$). The trend for 2008 was a quadratic plateau with parameters: $a = 0.19$, $b = 0.02$, and $xo = 1.99$ ($R^2 = 0.95$). In 2007 and 2008 the phosphorous in nonirrigated trees decreased linearly with VFW: $Y = 0.16 - 0.006$ VFW ($R^2 = 0.74$) and $Y = 0.289 - 0.03$ VFW ($R^2 = 0.93$), respectively. At Clayton, the effect of irrigation on phosphorous (%) was different by years. In 2006, irrigated trees had higher phosphorous (24%) versus 19% in nonirrigated trees ($p < 0.0001$). Phosphorous increased with VFW in irrigated trees following a quadratic plateau with parameters $a = 0.22$, $b = 0.06$, $w = 0.88$ ($R^2 = 0.81$). No treatment effects were significant in 2007. In 2008, irrigated trees had lower phosphorous (19%) versus 21% in nonirrigated trees ($p = 0.0025$). Also in 2008, phosphorous decreased linearly with VFW in nonirrigated trees, following the trend Y = 0.22 - 0.006 VFW ($R^2 = 0.80$).

At both locations, the trends of phosphorous closely resemble those of nitrogen as above: irrigated trees had more phosphorous in the early years, but by 2008 had less phosphorous compared to nonirrigated trees, phosphorous increased with VFW in irrigated trees, but decreased with VFW in nonirrigated trees. Soil N and P in noncultivated soils have been shown to be positively related and was attributed to mineralization of organic P being positively correlated with mineralization of organic N (Gupta and Rorison 1975). Haynes (1980) reported that foliar P, K, and Ca concentrations decrease in bareground compared to foliar P, K, and Ca concentrations in a grass sod. Phosphorus apparently accumulates near the soil surface in bare ground compared to a grass sod which is a consequence of surface compaction and resulting poor infiltration properties. This work agrees with the negative trend of foliar P in nonirrigated trees by the end of our study. In the companion paper (Wang Liang Ju personal communication.) mentioned above, preliminary soil testing results also showed that irrigated trees had higher vesicular arbuscular mycorrhizal fungi infection than nonirrigated trees. This symbiosis is known to aid in phosphorous uptake (Smith et al. 1997). However, phosphorous was decreased in the irrigated trees.

For potassium (%) at Jackson Springs, the effect of irrigation was different by year. For 2006 and 2007, irrigated trees had less potassium (1.67 and 1.10%) versus 2.22 and 1.21% in nonirrigated trees ($p < 0.0001$ and $p = 0.0063$). By 2008, the irrigated trees had more potassium (1.55%) versus that of nonirrigated trees (1.29%) ($p < 0.0001$). Potassium is adequate over 1.2. In 2006 and 2008, the nonirrigated tree potassium decreased linearly with VFW: $Y = 2.49 - 0.15$ VFW ($R^2 = 0.86$), and $Y = 1.41 - 0.06$ VFW ($R^2 = 0.83$), respectively. Percent leaf potassium showed no treatment differences at Clayton. Potassium leaches readily (Lockwood et al. 2005) and decreased with VFW presumably due to reduced water movement through the vegetation or vegetation uptake thereby reducing leaching.

For calcium (%) at Jackson Springs, irrigation and VFW effects were different by year. Irrigated trees had lower calcium in 2006 (0.70%) compared to the nonirrigated trees (0.78%) ($p = 0.0015$), but in 2007 irrigated trees had higher calcium (1.11%) than nonirrigated trees (0.90%) ($p < 0.0001$). No irrigation effect was found in 2008, but calcium in the nonirrigated trees increased with VFW: $Y = 0.71 + 0.06$ VFW ($R^2 = 0.70$). The average percent calcium for irrigated plots was 0.81, and for nonirrigated was 0.82, which do not differ from each other, but are important because both are deficient levels. However, no calcium deficiency symptoms were observed for any location or year. The adequate range is 1.0% or over. At Clayton, the effect of irrigation on calcium (%) was different by years. While calcium was not different among treatments in 2006 and 2007, irrigation did have a significant effect in 2008. Irrigated trees had higher calcium content at 1.09% versus 0.81% of nonirrigated trees. Calcium in irrigated trees decreased linearly with VFW ($Y = 1.2 - 0.07$ VFW, $R^2 = 0.54$). This result agrees with Haynes (1980) who reported foliar Ca concentrations decrease in bareground compared to foliar Ca concentrations in a grass sod, and Haynes and Goh (1980) who found less soil Ca from bare ground plots compared to grassed and suggested this was due to increased leaching. The positive effect of VFW in the nonirrigated trees by the third year in Jackson Springs could be due to the fact that those trees were in the deficiency range, and vegetation uptake decreased with increasing VFW (less competition), making more calcium available to the tree.

Magnesium (%) at Jackson Springs varied by year for VFW and irrigation. In 2006, magnesium in irrigated trees was 0.38 versus 0.41 in nonirrigated trees ($p = 0.0003$). In 2007, no treatment differences were found. In 2008, magnesium of nonirrigated trees followed a linear regression trend of the form $Y = 0.29 + 0.03$ VFW ($R^2 = 0.89$). Irrigation was not significant in 2008. At Clayton, magnesium displayed triple interaction by irrigation, VFW, and year therefore years were analyzed separately. Both irrigation and VFW affected magnesium in 2006. Irrigated trees had lower magnesium content at 0.32% versus 0.35% of nonirrigated trees ($p = 0.0377$). Magnesium decreased linearly with VFW in irrigated trees ($Y = 0.35 - 0.02$ VFW, $R^2 = 0.82$ and in nonirrigated trees ($Y = 0.37 - 0.01$ VFW, $R^2 = 0.52$). Welker and Glenn (1985) also reported that leaf Mg decreased as vegetation-free area increased. Irrigation did not have an effect in 2007, but magnesium in nonirrigated trees decreased linearly with VFW ($Y = 0.50 - 0.01$ VFW, $R^2 = 0.76$). By 2008, irrigated trees had higher magnesium content of 0.45% versus 0.35% in nonirrigated trees ($p < 0.0001$). Magnesium in irrigated trees decreased linearly with VFW ($Y = 0.49 - 0.03$ VFW, $R^2 = 0.76$). Magnesium is sufficient over 0.25. The lower magnesium content of irrigated trees in 2006 at both sites was probably due to leaching. The negative trend of decreased Mg with VFW in the irrigated trees is probably related to increased leaching with wider VFWs. Haynes and Goh (1980a, 1980b) found that exchangeable Ca and Mg in the surface soil under sod compared to bare ground was higher indicating less leaching under sod. However, why nonirrigated trees had lower leaf Mg by 2008 at Clayton is unclear. In fact, by the last year of the study, irrigated trees generally had more of each cation concentration (more potassium at Jackson Springs, more calcium at Jackson Springs 2007, and more calcium and magnesium at Clayton) compared to the nonirrigated trees, when one would expect these leachable ions to be less concentrated in irrigated trees than nonirrigated trees. Bould and Jarrett (1962) found that the negative correlation between K and N concentrations in trees resulting from various orchard management systems stemmed from the lower N content and reduced leaf growth consequently increasing concentration of K in the tree as a whole. This concentration effect was also suggested by Shribbs and Skroch (1986) to explain high phosphorous concentration in apple. This could be the case for K as well as each of the other cations.

Vegetation element content. For this discussion, sampling dates in spring of 2007, summer of 2007, spring of 2008 and summer of 2008 are referred to as sampling dates 1, 2, 3, and 4, respectively. Common to all of the sampling dates is a linear decrease in total aboveground shoot biomass with increasing VFW, and common to all of the following elements is a linear decrease in kg ha^{-1} with increasing VFW.

At Jackson Springs, **t**otal weight of vegetation decreased with VFW for all dates with no significant differences by irrigation (Table 9). Forbs made up 83 to 100% of winter vegetation dry weight, while 0 to 17% consisted of grasses and sedges (Table 12). Forbs made up 17 to 66% of summer vegetation dry weight, while 34 to 83% consisted of grasses and sedges (Table 13). A difference in makeup of forbs and grasses between irrigated and nonirrigated treatments was not apparent for any sampling date. Winter vegetation consisted of purple cudweed, cutleaf evening primrose, annual rye (*Lolium multiflorum* Lam.), horseweed, Carolina geranium, Virginia pepperweed , catsear falsedandelion, Florida pusley (*Richardia scabra* L.), yellow woodsorrel, narrowleaf vetch, and red sorrel. Summer vegetation included large crabgrass, Florida pusley, carpetweed (*Mollugo verticillata* L.), poorjoe, horseweed, Virginia pepperweed, cutleaf evening primrose, pink purslane, catsear falsedandelion, yellow nutsedge (*Cyperus esculentus* L.), and longspine sandbur (*Cenchrus longispinus* (Hack.) Fern).

At Clayton, total weight of vegetation decreased with VFW for all dates with no significant differences by irrigation, except summer of 2007, for which irrigation effect was significant (Table 9). This sample date coincided with a statewide drought that probably translated into reduced shoot biomass in the nonirrigated plots. For this sample date, the irrigated plots contained on average 739.0 kg ha^{-1} dry weight while nonirrigated plots contained on average 368.2 kg ha^{-1} ($p = 0.0006$). Forbs made up 98 to 100% of winter vegetation dry weight, while 0 to 2% consisted of grasses and sedges (Tables 10). Forbs made up 0 to 29% of summer vegetation dry weight, while 71 to 100% consisted of grasses and sedges (Table 11). A difference in makeup of forbs and grasses between irrigated and nonirrigated treatments was not apparent for any sampling date. Winter vegetation included purple cudweed (*Gnaphalium purpureum* L.), cutleaf evening primrose (*Oenothera laciniata* Hill), horseweed (*Conyza canadensis* (L.) Cronq.), Carolina geranium (*Geranium carolinianum* L.), Virginia pepperweed (*Lepidium virginicum* L.), catsear falsedandelion (*Hypochoeris radicata*), yellow woodsorrel (*Oxalis stricta* L.), narrowleaf vetch (*Vicea villosa* Roth), Carolina falsedandelion (*Pyrrhopappus carolinianus* (Walt.) DC), buckhorn plantain (*Plantago lanceolata* L.), rabbitfoot clover (*Trifolium arvense* L.), and red sorrel (*Rumex acetosella* L.).

Summer vegetation included large crabgrass (*Digitaria sanguinalis* (L.) Scop.), poorjoe (*Diodia teres* Walt.), horseweed, cutleaf evening primrose, pink purslane, catsear falsedandelion, dallisgrass (*Paspalum dilatatum* Poir.), bermudagrass (*Cynodon dactylon* (L.) Pers.), buckhorn plantain, white clover (*Trifolium repens* L.), yellow woodsorrel, broomsedge (*Andropogon virginicus* L.), red sorrel, tropic croton (*Croton glandulosus* var. *septentrionalis* Muell.-Arg.), and Carolina falsedandelion.

At Jackson Springs, nitrogen amount in vegetation was different by date, but all dates showed a linear decrease of N kg ha^{-1} with increasing VFW. For dates 1 and 4, the average for N kg ha^{-1} was also different by irrigation level. Dates 2 and 3 showed regression trends: $Y = 4.1 - 1.2$ VFW, $R^2 = 0.65$, and $Y = 37.1 - 9.7$ VFW, $R^2 = 0.64$ (respectively). For date 1, nitrogen followed the trend $Y = 20.2 - 6.3$ VFW, $R^2 = 0.90$. The average of irrigated plots (12.7) was higher than the average of nonirrigated plots (9.5) ($p = 0.0031$). For date 4, nitrogen followed the trend $Y = 30.3 - 8.6$ VFW, $R^2 = 0.92$. The average of irrigated plots (15.9) was lower than the average of nonirrigated plots (19.8) ($p = 0.0268$). At Clayton, nitrogen amount in vegetation was different by date, with a linear decrease of N kg ha^{-1} with increasing VFW for all dates. For dates 2 and 4, the averages for N kg ha^{-1} were also different by irrigation level. Regression trends were: $Y = 9.4 - 2.9$ VFW ($R^2 = 0.91$), $Y = 14.7 - 3.8$ VFW ($R^2 = 0.57$), and $Y = 18.9 - 5.6$ VFW ($R^2 = 0.86$), and $Y = 36.6 - 10$ VFW ($R^2 = 0.85$), respectively for dates one to four. The average of irrigated plots (12.4) was higher than the average of nonirrigated plots (6) for date 2 ($p = 0.0001$), but by date 4, the average of irrigated plots (18.7) was lower than the average of nonirrigated plots (25.5) ($p = 0.0040$).

The common trend between locations is that by the last sampling date, fall 2008 (date 4), irrigated plots contained less kg N ha^{-1} than nonirrigated plots. This effect is probably due to NO_3 leaching as discussed above for N foliar concentrations in the tree. However, reduced kg N ha^{-1} in irrigated plots wasn't translated into reduced weed growth because irrigated vegetation did not have decreased biomass production compared to the nonirrigated vegetation. Conclusions that vegetation or the trees were more competitive than the other for N are difficult. Results from these data suggest that both trees and vegetation reflect the soil situation of reduced soil nitrogen in irrigated plots.

At Jackson Springs, phosphorous amount in vegetation was different by date, but all dates showed a linear decrease of P kg ha^{-1} with increasing VFW. For dates 2 and 4, the average for P kg ha^{-1} was also different by irrigation level. Dates 1 showed regression trend: Y = 2.6 - 0.8 VFW, $R^2 = 0.96$. For date 3, the slopes for P kg ha^{-1} on VFW were different by irrigation level. Regression trends were: Y = 4.0 - 0.9 VFW ($R^2 = 0.43$), Y = 6.3 - 1.8 VFW ($R^2 = 0.88$), respectively for irrigated and nonirrigated plots. For date 2, phosphorous followed the trend Y = 0.8 - 0.2 VFW ($R^2 = 0.58$). The average of irrigated plots (0.6) was higher than the average of nonirrigated plots (0.4) ($p = 0.0286$). For date 4, the slopes of P kg ha^{-1} on VFW were different by irrigation level. P followed the trend Y = 9.1 - 2.8 VFW ($R^2 = 0.95$) and Y= 5.0 - 1.5 VFW ($R^2 = 0.95$) for irrigated and nonirrigated plots, respectively. The average of irrigated plots (5.1) was higher than the average of nonirrigated plots (2.9) ($p < 0.0001$). At Clayton, phosphorous amount in vegetation was different by date, with a linear decrease of P kg ha^{-1} with increasing VFW for all dates. Irrigation was not significant for any date except date 2, for which P content of irrigated plots (3.0) was marginally more than content in nonirrigated plots (2.0) ($p = 0.0521$). Regression trends for dates 1, 2, and 4 were: Y = 1.2 - 0.4 VFW ($R^2 = 0.91$), Y = 3.8 - 0.9 VFW ($R^2 = 0.67$), and Y = 8.7 - 2.4 VFW ($R^2 = 0.90$), respectively. Phosphorous trends were different by irrigation for date 3: Y = 2.3 - 0.7 VFW ($R^2 = 0.87$), for irrigated plots; Y = 1.9 - 0.5 VFW ($R^2 = 0.67$) for nonirrigated plots.

A common trend between locations was that more phosphorous in irrigated than nonirrigated vegetation was found for dates 2 and 4 at Jackson Springs and date 2 ($p = 0.0521$) and date 4 ($p = 0.0599$) at Clayton. These sampling dates were summer species and apparently tied up more phosphorous under irrigated conditions, but this effect was not strong at Clayton as seen in the marginally significant p - values.

At Jackson Springs, potassium amount in vegetation was different by date, but all dates showed a linear decrease of K kg ha^{-1} with increasing VFW. For dates 1 and 4, the average for K kg ha^{-1} was also different by irrigation level. Dates 2 and 3 showed regression trends: Y = 4.1 - 1.1 VFW, $R^2 = 0.57$, and Y = 45.2 - 10.7 VFW, $R^2 = 0.58$ (respectively). For date 1, potassium followed the trend Y = 20.3 - 6.2 VFW, $R^2 = 0.86$. The average of irrigated plots (13.3) was higher than the average of nonirrigated plots (9.2) ($p = 0.0026$). For date 4, potassium followed the trend Y = 52.3 - 15.8 VFW, $R^2 = 0.79$. The average of irrigated plots (22.3) was lower than the average of nonirrigated plots (36.7) ($p = 0.0001$). At Clayton, potassium amount in vegetation was different by date, with a linear decrease of K kg ha^{-1} with increasing VFW for all dates. For dates 2 and 4, the averages for K kg ha^{-1} were also different by irrigation level. Regression trends were: Y = 8.2 - 2.5 VFW ($R^2 = 0.86$), Y = 18.3 - 4.7 VFW ($R^2 = 0.58$), and Y = 46.7 - 12.3 VFW ($R^2 = 0.90$), respectively for dates one, two, and four, respectively. Potassium trends were different by irrigation for date three: Y = 13.1 - 3.8 VFW ($R^2 = 0.88$), for irrigated plots; Y = 10.7 - 2.5 VFW ($R^2 = 0.66$) for nonirrigated plots. The average of irrigated plots (15.2) was higher than the average of nonirrigated plots (7.9) for date 2 ($p = 0.0018$), but by date 4, the average of irrigated plots (26) was lower than the average of nonirrigated plots (32.2) ($p = 0.0139$).

The common trend between locations is that by the last sampling date, fall 2008 (date 4), irrigated plots contained less kg K ha^{-1} in the vegetation than nonirrigated plots. This effect is probably due to K leaching, similar to N kg ha^{-1} in the vegetation. However, the reduced kg K ha^{-1} in irrigated plots wasn't translated into reduced weed growth because irrigated vegetation did not have decreased biomass production compared to the nonirrigated vegetation (Table 9). The difference in K between irrigated and nonirrigated is reversed in the tree leaves: K concentration is higher in irrigated than nonirrigated trees. The increased possible cation concentration effect of decreased shoot biomass due to less nitrogen as postulated for the tree, is not evident in the vegetation. The concentration effect is not likely because the total weight of shoot biomass of the vegetation is not different between the irrigation levels for date 4 (fall 2008), in contrast to reduced tree growth concentrating the cation concentration in crop leaves. Instead the vegetation may have reflected the soil situation of leached, decreased amounts of K in the irrigated compared to the nonirrigated plots.

At Jackson Springs, calcium amount in vegetation was different by date, with a linear decrease of Ca kg ha^{-1} with increasing VFW for all dates except date 2 for which no treatment effects were found. Dates 1 and 4 were combined and were described by Y = 12.4

- 3.7 VFW ($R^2 = 0.94$). For date 3, effects of irrigation, VFW, and their interaction were found, so two trends were fit for irrigation levels: Irrigated plots displayed a relationship of Y = 12.2 - 2.9 VFW ($R^2 = 0.47$); nonirrigated plots displayed a relationship of Y = 19.8 - 5.6 VFW ($R^2 = 0.84$). The average of irrigated plots (8.0) was lower than the average of nonirrigated plots (11.6) ($p = 0.0450$). At Clayton, calcium amount in vegetation was different by date, with a linear decrease of Ca kg ha^{-1} with increasing VFW for all dates. However, for dates one, three, and four the difference was attributed to magnitude because charting the responses showed similar trends. The response was described by Y = 7.3 - 2.0 ($R^2 = 0.87$). For date 2, the average of irrigated plots (4.5) was higher than the average of nonirrigated plots (2.4) ($p = 0.0004$), and the response was Y = 5.5 - 1.4 VFW ($R^2 = 0.58$).

At Jackson Springs, magnesium amount in vegetation was different by date, but charting the different dates showed the difference to be in magnitude, so dates were combined. Mg kg ha^{-1} decreased linearly with higher VFWs (Y = 5.2 - 1.5 VFW, $R^2 = 0.92$), with no effect of irrigation. At Clayton, magnesium amount in vegetation was different by date, with a linear decrease of Mg kg ha^{-1} with increasing VFW for all dates. However, for dates one, three, and four the difference was attributed to magnitude because charting the responses showed similar trends. The response was described by Y = 3.4 - 0.9 ($R^2 = 0.92$). For date 2, the average of irrigated plots (2.6) was higher than the average of nonirrigated plots (1.6) ($p = 0.0128$), and the response was Y = 3.2 - 0.8 VFW ($R^2 = 0.64$).

The common trend for both Ca and Mg is that they didn't consistently differ by irrigation levels. At Clayton, for date 2 (summer 2007), kg Ca and Mg ha^{-1} of irrigated plots was almost twice that of nonirrigated plots (Table 9). Since this trend is not common between locations and is for only one sampling date, the difference is probably due to increased total biomass production of irrigated vegetation compared to nonirrigated vegetation for this date.

Conclusion

Data from Jackson Springs suggest that the irrigated VFW which would produce the same yield season total (kg ha^{-1}) as the grower standard (3.0 m nonirrigated) is 1.16 m, based on results from regression. (For maximum season total, the VFW needed to be 3.6 m.) The irrigated VFWs which would produce the same tree cross-sectional area as the grower standard was 1.5, 1.3 and 0.8 m for trees aged one, two, and three years old, respectively. At Clayton, trees aged two years old also needed a 1.3 m VFW for equivalent irrigated TCSA to the grower standard. Winter prunings at Jackson Springs produced similar results for the one and two year old trees. Based on these results, a conservative choice would be 1.5 m.

However, these recommendations are primarily based on only one location due to the lack of differences in tree growth and yield due to irrigation at Clayton. Harvest season totals and trunk cross-sectional areas in 2007 and 2008 at Clayton were not different by irrigation (but did increase linearly with VFW), so determining the equivalent irrigated VFW was not possible. The Clayton location serves to underscore the importance of water and nitrogen interaction.

At both locations, water and nitrogen were probably the limiting factors. Tworskoski et al. (1997) demonstrated that competition with grass will reduce fruit yield in young peach trees, largely by interfering with N availability and uptake. Similarly across locations, leaf nitrogen concentrations were lower but not deficient in the irrigated trees than the nonirrigated trees, presumably due to leaching of NO_3 by irrigation. Reduced leaf size in irrigated trees versus nonirrigated, and the lower SPAD readings in irrigated trees leaves were evidence that nitrogen was reduced in irrigated trees. However, N dilution effect could be postulated as the reason for the reduced leaf size and lower SPAD readings of the irrigated trees as well. A greater growth rate in the irrigated trees at Jackson Springs compared to the nonirrigated trees may have diluted the nitrogen in the irrigated trees' leaves so that foliar N is lower on a % basis. In the dilution scenario, the lower soil N measured in companion research could have been due to increased N uptake by the irrigated trees. Unfortunately, leaf number, an indicator of dilution effect, was not recorded in this study. (The dilution effect is evident when smaller, lighter, more numerous leaves accompanies increased growth compared to non-diluted plants.) The dilution effect scenario however, does not hold at Clayton, where similar growth and yields were found for irrigated and nonirrigated trees, but still decreased % foliar N concentration, reduced leaf size, and SPAD measurements were recorded. Therefore, N differences are probably due to leaching rather than dilution effect.

Foliar N, SPAD values, soil moisture, and growth responses were positively related to VFW at Jackson Springs therefore growth responses there were probably due to water and N competition with vegetation. In contrast, foliar N concentration was not different by VFW at Clayton. However, growth responses were positively related to VFW. SPAD increased with VFW so vegetation had some effect on nitrogen. For the first two years of the study, VFW did have an effect on soil moisture at 30 cm depth.

The different response at Clayton versus Jackson Springs is probably due to several factors. During the first year after planting, a very susceptible time to competition as trees become established, all trees were treated the same with no treatments applied. Basal weed control as well as several waterings of approximately 11 liters per time per tree during the summer given to all trees could have reduced differences between treatments in subsequent years. In addition, since Clayton trees were one year older, they were probably better competitors due to increased tree size than those trees at Jackson Springs. The difference in a sand (Jackson Springs) versus a loamy sand (Clayton) would suggest greater benefit of irrigation at Jackson Springs. All of these factors could have contributed to greater treatment differences at Jackson Springs compared to Clayton.

The interaction of allelopathic effects should not be minimized in young peach trees. The influence of vegetation growing within close proximity to peach tree roots, especially young trees, may reduce tree growth due to allelopathy. Weller postulated that tree response to vegetation was not only due to competition for nutrients, but suspected possible allelopathy. Initial tree growth inhibition was followed in the second season by the overcoming of the negative influence of bermudagrass as roots grew deeper outside of the area of influence of possible allelopathy (Weller et al. 1985).

Future research should include scheduling irrigation based on soil moisture content in narrow VFWs early in the season, starting at full bloom. Haynes and Goh (1980a) found that the major loss of P and K in an apple orchard was through the harvested fruit crop, for Mg and Ca through leaching, while for N, losses were about equally divided between the fruit crop and leaching. Therefore, further nutrient testing during bearing years to see how responses change would be useful.

Greater attention to N status is required in orchards with irrigation and narrower strip widths. Data suggest that a 1.5 m VFW combined with proper irrigation and fertilization will produce tree growth and yield in volunteer weedy vegetation similar to the current grower standard. The practical implications of this research suggest that if the grower does not irrigate, nitrogen fertilization could be scaled back. If the grower irrigates, and chooses narrower VFWs, N is at the upper limit and needs to be monitored.

Acknowledgements

The authors express appreciation to the USDA RAMP project AG , Drs. Cavell Brownie and Consuello Arellano for their statistical assistance, fellow graduate students for their assistance in the field, and the staff at the Central Crops Research (Clayton) and Sandhills Research (Jackson Springs) Stations.

Sources of Materials

[3] Vaughn Nursery, 8678 Smithville Highway, McMinnville, TN 37110.

[4] X-77, Loveland Industries, Inc., P.O. Box 1289, Greely, CO 80632.

[5] Irrometer Company, Inc., P.O. Box 2424, Riverside, CA, 92516.

[6] LI-COR, Inc. P.O. Box 4425, Lincoln, NE, 68504.

[7] Konica Minolta Business Solutions U.S.A. Inc., 100 Williams Dr., Ramsey, NJ, 07446.

[8] ATAGO U.S.A, Inc., 12011 NE First St., Building C Suite 110, Bellevue, WA,

98005.

Literature Cited

Anonymous, 1999. Vegetation Management *in* Integrated Pest Management for Stone Fruits. University of California Division of Agriculture and Natural Resources, Publication 3389, pages 177-200.

Anonymous 2007. Chlorophyll concentration meter: Apogee Instruments: How the meter works. accessed June 14, 2007. http://www.apogee-inst.com/CCM_measurement.htm

Anonymous, 2008. North Carolina 2008 Agricultural Statistics. North Carolina Department of Agriculture and Consumer Services: Raleigh, NC accessed February 18, 2009. http://www.ncagr.com/stats/fruit/fruallyr.htm

Belding R.D., B.A. Majek, G.R. Lokaj, J. Hammerstedt, and A.O. Ayeni. 2004. Orchard floor management influence on summer annual weeds and young peach tree performance. Weed Technol. 18:215-222.

Bould, C., and R.M. Jarrett, 1962. The effects of cover crops and N P K fertilizers on growth, crop yield and leaf nutrient status of young dessert apples. J. Hortic. Sci., 37:58-82.

Bullock, D. 1994. Quadratic and quadratic-plus-plateau models for predicting optimal nitrogen rate of corn: a comparison. Agron. J. 86:191-195.

Bullock D. Evaluation of the Minolta SPAD-502 chlorophyll meter for on-farm N management of corn in Illinois. Illinois Fertilizer Conference Proceedings. January 24-26, 1994. accessed April 21, 2007. http://frec.cropsci.uiuc.edu/1994/report11/index.htm.

Bussi, C., J. Huguet, J. Besset, and T. Girard. 1994. The consequences of cultural practices on

growth and cropping of peach trees subjected to localized irrigation: Effects of soil management, nitrogen fertilization and tree density. J. Hort. Sci. 69(5):905-914.

Daniell, J.W. and W.S. Hardcastle. 1972. Response of peach trees to herbicide and mechanical weed control. Weed Sci. 20:133-136.

Edson, C., S. Swinton, J. Nugent, G. Bird, A. Coombs, and D. Epstein. 2003. Cherry orchard floor management. Michigan State University Extension Bulletin E-2890.

Glenn, D.M., W.V. Welker, and G.M. Greene. 1996. Sod competition in peach production: I. Managing sod proximity. J. Amer. Soc. Hort. Sci. 121(4):666-669.

Glenn, D.M., and W.V. Welker. 1991. Soil management affects shoot and root growth, nutrient availablility, and water uptake of young peach trees. J. Amer. Soc. Hort. Sci. 116(2):238-241.

Glenn, D.M., and W.V. Welker. 1993a. Root development patterns in field grown peach trees. J. Amer. Soc. Hort. Sci. 118(3):362-365.

Glenn, D.M., and W.V. Welker. 1993b. Water transfer diminishes root competition between peach and tall fescue. J. Amer. Soc. Hort. Sci. 118(5):570-574.

Gupta P.L. and I.H. Rorison. 1975. Seasonal differences in the availability of nutrients down a podzolic profile. J. Ecol. 63:521-534.

Haynes R.J. and K.M. Goh.1980a. Distribution and budget of nutrients in a commercial apple orchard. Plant and Soil 56:445-457.

Haynes R.J. and K.M. Goh.1980b. Seasonal levels of available nutrients under grassed-down, cultivated and zero-tilled orchard soil management practices. Aust. J. Soil Res. 18:363-373.

Huffman, L. 2006. Season-long weed control not necessary. Good Fruit Grower. May 15, 2006.

Huslig, S.M., M.W. Smith, and G.H. Brusewitz. 1993. Irrigation schedules and annual ryegrass as a ground cover to conserve water and control peach tree growth. Hort. Sci. 28(9): 908-913.

Killian, J.C. and J.R. Meyer, 1984. Effect of weed management on catfacing damage to peaches in North Carolina. J. Econ. Entomol. 77:1596-1600.

Lane, R., and C. Tan. 1988. Influence of cultivars, groundcovers, and trickle irrigaton on early growth, yield, and cold hardiness of peaches on Fox Sand. J. Amer. Soc. Hort. Sci. 113(4):518-525.

Lockwood, D.W., M.E. Ferree, and S.C. Meyers. 2005. Nutrition *in* Southeastern Peach Growers' Handbook. Cooperative Extension Service, University of Georgia College of Agricultural and Environmental Sciences.

Lockwood, D.W. and S.C. Myers. 2005. Tree density, orchard design, and training systems *in* Southeastern Peach Growers' Handbook. Cooperative Extension Service, University of Georgia College of Agricultural and Environmental Sciences.

MacRae, A.W., W.E. Mitchem, D.W. Monks, M.L. Parker, and R.K. Galloway. 2007. Tree growth, fruit size, and yield response of mature peach to weed-free intervals. Weed Technol. 21:102-105.

Marriage, P.B., and H.A. Quamme. 1980. Effect of weed control on the winter hardiness of the bark and wood of young peach trees. Hort. Sci. 15(3):290-291.

Meyer, J.R. 1984. Catfacing in peaches: effects of ground cover and surrounding vegetation. Proc. Joint Nat. Peach Council and Southeast. Peach Conv., pp.5-11.

Meagher, Jr.,R.L. and J.R Meyer, 1990. Influence of ground cover and herbicide treatments on *Tetranychus urticae* populations in peach orchards. Exp. Appl. Acarol. 9:149-158.

Mitchem, W. E., 2005. Weed management considerations for peach orchards *in* Southeastern Peach Growers' Handbook. Cooperative Extension Service, University of Georgia College of Agricultural and Environmental Sciences. p281.

North Carolina Agricultural Statistics, 2005. North Carolina Department of Agriculture and Consumer Services: Raleigh, NC, p42.

North Carolina State University Cooperative Extension Service, 1999. http://pestdata.ncsu.edu/cropprofiles/docs/ncpeacheshtml

Parker, M.L., J. Hull, and R.L. Perry. 1993. Orchard floor management affects peach rooting. J. Amer. Soc. Hort. Sci. 118(6):714-718.

Parker, M.L. and J.R. Meyer. 1996. Peach tree vegetative and root growth respond to orchard floor management. Hort. Sci. 31(3):330-333.

(SAS) Statistical Analysis Systems. 1998. SAS/STAT® User's Guide. Release 8.0. Cary, NC: Statistical Analysis Systems Institute. 1028p.

Shribbs, J.M., and W.A. Skroch. 1986. Influence of 12 ground cover systems on young 'Smoothee Golden Delicious' apple trees: II Nutrition. J. Amer. Soc. Hort. Sci. 111(4)529-533.

Smith, M.W., B.S. Cheary, and B.L. Carroll. 2002. Fescue sod suppresses young pecan tree growth. Hort. Sci. 37(7):1045-1048.

Smith, S.E., D.J. Read, and J.L. Harley. 1997. Mycorrhizal Symbiosis. Academic Press: San Diego, CA.

Sullivan, T. P., and E.J. Hogue, 1987. Influence of orchard floor management on vole and pocket gopher populations and damage in apple orchards. J. Amer. Soc. Hort. Sci. 112(6):972-977.

Taiz, L., and E. Zeiger. 2002. Mineral Nutrition *in* Plant Physiology. Sinauer Associates, Inc.: Sunderland, Massachusetts.

Taylor, K.C. and M. Rieger. 2005. Irrigation scheduling *in* Southeastern Peach Growers' Handbook. Cooperative Extension Service, University of Georgia College of Agricultural and Environmental Sciences.

Tworkoski, T.J. D.M. Glenn, and W.V. Welker. 1997. Carbohydrate and nitrogen partitioning within one-year shoots of young peach trees grown with grass competition. Hort. Sci. 32(7):1174-1177.

Warren, S.L., 1986. Plantation management: its influence on soil fertility, herbaceous vegetation and growth of Fraser fir and Norway spruce. NC State University PhD dissertation.

Welker, W.V. and D.M. Glenn. 1985. The relationship of sod proximity to the growth and nutrient composition of newly planted peach trees. Hort. Sci. 20(3):417-418.

Welker, W.V., and D. M. Glenn. 1988. Growth responses of young peach trees and changes in soil characteristics with sod and conventional planting systems. J. Amer.

Soc. Hort. Sci. 113(5):652-656.

Welker, W.V., and D.M. Glenn. 1989. Sod proximity influences the growth and yield of young peach trees. J. Amer. Soc. Hort. Sci. 117(6):856-859.

Welker, W.V. and D.M. Glenn. 1990. Peach tree growth as influenced by grass species used in a killed-sod system.. Hort. Sci. 25(5):514-515.

Welker, W.V. and D.M. Glenn. 1991. Growth response of young peach trees to distribution pattern of vegetation-free area. Hort. Sci. 26(9):1141-1142.

Welker, W.V., and D. M. Glenn. 1993. Root development patterns in field grown peach trees. J. Amer. Soc. Hort. Sci. 118(3)362-365.

Weller, S.C., W.A. Skroch, and T.J. Monaco. 1985. Common bermudagrass (*Cynodon dactylon*) interference in newly planted peach (*Prunus persica*) trees. Weed Sci. 33:50-56.

Wold, S. 1974. Splined functions in data analysis. Technometrics 16:1-11.

Table 1. Parameter estimates and equivalent irrigated VFW to 3.0 m nonirrigated for peach trunk cross - sectional area as affected by vegetation - free area (VFW) and irrigation,[a] Clayton and Jackson Springs, NC, 2006 to 2008.

Location	Year	Tree age	Irrigated				Nonirrigated				Equivalent irrigated VFW[b]
			a	b	w	R^2	a	b	w	R^2	
			cm^2		m		cm^2		m		m
Clayton	2006	2	12.09	10.92	2.88	0.68	12.57	4.71	6.08	0.93	1.32
Clayton[c]	2007	3	-	-	-	-	-	-	-	-	2.17 (NS)
Clayton[d]	2008	4	-	-	-	-	-	-	-	-	-
Jackson Springs	2006	1	3.28	8.51	2.28	0.99	3.78	4.06	4.50	0.97	1.52
Jackson Springs	2007	2	10.9	11.20	4.12	0.94	7.64	6.40	8.29	0.97	1.32
Jackson Springs	2008	3	26.93	30.60	2.36	0.92	23.69	10.91	5.50	0.88	0.80

[a] VFW and irrigation are significant at the $p \leq 0.05$ level unless noted below.

[b] The value of the irrigated VFW for which TCSA is equivalent to the 3.0 m VFW, nonirrigated treatment.

[c] Clayton 2007 effect for irrigation was significant at $p = 0.0784$, and irrigated plots followed the trend $Y = 24.13 + 7.33$ VFW ($R^2 = 0.62$) and nonirrigated plots followed the trend $Y = 20.33 + 6.56$ VFW ($R^2 = 0.95$).

[d] Clayton 2008 was not different by irrigation ($p = 0.7342$), and both levels followed the trend $Y = 34.25 + 11.33$ VFW ($R^2 = 0.74$).

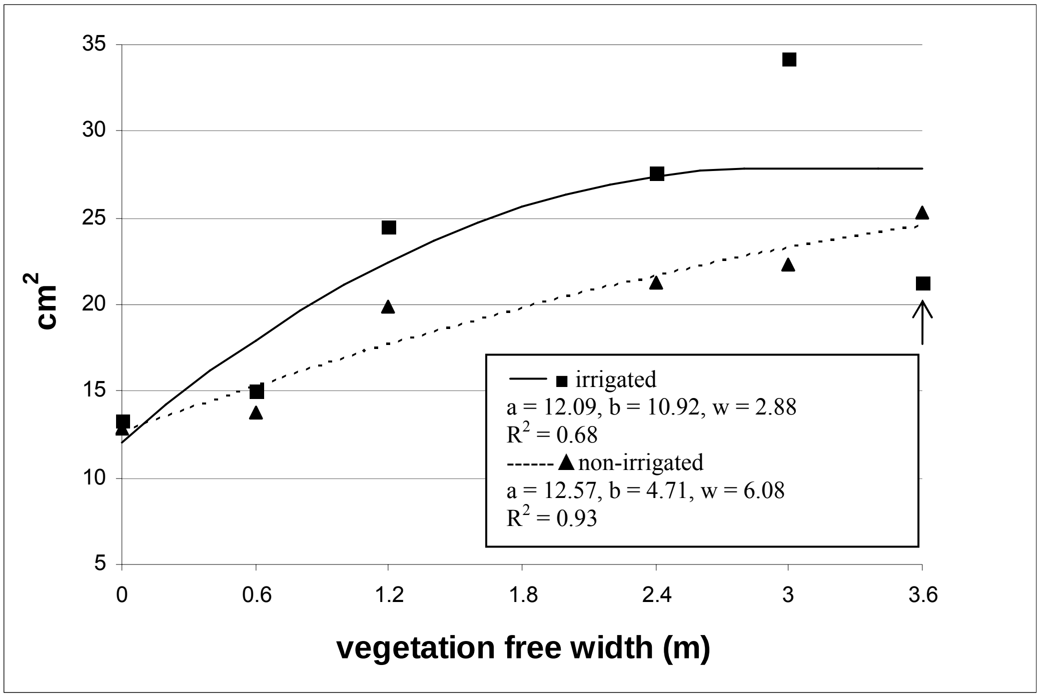


Figure 1. Effect of irrigation and vegetation - free width (VFW) on trunk cross - sectional area (TCSA), Clayton, NC, December 30, 2006 (representing second leaf). The datapoint designated with (↑) appeared low, but was not an outlier when residuals were plotted.

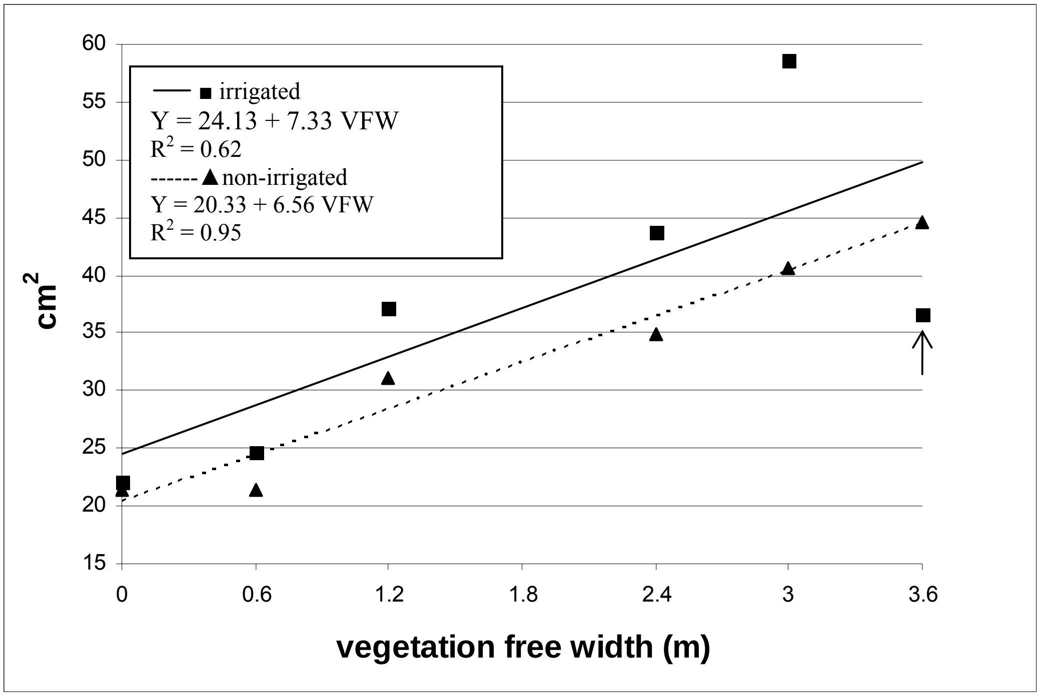


Figure 2. Effect of irrigation and vegetation - free width (VFW) on trunk cross - sectional area (TCSA), Clayton, NC, December 13, 2007 (representing third leaf). The datapoint designated with (↑) appeared low, but was not an outlier when residuals were plotted.

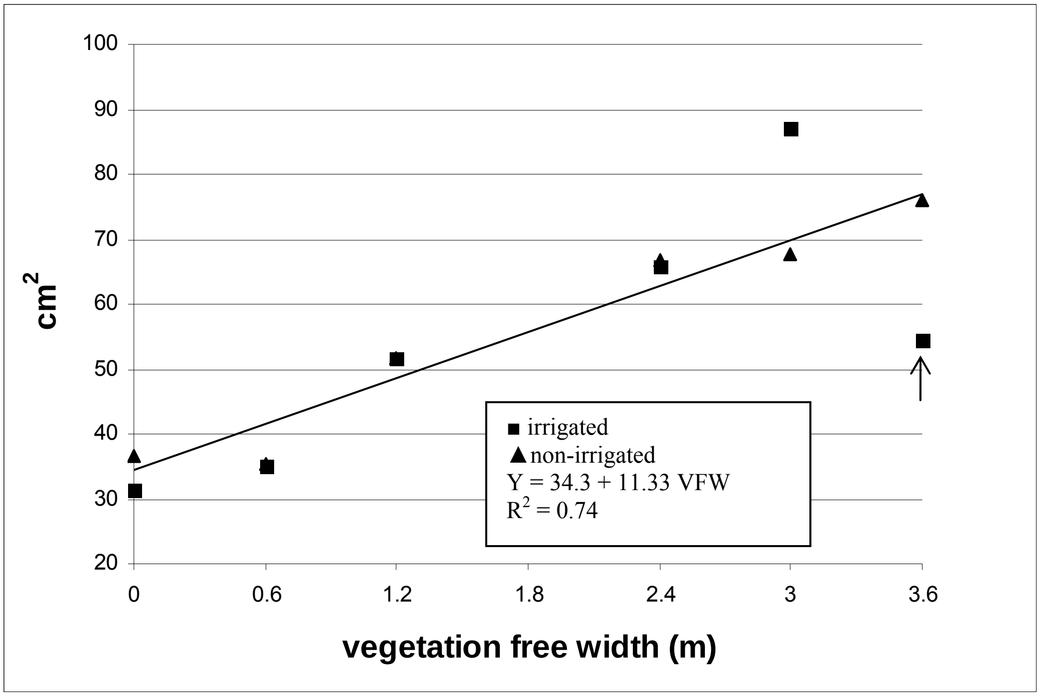


Figure 3. Effect of irrigation and vegetation - free width (VFW) on trunk cross - sectional area (TCSA), Clayton, NC, January 3, 2009 (representing fourth leaf). The datapoint designated with (↑) appeared low, but was not an outlier when residuals were plotted.

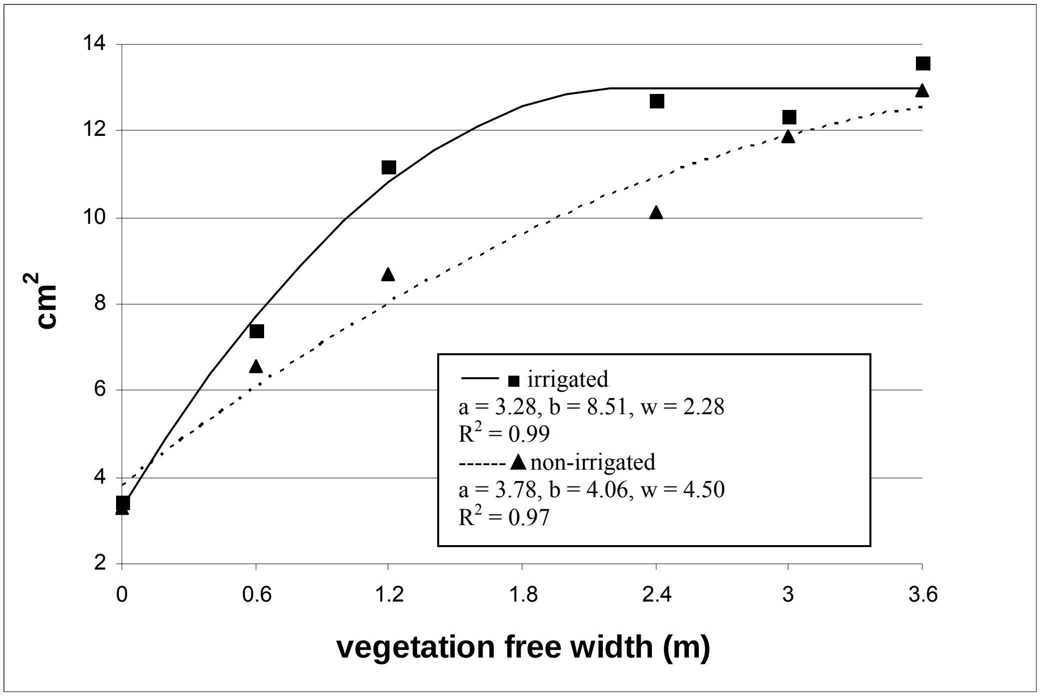


Figure 4. Effect of irrigation and vegetation - free width (VFW) on trunk cross - sectional area (TCSA) of newly planted peach, Jackson Springs, NC, February 3, 2007 (representing first leaf).

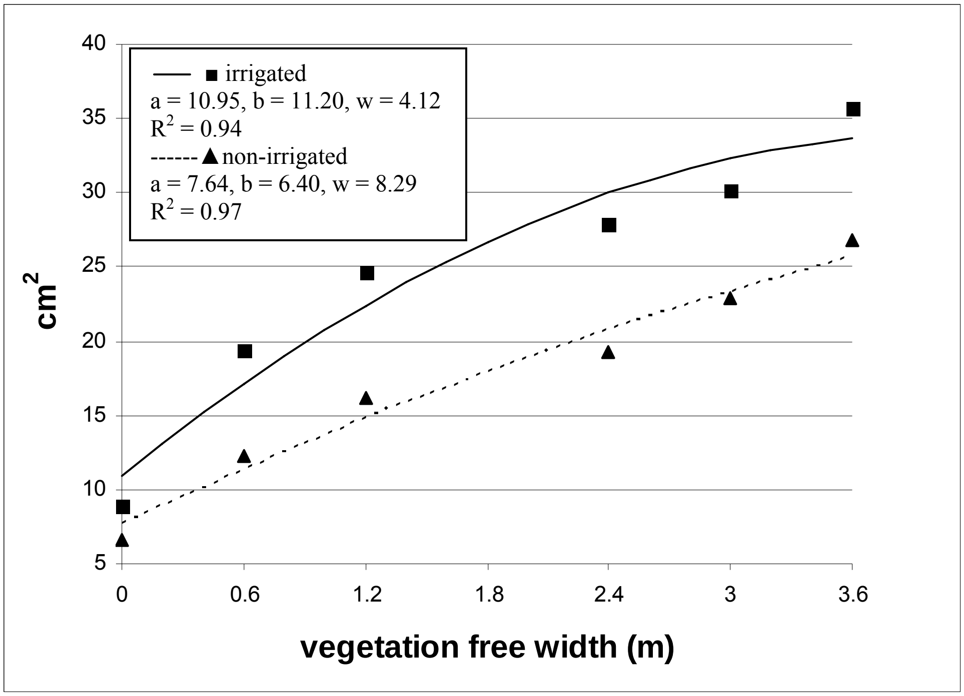


Figure 5. Effect of irrigation and vegetation - free width (VFW) on trunk cross - sectional area (TCSA) of newly planted peach, Jackson Springs, NC, November 20, 2007 (representing second leaf).

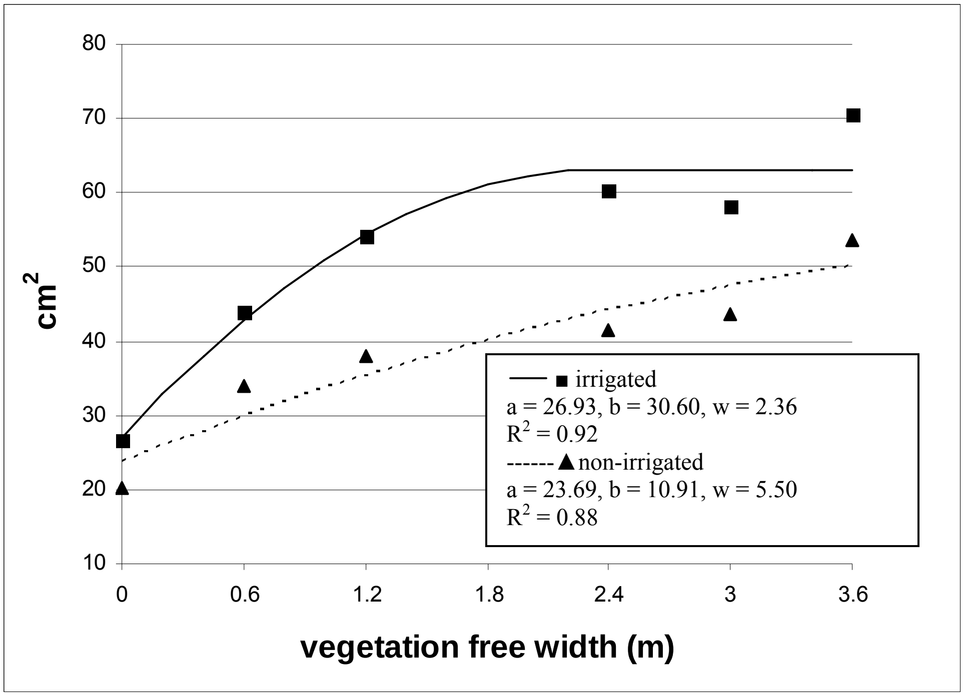


Figure 6. Effect of irrigation and vegetation - free width (VFW) on trunk cross - sectional area (TCSA) of newly planted peach, Jackson Springs, NC, January 3, 2009 (representing third leaf).

Table 2. Mean comparisons of mean peach trunk cross-sectional area of various combinations of vegetation free widths (VFW) and irrigation levels (IRR) with the 3.6 m VFW, nonirrigated treatment, Clayton, NC, December 30, 2006, December 13, 2007, and January 3, 2009 (reflects 2008 growing season). Means are different from each other if p≤0.0005.

VFW (m)	IRR	2006	2007	2008
0	yes	<0.0001	0.0018	0.0004
0.6	yes	0.0002	0.0047	0.0008
1.2	yes	0.7262	0.2567	0.0308
2.4	yes	0.3392	0.8851	0.3404
3.0	yes	0.0008	0.0393	0.3092
3.6	yes	0.0805	0.2184	0.0551
0	no	<0.0001	0.0014	0.0012
0.6	no	<0.0001	0.0014	0.0009
1.2	no	0.0231	0.0455	0.0322
2.4	no	0.0832	0.1382	0.3866
3.0	no	0.1953	0.5396	0.4349
3.6		N/A	N/A	N/A

Table 3. Mean comparisons of mean peach trunk cross sectional area of various combinations of vegetation free widths (VFW) and irrigation levels (IRR) with the 3.6 m VFW, nonirrigated treatment, Jackson Springs, NC, February 3, 2007 (reflects 2006 growing season), November 20, 2007 (2007 growing season), and January 3, 2009 (2008 growing season). Means are different from each other if $p \leq 0.0005$.

VFW (m)	IRR	2006	2007	2008
0	yes	<0.0001	<0.0001	<0.0001
0.6	yes	<0.0001	0.0005	0.0309
1.2	yes	0.1333	0.2893	0.8971
2.4	yes	0.8512	0.5627	0.1258
3.0	yes	0.6163	0.1070	0.3027
3.6	yes	0.5773	<0.0001	0.0003
0	no	<0.0001	<0.0001	<0.0001
0.6	no	<0.0001	<0.0001	<0.0001
1.2	no	0.0006	<0.0001	0.0008
2.4	no	0.0181	0.0005	0.0075
3.0	no	0.3665	0.0673	0.0364
3.6		N/A	N/A	N/A

Table 4. Mean comparisons of peach trunk cross sectional areas of irrigation levels within vegetation free widths (VFW), Clayton, NC, December 30, 2006, December 13, 2007, and January 3, 2009 (2008 growing season). Means are different from each other if $p \leq 0.0005$.

VFW (m)	2006	2007	2008
0	0.8374	0.9161	0.6254
0.6	0.5630	0.6086	0.9636
1.2	0.0487	0.3494	0.9840
2.4	0.0106	0.1778	0.9282
3.0	<0.0001	0.0101	0.0799
3.6	0.0805	0.2184	0.0551

Table 5. Comparisons of peach trunk cross - sectional areas of irrigation levels within vegetation free widths (VFW), Jackson Springs, NC, February 3, 2007 (2006 growing season), November 20, 2007, and January 3, 2009 (2008 growing season). Means are different from each other if p≤0.0005.

VFW (m)	2006	2007	2008
0	0.9082	0.2660	0.1422
0.6	0.4588	0.0008	0.0368
1.2	0.0363	<0.0001	0.0005
2.4	0.0286	<0.0001	<0.0001
3.0	0.7197	0.0015	0.0037
3.6	0.5773	<0.0001	0.0003

Table 6. Parameter estimates and equivalent irrigated VFW to 3.0 m nonirrigated for peach tree winter prunings as affected by vegetation - free area (VFW) and irrigation,[a] Clayton and Jackson Springs, NC, 2007 and 2008. (All prunings were cut and recorded in March of the year listed, therefore reflect previous growing season.)

Location	Year	Tree age	Irrigated				Nonirrigated				Equivalent irrigated VFW[b]
			a	b	w	R^2	a	b	w	R^2	
			kg / tree		m		kg / tree		m		m
Clayton[c]	2007	3	0.86	1.61	2.72	0.75	-	-	-	-	2.17
Clayton[d]	2008	4	-	-	-	-	-	-	-	-	-
Jackson Springs	2007	2	0.12	0.73	3.04	0.98	0.20	0.34	5.98	0.98	1.53
Jackson Springs	2008	3	0.83	1.26	6.27	0.95	0.63	0.81	7.19	0.96	1.60

[a] VFW and irrigation are significant at the $p \leq 0.05$ level unless noted below.

[b] The value of the irrigated VFW for which prunings are equivalent to the 3.0 m VFW, nonirrigated treatment.

[c] Clayton 2007 was not different by irrigation ($p = 0.6877$), and nonirrigated plots followed the trend $Y = 1.11 + 0.62$ VFW ($R^2 = 0.88$).

[d] Clayton 2008 was not different by irrigation ($p = 0.7980$), and both levels followed the trend $Y = 0.73 + 0.76$ VFW ($R^2 = 0.55$).

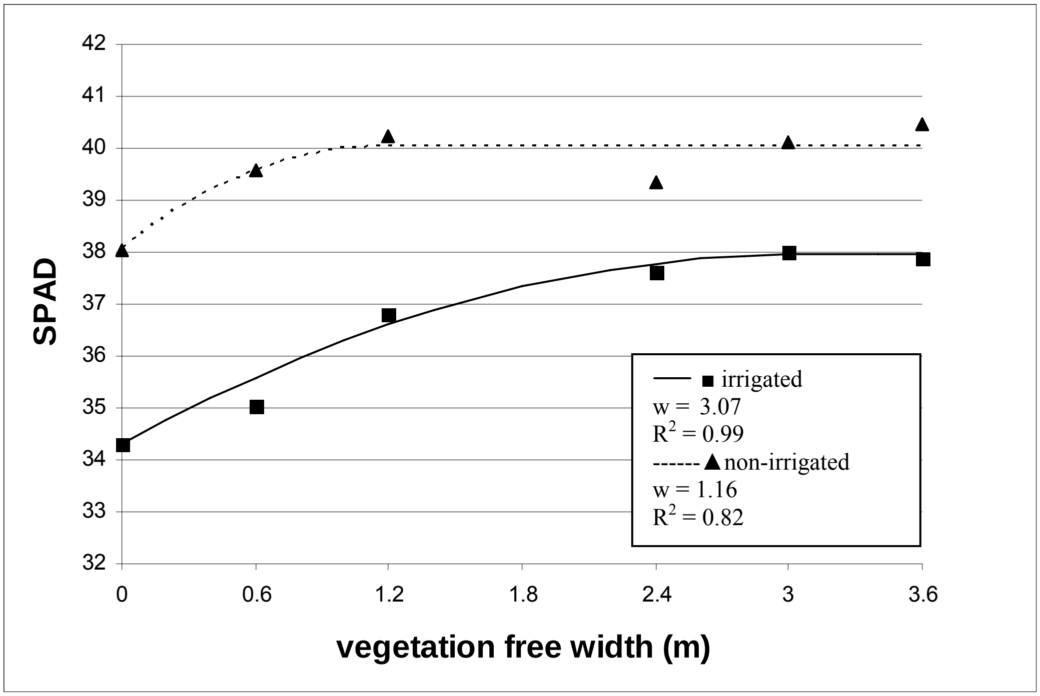
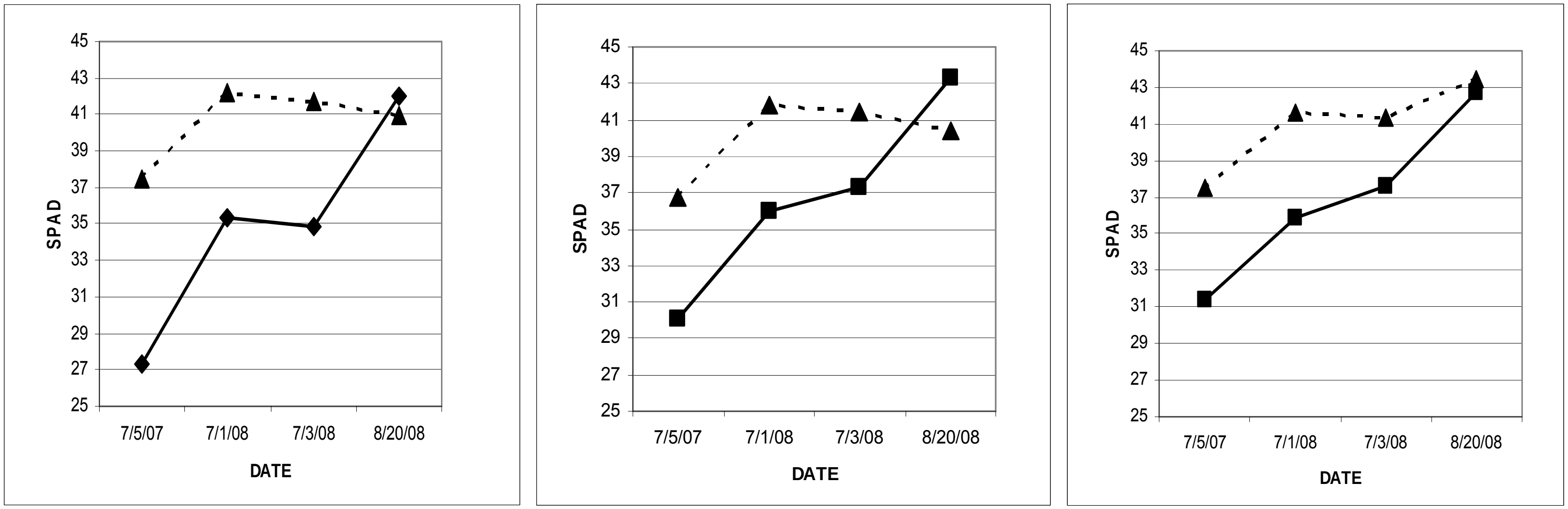


Figure 7. Effect of irrigation and vegetation - free width (VFW) on SPAD value of newly planted peach, averaged across four sampling dates, Clayton, NC. (The value of VFW at which the response plateaus is represented by "w.")



a) b) c)

Figure 8. Effect of irrigation on SPAD value by vegetation - free width (VFW) at various sampling dates, Jackson Springs, NC. a) 0 m VFW, b) 0.6 and 1.2 m VFW and c) 2.4, 3.0 and 3.6 m VFW. (Note: Date is not to scale but is meant to show trends.) nonirrigated = ▲------, irrigated = ■ ——— .

Table 7. Parameter estimates for peach harvest as influenced by vegetation - free width (VFW) and irrigation, Jackson Springs, NC, 2008.

Parameter	Unit	Irrigated				Nonirrigated				Equivalent irrigated VFW[a]
		a	b	w	R^2	a	b	w	R^2	
										m
Season totals	1000 kg ha^{-1}	2.40	1.49	5.12	0.83	1.44	1.07	7.07	0.86	1.16
Individual fruit length	cm / fruit	6.75	0.58	1.89	0.97	6.16	1.52	0.84	0.90	0.09
Individual fruit weight	g / fruit	42.4	7.07	2.83	0.96	35.6	8.12	1.96	0.74	0.07
Earliness[b]	%	NS	NS	NS	NS	42	-54	1.04	0.82	-

[a] The value of the irrigated VFW for which TCSA is equivalent to the 3.0 m VFW, nonirrigated treatment.

[b] Earliness was measured by dividing the first of the four harvests by the total season harvest.

Table 8. Regression analyses for peach harvest as influenced by vegetation - free width (VFW) and irrigation, Clayton, NC, 2008.

Parameter	Unit	Irrigated		Nonirrigated		Equivalent irrigated VFW[a]
		Equation	R^2	Equation	R^2	
						m
Season totals	1000 kg ha^{-1}	Y = 4.79 +2.03 x	0.87	Y = 6.14 + 2.22 x	0.90	3.95
Individual fruit length	cm / fruit	Y = 6.48 + 0.13 x	0.90	Y = 6.79 + 0.13 x	0.79	5.27
Individual fruit weight	g / fruit	Y = 38.61 + 2.69 x	0.82	Y = 44.71 + 2.60 x	0.87	5.17
Earliness[b]	%	NS	NS	NS	NS	-

[a] The value of the irrigated VFW for which TCSA is equivalent to the 3.0 m VFW, nonirrigated treatment.

[b] Earliness was measured by dividing the first of the four harvests by the total season harvest.

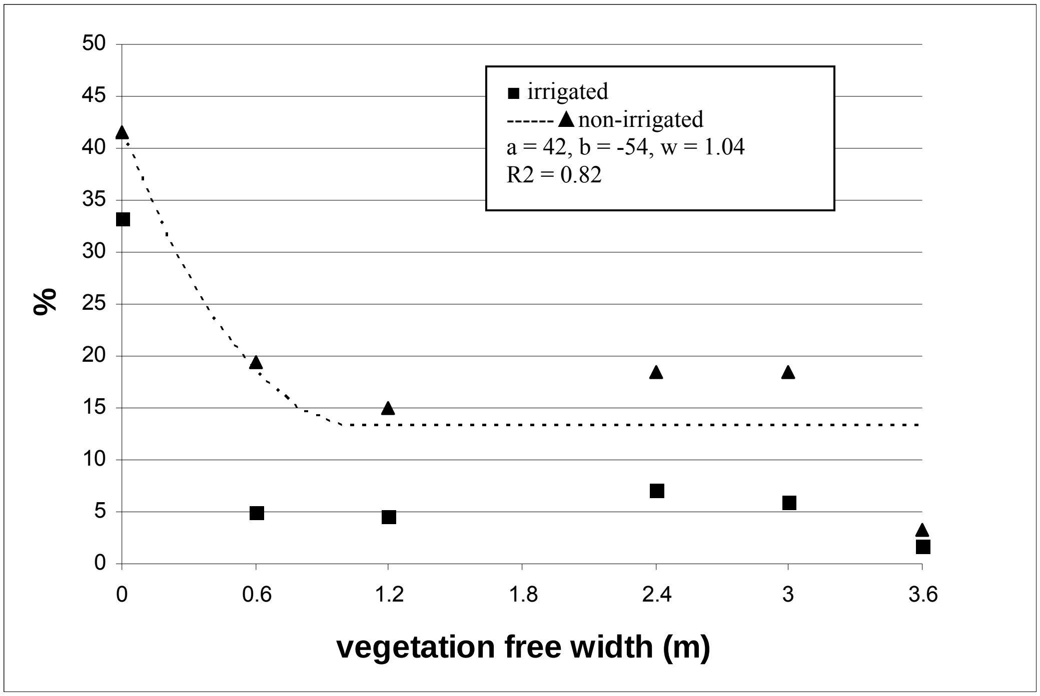


Figure 9. Effect of irrigation and vegetation - free width on percent first harvest of season total, Jackson Springs, NC, 2008.

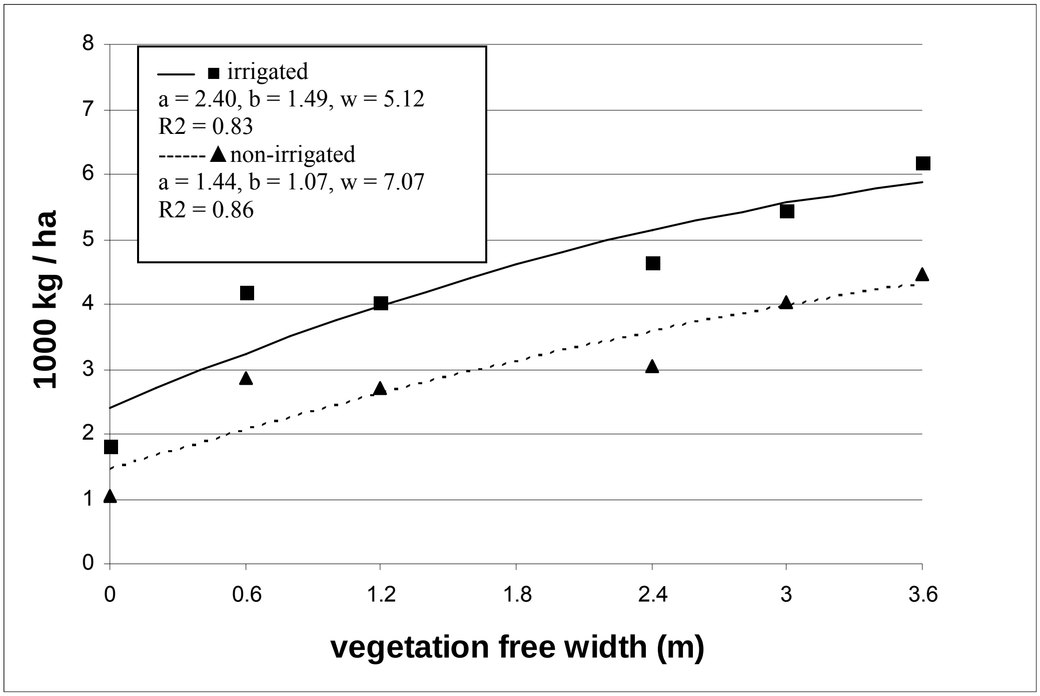


Figure 10. Effect of irrigation and vegetation - free width on yield season total (1000 kg ha^{-1}), Jackson Springs, NC, 2008.

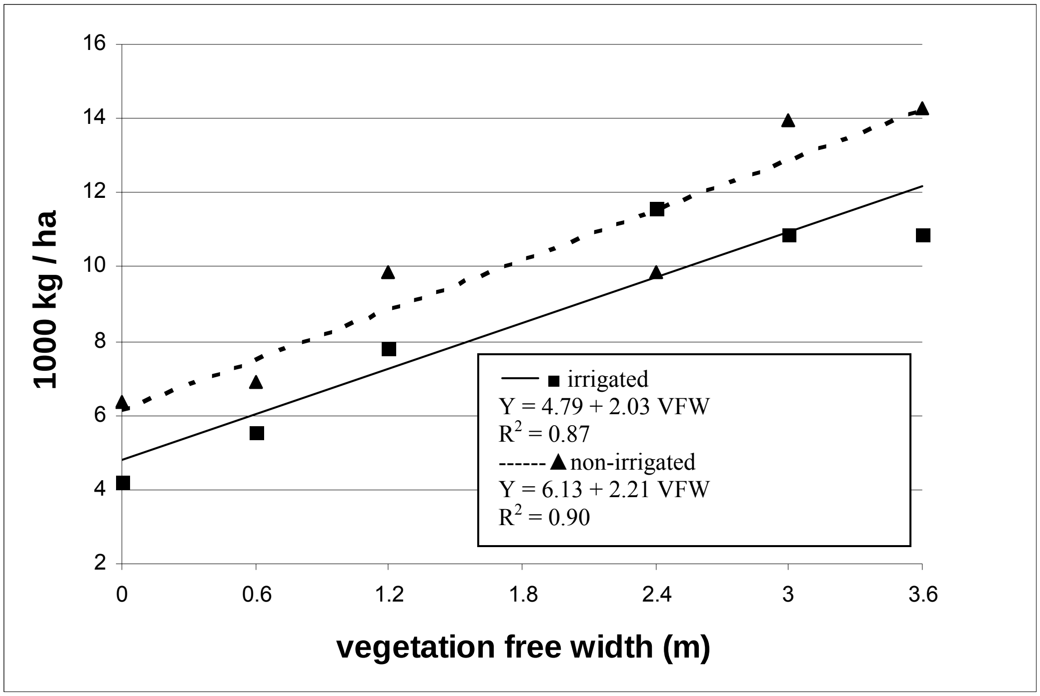
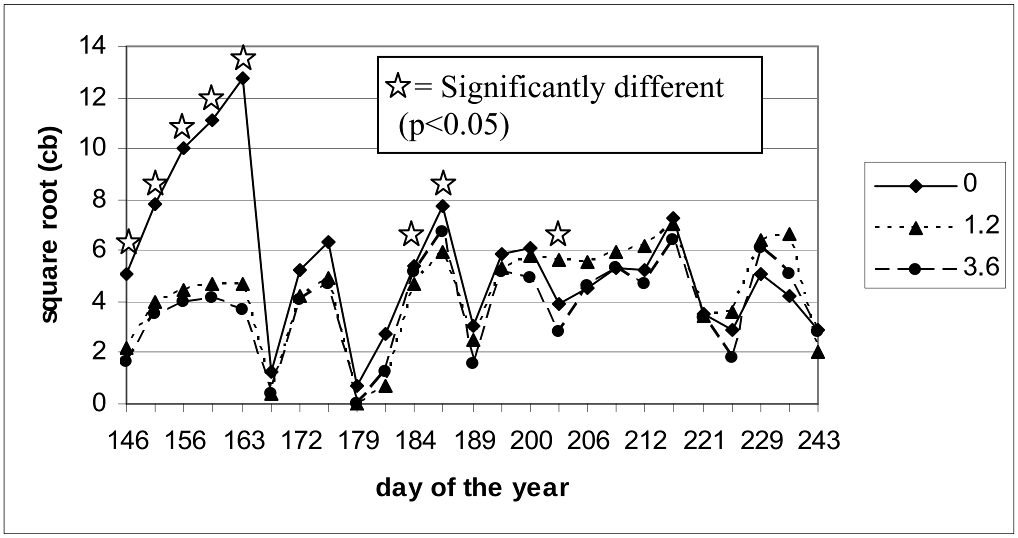
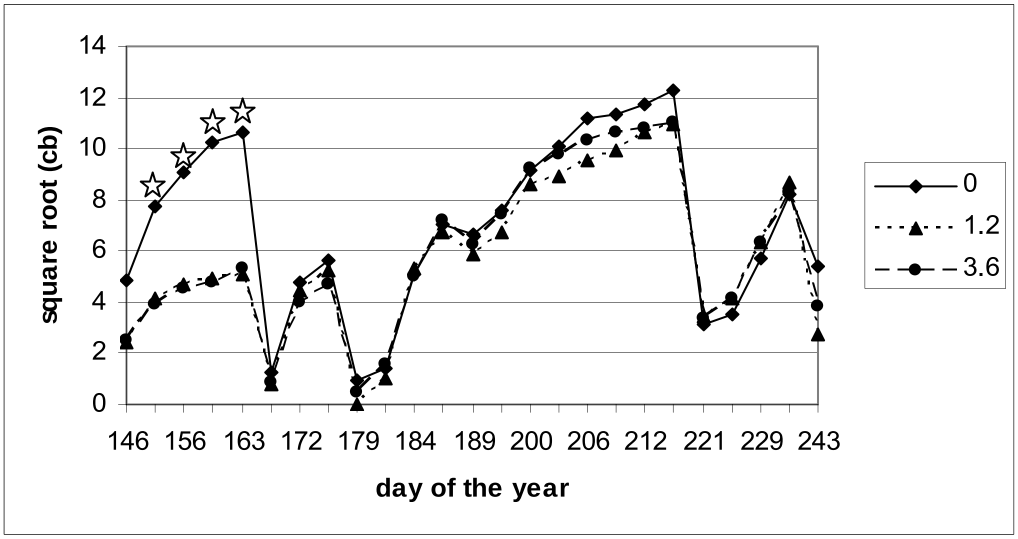


Figure 11. Effect of irrigation and vegetation - free width (VFW) on yield season total (1000 kg ha^{-1}) Clayton, NC, July, 2008.



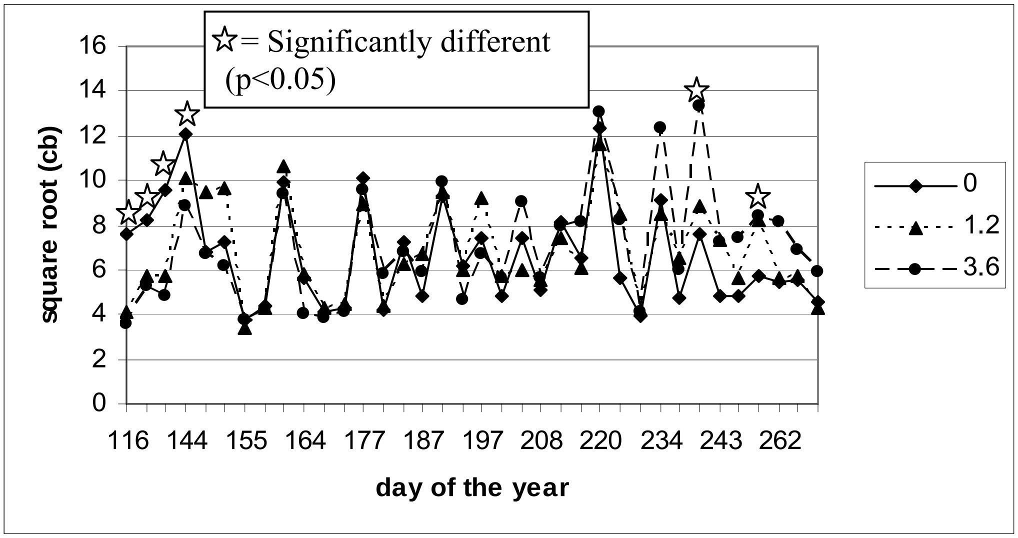
a)



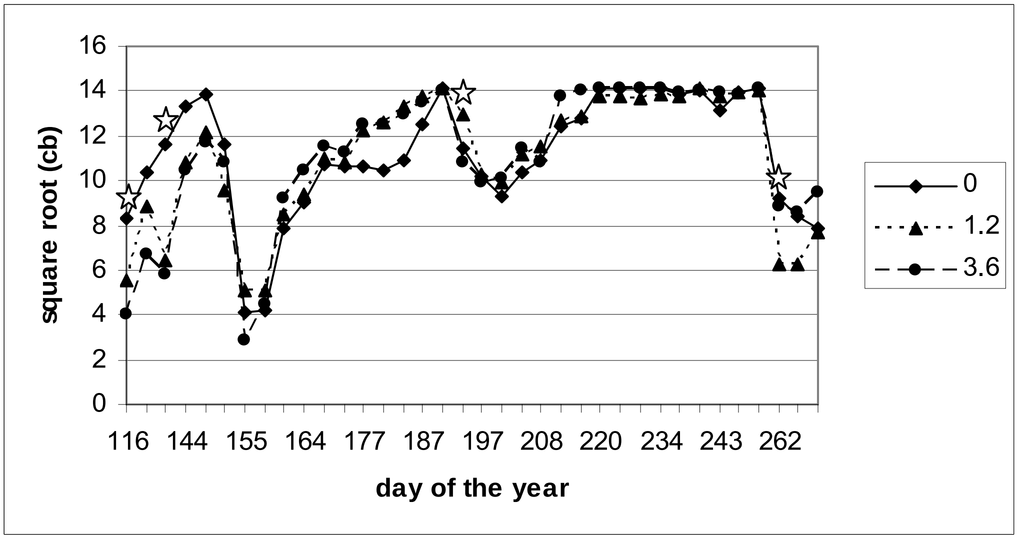
b)

Figure 12. Effect of irrigation and vegetation - free width (VFW) on soil water tension at various sampling dates, Jackson Springs, NC, 2006.

a) irrigated trees, b) nonirrigated trees. The lsd for a) is 2.12 and for b) is 2.42. (Note: Day of year is not to scale but is meant to show trends.) All VFWs were included in analyses but only three are shown for data presentation.



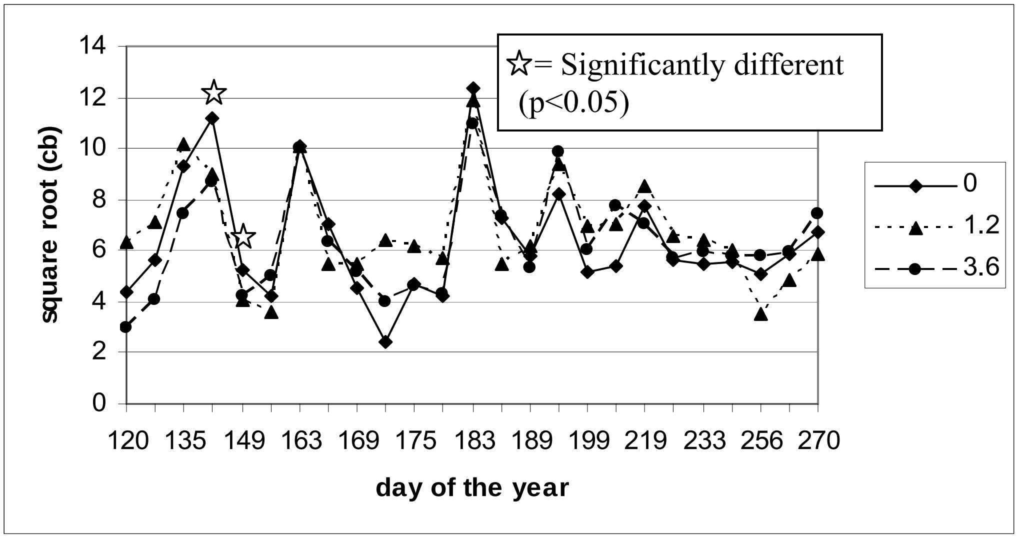
a)



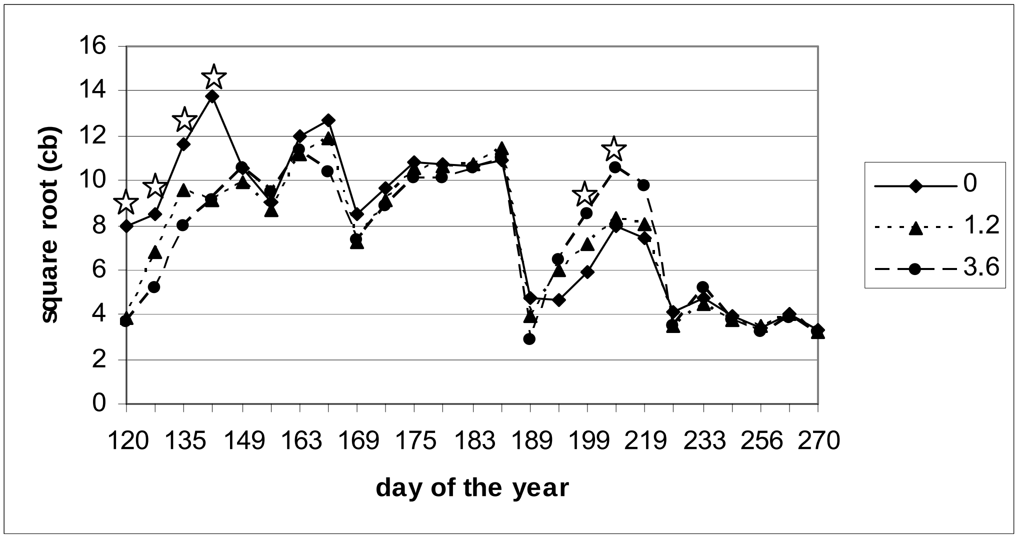
b)

Figure 13. Effect of irrigation and vegetation - free width (VFW) on soil water tension at various sampling dates, Jackson Springs, NC, 2007.

a) irrigated trees, b) nonirrigated trees. The lsd for a) is 3.20 and for b) is 2.66. (Note: Day of year is not to scale but is meant to show trends.) All VFWs were included in analyses but only three are shown for data presentation.



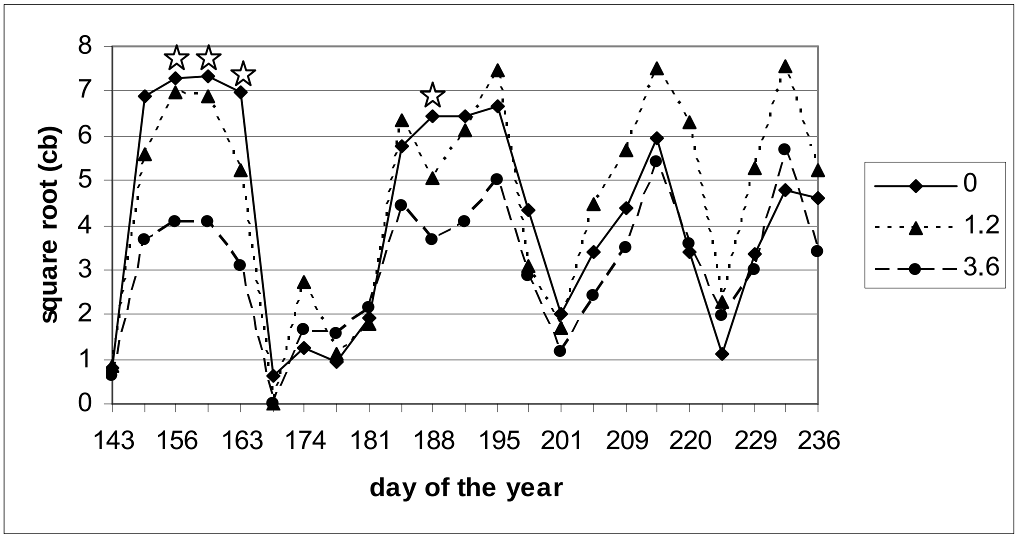
a)



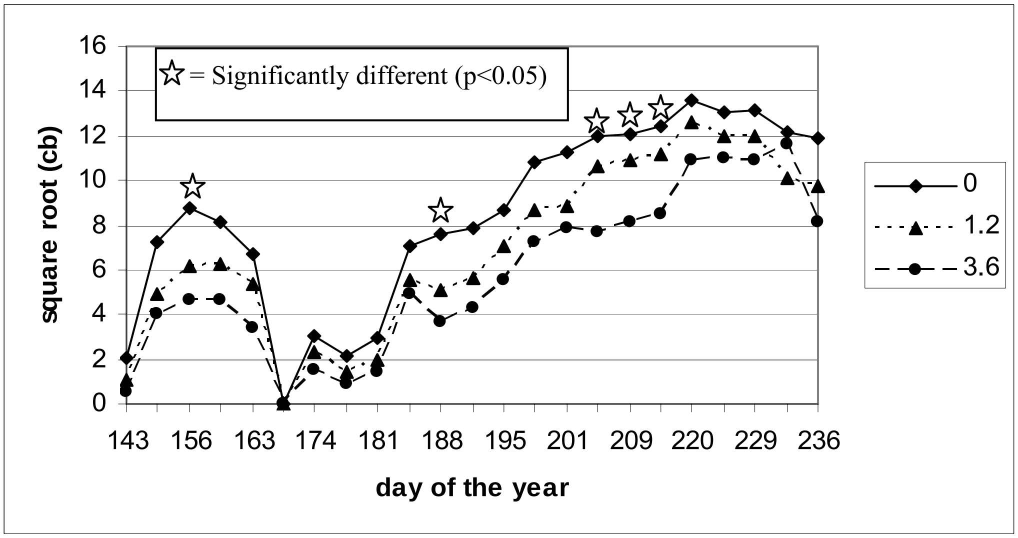
b)

Figure 14. Effect of irrigation and vegetation - free width (VFW) on soil water tension at various sampling dates, Jackson Springs, NC, 2008.

a) irrigated trees, b) nonirrigated trees. The lsd for a) is 3.43 and for b) is 2.43. (Note: Day of year is not to scale but is meant to show trends.) All VFWs were included in analyses but only three are shown for data presentation.



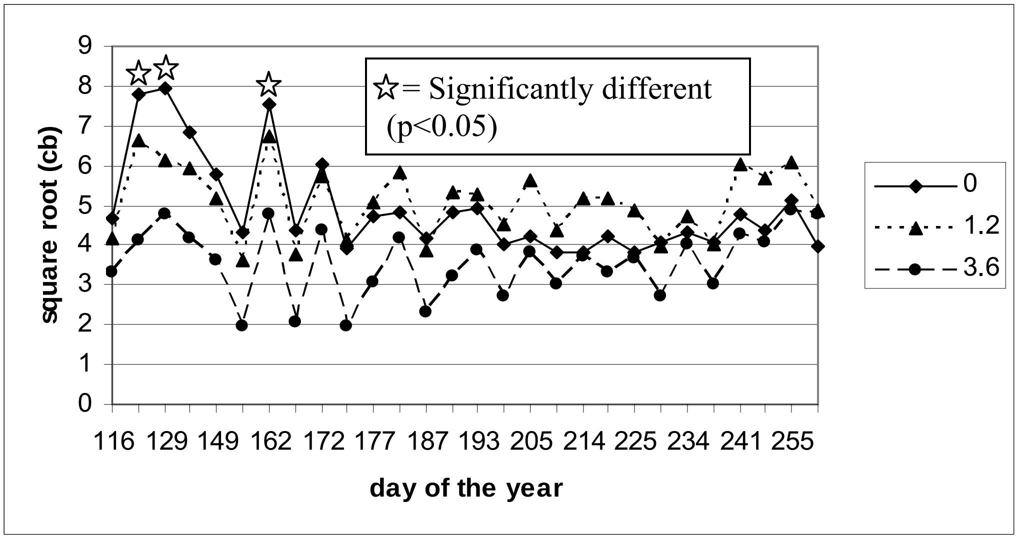
a)



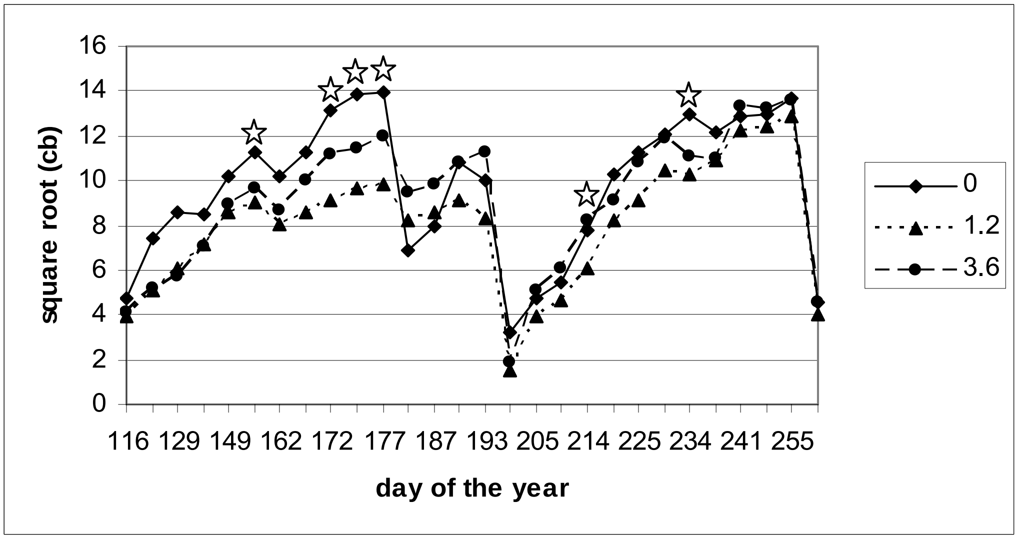
b)

Figure 15. Effect of irrigation and vegetation - free width (VFW) on soil water tension at various sampling dates, Clayton, NC, 2006.

a) irrigated trees, b) nonirrigated trees. The lsd for a) is 2.32 and for b) is 2.75. (Note: Day of year is not to scale but is meant to show trends.) All VFWs were included in analyses but only three are shown for data presentation.



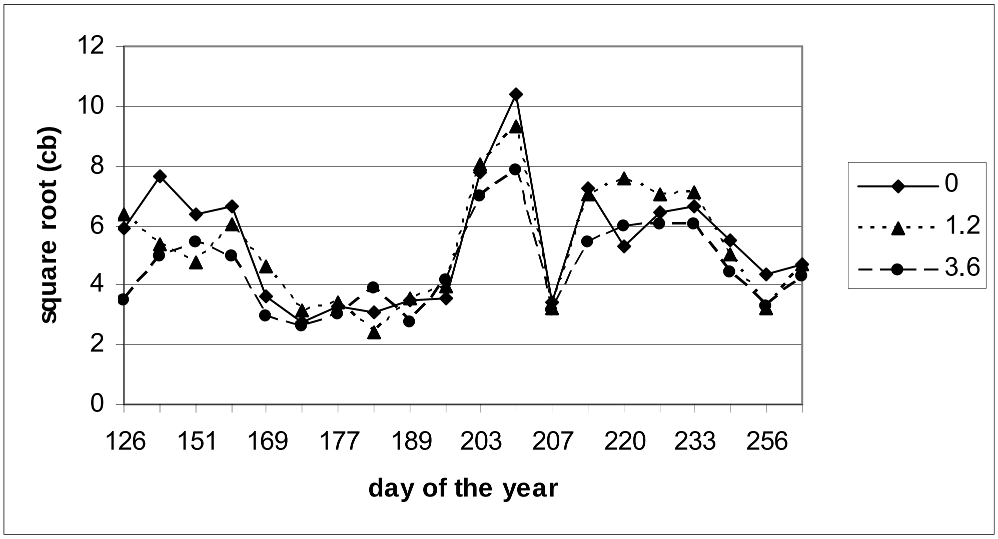
a)



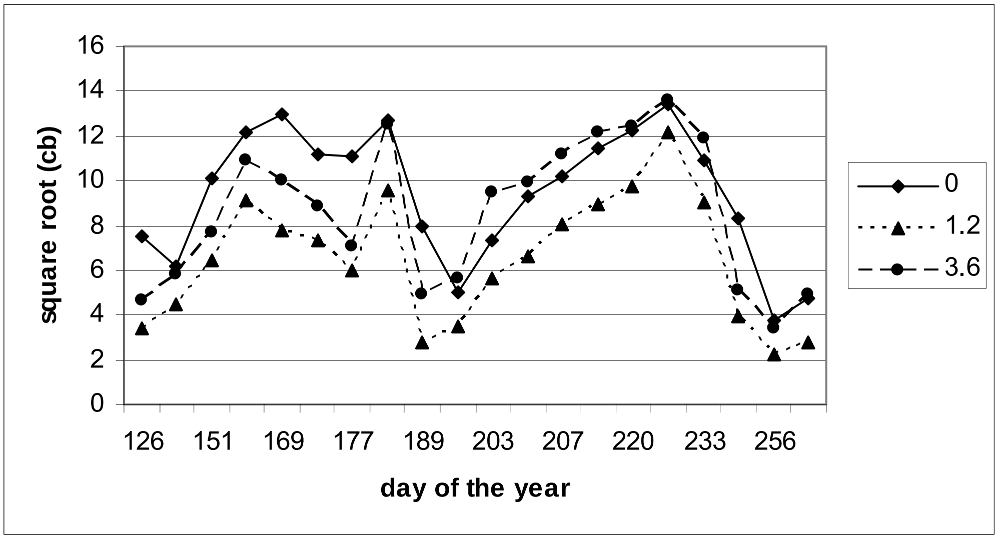
b)

Figure 16. Effect of irrigation and vegetation - free width (VFW) on soil water tension at various sampling dates, Clayton, NC, 2007.

a) irrigated trees, b) nonirrigated trees. The lsd for a) is 1.83 and for b) is 2.51. (Note: Day of year is not to scale but is meant to show trends.) All VFWs were included in analyses but only three are shown for data presentation.



a)



b)

Figure 17. Effect of irrigation and vegetation - free width (VFW) on soil water tension at various sampling dates, Clayton, NC, 2008.

a) irrigated trees, b) nonirrigated trees. The lsd for a) is 6.41 and for b) is 5.80. No significant effect of VFW was found for any day. (Note: Day of year is not to scale but is meant to show trends.) All VFWs were included in analyses but only three are shown for data presentation.

Table 9. Regression analyses of total dry weight (kg ha^{-1}) of herbaceous vegetation as influenced by vegetation - free width (VFW) and irrigation for various sampling dates. VFWs of 3.6 m were not included in the analysis.

Location	Sample Date	VFW p-value	Equation	R^2
Clayton	May 21, 2007	0.0002	Y=402.0-121.7x	0.87
Clayton	August 13, 2007	0.0008[a]	Y=873.4-222.1x	0.57
Clayton	April 22, 2008	0.0002	Y=760.5-215.8x	0.80
Clayton	September 8, 2008	<0.0001	Y=2927.0-789.6x	0.90
Jackson Springs	May 16, 2007	<0.0001	Y=929.8-286.3x	0.95
Jackson Springs	August 10, 2007	0.0142	Y=181.8-49.1x	0.57
Jackson Springs	May 22, 2008	0.0003	Y=1950.3-511.3x	0.61
Jackson Springs	September 15, 2008	<0.0001	Y=2159.5-658.2x	0.94

[a] Irrigation effect was significant for this sampling date only: The mean of irrigated plots was 738.97 compared to 368.19 of nonirrigated trees (p = 0.0006).

Table 10. Percent (averaged over three reps) of total dry weight of total herbaceous vegetation for winter grasses and forbs by irrigation and VFW, Clayton, NC, 2007 and 2008.[a]

	Irrigated				Nonirrigated			
	Grass and Sedges		Forb		Grass and Sedges		Forb	
	2007	2008	2007	2008	2007	2008	2007	2008
VFW	%				%			
0	0	2	100	98	0	0	100	100
0.6	0	0	100	100	0	0	100	100
1.2	0	0	100	100	0	0	100	100
2.4	0	0	100	100	0	0	100	100
3	0	0	100	100	0	0	100	100

[a] Samples were harvested May 21, 2007 and April 22, 2008.

Table 11. Percent (averaged over three reps) of total dry weight of total vegetation for summer grasses and forbs by irrigation and VFW, Clayton, NC, 2007 and 2008.[a]

	Irrigated				Nonirrigated			
	Grass and Sedges		Forb		Grass and Sedges		Forb	
	2007	2008	2007	2008	2007	2008	2007	2008
VFW	%				%			
0	79	94	21	6	79	100	21	0
0.6	73	92	27	8	71	84	29	16
1.2	94	92	6	8	83	99	17	1
2.4	94	80	6	20	84	72	16	28
3	72	100	28	0	83	88	17	12

[a] Samples were harvested August 13, 2007 and September 8, 2008.

Table 12. Percent (averaged over three reps) of total dry weight of total vegetation for winter grasses and forbs by irrigation and VFW, Jackson Springs, NC, 2007 and 2008.[a]

	Irrigated				Nonirrigated			
	Grass and Sedges		Forb		Grass and Sedges		Forb	
	2007	2008	2007	2008	2007	2008	2007	2008
VFW	%				%			
0	0	0	100	100	0	2	100	98
0.6	0	4	100	96	0	0	100	100
1.2	0	4	100	96	0	15	100	90
2.4	0	7	100	93	1	4	99	96
3	16	1	89	99	16	17	89	83

[a] Samples were harvested May 16, 2007 and May 22, 2008.

Table 13. Percent (averaged over three reps) of total dry weight of total vegetation for summer grasses and forbs by irrigation and VFW, Jackson Springs, NC, 2007and 2008.[a]

	Irrigated				Nonirrigated			
	Grass and Sedges		Forb		Grass and Sedges		Forb	
	2007	2008	2007	2008	2007	2008	2007	2008
VFW	%				%			
0	34	83	66	17	49	60	51	40
0.6	56	79	44	21	56	58	44	42
1.2	56	67	44	33	56	58	44	42
2.4	77	82	23	18	45	52	55	48
3	79	59	21	41	53	47	47	53

[a] Samples were harvested August 10, 2007 and September 15, 2008.

Weed control and peach response to sulfentrazone herbicide systems[1]

JULIANA K. BUCKELEW, WAYNE E. MITCHEM, and DAVID W. MONKS[2]

Abstract: Field experiments were conducted in 2006 and 2007 to determine newly planted peach tolerance to sulfentrazone herbicide applied PRE at various rates and to determine the effect of sequential sulfentrazone when tank mixed with other PRE herbicides on peach tolerance and weed suppression. Henbit, common lambsquarters, large crabgrass, and yellow foxtail were present at the study sites. For tolerance studies, treatments were 0.21, 0.28, 0.35, and 0.42 kg / ha sulfentrazone. For the systems study, treatments were 0.21 kg / ha sulfentrazone, 0.28 kg / ha sulfentrazone, 0.21 kg / ha sulfentrazone plus 1.34 kg / ha norflurazon, 0.28 kg / ha sulfentrazone plus 1.34 kg / ha norflurazon, 0.21 kg / ha sulfentrazone plus 1.12 kg / ha oryzalin, 0.28 kg / ha sulfentrazone plus 1.12 oryzalin, 0.89 kg / ha terbacil, 0.89 kg / ha terbacil plus 1.12 kg / ha rimsulfuron, and 0.28 kg / ha flumioxazin. Sulfentrazone PRE did not injure newly planted peach trees. Sulfentrazone alone controlled several broadleaf weeds however it did not adequately control large crabgrass and yellow foxtail. Control of these grasses increased with the addition of norflurazon or oryzalin. Norflurazon and rimsulfuron were safe for peach trees when applied as a tank mix partner in this study, therefore deserve further investigation for weed control in newly planted peach. Sulfentrazone was safe to newly planted peach and likely would be

---

[1] Received for publication date and in revised form date.

[2] Graduate student and professor, Department of Horticultural Science, North Carolina State University, Raleigh, NC 27695.

useful to growers developing weed management programs for peach.

Nomenclature: Common lambsquarters, *Chenopodium album* (L.) #[3] CHENAL; henbit, *Lamiam amplexicaule* (L.) # LAMAM**;** large crabgrass, *Digitaria sanguinalis* (L.) Scop. # DIGSA; peach, *Prunus persica*; yellow foxtail, *Setaria glauca* (L.) Beauv. #SETGL.

Additional index words: Aryl triazinone, dinitroaniline, flumioxazin, oryzalin, norflurazon, N-Phenylphthalimide, pyridazinones, rimsulfuron, sulfonylurea, sulfentrazone, terbacil, uracil.

Introduction

Managing weeds in the first three years after planting a peach orchard is important to maximize tree growth and subsequent returns on investment once trees start producing (Mitchem 2008). Traditionally in peach orchards, a PRE herbicide is applied in the spring, with a POST herbicide applied as needed through summer. Without the use of PRE herbicides, four trips with POST herbicides would be needed through the season (W.E. Mitchem, personal communication). However, water quality concerns about the traditionally-used simazine and diuron (Baer and Calvert 1999, Barbash et al. 2001, Comber 1999) applied PRE have necessitated the screening of safer alternative herbicides and the reduction of herbicide active ingredient per hectare through sequential PRE applications at reduced

---

[3] Letters following this symbol are a WSSA-approved computer code from Composite List of Weeds, Revised 1989. Available on computer disk from WSSA, 810 East 10th Street, Lawrence, KS 66044-8897.

rates. The only current PRE options available to growers for use on newly planted peach trees are terbacil, flumioxazin, oryzalin, oxyfluorfen, and pendimethalin. The first two herbicides are grower standards due to their superior control of larger seeded broadleaf weeds. These herbicides are applied sequentially once control from the first timing expires. Additional control options are needed. Sulfentrazone is one such option and belongs to the herbicide family aryl triazinones which produce symptoms in susceptible plants that include necrosis and death upon exposure to light. Sulfentrazone disrupts cell membranes, and foliar contact causes rapid desiccation and necrosis of exposed plant tissue (Ferrell et al. 2005). Additionally, sulfentrazone is known to be active against broadleaf weeds and yellow nutsedge which are increasing problems in North Carolina peaches.

Our objective was to determine the effect of sulfentrazone PRE at various rates on newly planted peach trees and to determine the effect of sequential applications of sulfentrazone when tank mixed with other PRE herbicides on crop tolerance and weed suppression.

Materials and Methods

Tolerance studies were conducted in 2006 at the Central Crops Research Station in Clayton, NC (35.65 degrees N, 78.46 degrees W) and in 2007 in an orchard near Vale, NC (35.49 degrees N, 81.52 degrees W). Soil at Clayton was Norfolk loamy sand (fine-loamy, Kaolinitic, thermic Typic Kandiudults) with pH 5.6 and humic matter 0.86 %. Soil at Vale was Cecil clay loam. The objective of the tolerance studies was to evaluate peach tree tolerance to sulfentrazone applied sequentially at 0.21, 0.28, 0.35, and 0.42 kg / ha. Herbicides were applied May 22 and August 7, 2006 at Clayton, and March 23 and June 24, 2007 at Vale. Visual estimates of peach tree injury (0 % =no injury, 100 % =plant death) were determined 4 and 8 wk after each treatment. A systems trial was also conducted in 2007 near Vale, NC at the same site to determine weed control and peach tree response to various sequentially-applied tank mixes (Table 1) when compared to grower standards flumioxazin and terbacil. Norflurazon and rimsulfuron were also evaluated. Norflurazon is not registered on newly planted trees for 6 months after transplant, and rimsulfuron is not registered for orchards planted less than one year. Herbicides were applied March 31 and June 27, 2007 in Vale. Visual estimates of percent weed control and percent bareground (area weed-free) were recorded 4 and 8 wk after each treatment application. For both studies, tree cross-sectional area (TCSA) was measured at the end of the season after leaf fall.

For both sites, the bottom 30 cm of each tree was painted at planting with white latex paint for protection from contact herbicide. At Clayton, peach trees 61 to 76 cm tall were hand planted in January 2006. Plots were three tree plantings of ‘Contender’ on ‘Guardian’ rootstock. Tree spacing was 2.74 m apart in rows spaced 6.10 m between rows. At Vale, peach trees 80 cm tall were hand planted in early 2007. The tolerance study consisted of three replications of ‘Flavor Rich’ and one replication of ‘July Prince’ on ‘Lovell.’ The systems study at Vale consisted of ‘July Prince’ on ‘Lovell. Tree spacing was 4.88 m in rows spaced 6.10 m between rows. The tolerance study consisted of four-tree plots and the systems study consisted of two-tree plots.

For all studies, the experimental design was a randomized complete block design replicated four times. Each study included a nontreated check. Herbicide strips in the tolerance studies were chemically maintained with flumioxazin at 213.3 g / ha for PRE weed control, and paraquat at 0.67 to 1.0 kg / ha with non-ionic surfactant[4] at 0.25% volume per volume for POST weed control. A graminicide (fluazifop, sethoxydim or clethodim) was used as needed for perennial grass control. Application equipment was a CO_2 backpack sprayer pressurized at 220-234 kPa using a flat fan 8002XR nozzle to apply 187 L/ha spray volume. A two nozzle boom applied herbicide to a total strip width of 2 m. The nozzle applied the herbicide solution down each side of the peach row and contacted the bottom 10 cm of peach stem. Analysis of variance was determined in the GLM procedure of SAS (SAS 1998) and means were separated by Fisher's protected least significant difference at the 5% level.

Results and Discussions

Tolerance studies. Tolerance trials were combined because no significant differences due to year were found. Sulfentrazone did not injure peach trees or reduce TCSA relative to the nontreated check (data not shown). However, rainfall at both sites subsequent to the first application was lacking and may have mitigated crop injury (Table 3). Sulfentrazone needs 1.25 to 5 cm of moisture within 7-10 d after application

(Anonymous 2004). Precipitation was 0.3 cm at Clayton and 0.36 cm at Vale for the first two weeks after the first application, and 1.31 at Clayton and 0.68 cm at Vale for the first two weeks after the second application.

[4] X-77, Loveland Industries, Inc., P.O. Box 1289, Greely, CO 80632.

System studies.

Crop response. With the weedy check excluded from statistical analysis, no differences were found for TCSA among treatments and the commercially registered grower standards flumioxazin and terbacil (Table 2). Although precipitation after the first application was adequate, precipitation during the first two weeks after the second application was only 0.63 cm (Table 3).

Weed control. All percent control ratings did not include the nontreated check in data analyses. At 4 wk after the first treatment, henbit and common lambsquarters were rated for control. All treatments provided excellent control (≥ 97 %) of these weeds (data not shown). At 8 wk after the first treatment, large crabgrass and yellow foxtail were rated for control. Sulfentrazone alone exhibited no control of large crabgrass and yellow foxtail while the other treatments (with the exception of sulfentrazone at the lower rate combined with norflurazon or oryzalin) exhibited control of 93 % or higher (Table 2). With respect to large crabgrass, yellow foxtail, common lambsquarters, and henbit, rimsulfuron did not increase control of these weeds over terbacil alone. The herbicides norflurazon and rimsulfuron did not however, injure peach trees. As the season progressed and ratings were performed at 4 and 8 wk after the second treatment date, few seeds of large crabgrass and yellow foxtail germinated due to drought (Table 3). Therefore ratings on these subsequent dates were not significantly different (data not shown).

The treatments were significantly different for percent bareground (with the nontreated check included) at all rating dates (Table 2). Four wk after the first treatment timing, the nontreated check was 61 % bareground, compared to 96 % and higher bareground for all other treatments (Table 2). At eight wk after the first treatment, sulfentrazone alone (80 and 87 %) was greater than the nontreated check, but less than terbacil (100 %), terbacil + rimsulfuron (99 %) and sulfentrazone at the higher rate + norflurazon (99 %). At four and eight wk after the second treatment timing (last rating date of the study), all treated plots except sulfentrazone alone exhibited 87% or greater bareground, while the weedy check and sulfentrazone alone were 20 to 22 and 50 to 81 % bareground, respectively (Table 2).

In summary, sulfentrazone did not injure newly planted peach trees when applied PRE, and therefore has potential for registration to control weeds in newly planted peach in North Carolina. However, tolerance of peach to sulfentrazone under increased rainfall (timings, amounts) occurrence needs confirmation. Sulfentrazone did not adequately control large crabgrass and yellow foxtail, but control of these weeds was improved with the addition of norflurazon or oryzalin. Applied alone, it controlled several broadleaf weeds. Neither norflurazon nor rimsulfuron injured peach trees when applied as a tank mix partner in this study, therefore deserve further investigation for weed control in newly planted peach. Sulfentrazone has the potential to be a useful part of integrated pest management programs for weed management in newly planted peach and likely would be useful to growers developing weed management programs for peach.

Acknowledgements

The authors express appreciation to Jeff Crotts, grower in Vale, NC, and to the staff at the Central Crops Research Station.

Literature Cited

Anonymous, 2004. Spartan 4F Herbicide Label. FMC Corporation, Agricultural Products Group. Philadelphia, PA http://www.cdms.net/LDat/ld3LT010.pdf

Baer, U. and R. Calvert. 1999. Fate of soil applied herbicides: experimental data and prediction of dissipation kinetics. J. Environ. Quality 28:1765-1777.

Barbash, J.E., G.P. Thelin, D.W. Kolpin, and R.J. Gilliom. 2001. Major herbicides in ground water: results from the National Water-Quality Assessment. J. Environ. Quality 30:831-845.

Comber, S.D.W. 1999. Abiotic persistence of atrazine and simazine in water. Pesticide Sci. 55:696-702.

Ferrell, J.A., W.M. Stall, and G.E. MacDonald. 2007. Diagnosing Herbicide Injury-2007. Pub. #SS-AGR-15. University of Florida Cooperative Extension. http://edis.ifas.ufl.edu

Mitchem, W.E. 2008. North Carolina Peach and Nectarine Disease and Pest Management Guide. http://www.ent.uga.edu/peach/peachhbk/toc.htm

Mitchem, W.E. 2009. Chemical weed control in fruit crops. p. 446. *in* North Carolina Agricultural Chemicals Manual. AG-1. College of Agric. and Life Sci., North Carolina State Univ., Raleigh, NC.

(SAS) Statistical Analysis Systems. 1998. SAS/STAT® User's Guide. Release 8.0. Cary, NC: Statistical Analysis Systems Institute.

Table 1. Common name, trade name, formulation, and application rates of herbicides used in sulfentrazone systems study.

Treatment	Common name	Trade name	Formulation	Rate
				kg ai /ha
1	none			0
2	sulfentrazone	Spartan	4F	0.21
3	sulfentrazone	Spartan	4F	0.28
4	sulfentrazone	Spartan	4F	0.21
	norflurazon	Solicam	80WDG	1.34
5	sulfentrazone	Spartan	4F	0.28
	norflurazon	Solicam	80DF	1.34
6	sulfentrazone	Spartan	4F	0.21
	oryzalin	Surflan	4AS	1.12
7	sulfentrazone	Spartan	4F	0.28
	oryzalin	Surflan	4AS	1.12
8	terbacil	Sinbar	80WP	0.89
9	terbacil	Sinbar	80WP	0.89
	rimsulfuron	Matrix	25DF	1.12
10	flumioxazin	Chateau	51WDG	0.28

Table 2. The effect of various PRE herbicides on peach trees, weeds, and percent bareground, Vale, NC, 2007.

			Peach[a]	Weed[b]		Bareground			
Trt	Chemical	Rate	TCSA	DIGSA	SETGL	Weeks after 1st application		Weeks after 2nd application	
						4	8	4	8
		kg/ha	cm^2	%		%			
1	nontreated	0	-	-	-	61	55	20	22
2	sulfentrazone	0.21	7.6	38	16	99	80	81	81
3	sulfentrazone	0.28	4.9	5	5	98	87	50	50
4	sulfentrazone norflurazon	0.21 1.34	4.7	82	87	96	98	94	94
5	sulfentrazone norflurazon	0.28 1.34	5.5	95	100	99	99	97	96
6	sulfentrazone oryzalin	0.21 1.12	6.2	66	87	99	94	92	94
7	sulfentrazone oryzalin	0.28 1.12	4.8	93	93	99	92	87	87
8	terbacil	0.89	6.0	100	100	100	100	100	100
9	terbacil rimsulfuron	0.89 1.12	5.2	95	100	100	99	98	100
10	flumioxazin	0.28	5.5	95	100	100	98	97	93
LSD(.05)			NS	28	22	13	11	24	23

[a] TCSA was not significantly different with the weedy check excluded.

[b] Weed name abbreviations: DIGSA, large crabgrass; SETGL, yellow foxtail. Visual ratings at 8 weeks after the first treatment timing using a 0 to 100 % scale, with 0 = no control and 100 = complete control.

Table 3. Precipitation records (cm) for Clayton and Vale, NC, 2006 and 2007.

Study	Weeks after 1st application					Weeks after 2nd application					Cumulative[c]
	1	2	3	4	5+[a]	1	2	3	4	5+[b]	
Tolerance (Clayton 2006)	0.10	0.20	0.08	0.20	5.70	1.28	0.03	2.93	6.63	6.38	23.5
Tolerance (Vale 2007)	0.13	0.23	1.55	2.53	5.28	0.68	0	0.43	0.15	0.58	11.53
Systems	0.23	2.5	1.58	0.53	5.23	0.20	0.43	0.05	0.10	0.80	11.63

[a] Precipitation from 5 weeks after first application to the second treatment application.

[b] Precipitation from 5 wk after second application to the eighth wk after the second application.

[c] Cumulative precipitation amount from the first application to the eighth wk after the second application.

Response of newly planted peach to certain PRE herbicides[1]

JULIANA K. BUCKELEW, WAYNE E. MITCHEM, and DAVID W. MONKS[2]

Abstract: Field experiments were conducted in 2006 and 2007 to determine tolerance to halosulfuron, mesotrione, and rimsulfuron applied at various rates on newly planted peach. The halosulfuron study included treatments 0, 26.3, 52.5, 79, and 105 g / ha. The mesotrione study included treatments 0, 105.7, 140.3, 211.4, and 280.1 g / ha. The rimsulfuron study included treatments 0, 70, 140, 210, and 280 g / ha. Halosulfuron, mesotrione and rimsulfuron did not reduce TCSA or winter pruning weight relative to the nontreated check. In 2006, no injury from halosulfuron occurred at 1 WAT, but at 3 WAT injury was 39 to 50 % on the highest rates of the study at 79 and 105 g / ha, respectively. Partial recovery of peach was seen at 5 WAT, as shown by 12 and 24 % injury on the highest rates (79 and 105 g / ha) of the study, respectively. No visual injury symptoms occurred in 2007 for any study. Mesotrione and rimsulfuron were safe to newly planted peach and likely would be useful to growers developing weed management programs for peach. Halosulfuron at the higher rates caused visual injury but did not reduce TCSA or winter pruning weight. Therefore, further testing is needed to define conditions that may contribute to injury from halosulfuron.

Nomenclature: peach, *Prunus persica.*

---

[1] Received for publication date, and in revised form date.

[2] Graduate research assistant, extension associate, and professor, Department of Horticultural Science, NC State University, Raleigh, NC 27695.

Additional index words: halosulfuron, mesotrione, rimsulfuron, sulfonylurea.

Introduction

Managing weeds in the first three years after planting a peach orchard is important to maximize tree growth and subsequent returns on investment once trees start producing (Mitchem 2008). Traditionally in peach orchards, a PRE herbicide is applied in the spring, with a POST herbicide applied as needed through summer. Without the use of PRE herbicides, four trips with POST herbicides would be needed through the season (W.E. Mitchem, personal communication). However, water quality concerns about the traditionally-used simazine and diuron (Baer and Calvert 1999, Barbash et al. 2001, Comber 1999) applied PRE have necessitated the screening of alternative herbicides and the reduction of herbicide active ingredient per hectare through sequential PRE applications at reduced rates.

The only current PRE herbicide options available to growers for use on newly planted peach trees are terbacil, flumioxazin, oryzalin, oxyfluorfen, and pendimethalin. The first two are grower standards due to their superior control of large seeded broadleaf weeds, and are applied sequentially once control from the first timing expires. Additional weed control options are needed. Halosulfuron, mesotrione, and rimsulfuron are possibilities that possess both POST and PRE activity and could be used PRE in newly planted peach.

Our objective was to determine the effect of halsofuluron, mesiotrione, and rimsulfuron at various rates on newly planted peach trees.

Materials and Methods

Field studies were conducted in 2006 and 2007 at the Sandhills Research Station in Jackson Springs, NC (35.21 degrees N, 79.63 degrees W). Soil in 2006 was Candor sand (sandy, Kaolinitic, thermic Grossarenic Kandiudults) with pH 5.8 and humic matter 0.60%. Soil in 2007 was also Candor sand, with pH 6.2 and humic matter 0.60 %. The first study evaluated response to halosulfuron applied at 26.3, 52.5, 79, 105 g / ha. The second study evaluated mesotrione applied at 105.7, 140.3, 211.4,

and 280.1 g / ha. The third study evaluated rimsulfuron at 70, 140, 210, and 280 g / ha. Herbicides were applied June 7, 2006 for halosulfuron and rimsulfuron trials, and June 21, 2006 for mesotrione applications. In 2007, herbicides were applied June 23, 2007.
Visual estimates of peach tree injury (0 % = no injury, 75 % = leaf drop, 100 % =plant death) were determined 1, 3, and 5 wk after treatment (WAT). Tree cross-sectional area (TCSA) was measured at the end of the season after leaf fall. Winter prunings were weighed after open-center pruning from two trees per plot.

The bottom 30 cm of each tree was painted at planting with white latex paint for protection from contact herbicide. Trees were newly planted ‘Contender’ (freestone fresh-market type) on ‘Guardian’ rootstock. In 2006, plots were four tree plantings with spacing 2.74 m apart in rows spaced 6.10 m apart between rows. In 2007, plots were three tree plantings with spacing 4.88 m in rows spaced 6.10 m apart between rows.

For all studies, the experimental design was a randomized complete block design

---

[3] X-77, Loveland Industries, Inc., P.O. Box 1289, Greely, CO 80632

replicated four times. Strips were maintained as needed with paraquat at 0.67 to 1.0 kg / ha and non-ionic surfactant[3] at 0.25% volume per volume. Application equipment was a CO_2 backpack sprayer pressurized at 220-234 kPa using a flat fan 8002XR nozzle to apply 187 L/ha spray volume. A double nozzle boom applied herbicide to a total strip width of 2 m. The nozzle applied the herbicide solution down each side of the peach row and contacted the bottom 10 cm of peach stem. Analysis of variance was determined using the GLM procedure of SAS (SAS 1998) and means were separated by Fisher's protected least significant difference at the 5% level.

Results and Discussion

Tree injury. Injury analyses did not include the nontreated check. In 2006, no injury was seen on any trial at 1 WAT. The rimsulfuron trial did not show any injury for any rating date. Likewise, the mesotrione trial did not show any significant treatment differences for any rating date. At 3 WAT, 39 to 50 % injury was observed from halosulfuron at 79 and 105 g / ha, respectively (data not shown). The injury was chlorotic shoot tips, intraveinal chlorosis of new growth, narrow, small new leaves, and shortened internodes of new growth. Other rates of halosulfuron caused 10 % or less injury to peach. At 5 WAT, the trees were growing out of the damage, with the new growth appearing more normal, but still having narrow, small new leaves, and the old damaged growth retaining the intraveinal chlorosis. Injury was observed to be 12 and 24 % from halosulfuron at 79 and 105 g/ha, respectively. Other rates caused percent injury of 1 % or less. No peach injury from herbicides occurred for any study in 2007 (data not shown).

TCSA and winter prunings. Analyses included the nontreated check. Years were combined for the halosulfuron and mesotrione studies because no significant interaction with year was found. For both studies, no treatment differences occurred (Table 1). Interaction with year was significant for the rimsulfuron study, with significant differences among treatments. However, the nontreated check was not different from the highest rate of 280 g / ha (2006 TCSA and prunings) and the check was less in cross-sectional area than the highest rate of 280 g / ha (2007 TCSA) (Table 1). The lack of meaningful differences among rates of rimsulfuron suggest that it did not reduce TCSA or winter pruning weight.

In summary, halosulfuron, mesotrione, and rimsulfuron did not injure peach or reduce TCSA relative to the nontreated check. Thus, these herbicides have potential for registration to control weeds in newly planted peach. However, halosulfuron at the higher rates needs further testing to further define conditions associated with injury by this herbicide.

Acknowledgements

The authors express appreciation to the staff at Sandhills Research Station.

Literature Cited

Baer, U. and R. Calvert. 1999. Fate of soil applied herbicides: experimental data and prediction of dissipation kinetics. J. Environ. Quality 28:1765-1777.

Barbash, J.E., G.P. Thelin, D.W. Kolpin, and R.J. Gilliom. 2001. Major herbicides in ground water: results from the National Water-Quality Assessment. J. Environ. Quality 30:831-845.

Comber, S.D.W. 1999. Abiotic persistence of atrazine and simazine in water. Pesticide Sci. 55:696-702.

Mitchem, W.E. 2008. North Carolina Peach and Nectarine Disease and Pest Management Guide. http://www.ent.uga.edu/peach/peachhbk/toc.htm

Mitchem, W.E. 2009. Chemical weed control in fruit crops. p. 446. *in* North Carolina Agricultural Chemicals Manual. AG-1. College of Agric. and Life Sci., North Carolina State Univ., Raleigh, NC.

(SAS) Statistical Analysis Systems. 1998. SAS/STAT® User's Guide. Release 8.0. Cary, NC: Statistical Analysis Systems Institute.

Table 1. The effect of various PRE herbicides on tree cross-sectional area (TCSA) and weight of winter prunings, Jackson Springs, NC, 2006 and 2007.

		Combined years		2006		2007	
Chemical	Rate	TCSA	Prunings	TCSA	Prunings	TCSA	Prunings
	g/ha	cm^2	kg/tree	cm^2	kg/tree	cm^2	kg/tree
nontreated	0	6.8	0.6				
halosulfuron	26.3	7.8	0.7				
halosulfuron	52.5	6.8	0.5				
halosulfuron	79	7.0	0.6				
halosulfuron	105	7.2	0.6				
nontreated	0	8.8	0.8				
mesotrione	105.7	9.5	0.8				
mesotrione	140.3	9.4	0.8				
mesotrione	211.4	8.9	0.8				
mesotrione	280.1	8.6	0.8				
nontreated	0			10.9	0.9	5.1	0.4
rimsulfuron	70			12.4	1.1	6.4	0.6
rimsulfuron	140			10.3	0.8	7.2	0.6
rimsulfuron	210			11.2	0.9	6.2	0.5
rimsulfuron	280			9.9	0.7	8.5	0.7
LSD(.05)		NS[a]	NS[a]	1.3	0.3	1.9	NS

[a] Each herbicide was evaluated in a separate study and each study was analyzed separately.

Appendix

Appendix Table 1. Precipitation and irrigation data, Clayton, NC, 2006 - 2008. (Source for precipitation data for 2006 and 2008 is Central Crops Research Station, and 2007 is ECONET).

	Precipitation (cm)			Irrigation (cm)[a]		
Month	2006	2007	2008	2006	2007	2008
March	3.20	8.10	8.02	0	0	0
April	9.67	8.40	14.42	0	0	0
May	11.17	2.31	7.34	0	5.08[d]	0
June	21.92	6.5	6.78	0	5.08[e]	7.62[h]
July	5.38	10.38	12.44	5.08[b]	2.54[f]	5.08[i]
August	8.35	1.80	4.95	7.62[c]	12.7[g]	2.54[j]
September	11.02	8.0	4.26	0	0	0
October	9.09	7.79	3.98	0	0	0

[a] Irrigation applied to irrigated plots only and was 2.54 cm in quantity.

[b] Irrigation applied July 14 and 19, 2006.

[c] Irrigation applied August 3, 10, and 25, 2006.

[d] Irrigation applied May 24 and 31, 2007.

[e] Irrigation applied June 13 and 21, 2007.

[f] Irrigation applied July 5, 2007

[g] Irrigation applied August 2, 9, 16, 23, and 30, 2007.

[h] Irrigation applied June 6, 12 and 19, 2008.

[I] Irrigation applied July 3 and 24, 2008.

[j] Irrigation applied August 7, 2008.

Appendix Table 2. Precipitation and irrigation data, Jackson Springs, NC, 2006 - 2008. (Source for precipitation data is Jackson Springs Research Station).

	Precipitation (cm)			Irrigation (cm)[a]		
Month	2006	2007	2008	2006	2007	2008
March	4.97	7.49	8.76	0	0	0
April	8.48	9.14	11.96	0	0	0
May	8.28	3.47	5.33	0	5.08[e]	0
June	29.38	8.53	4.08	2.54[b]	10.16[f]	10.16[i]
July	3.3	6.37	13.23	8.89[c]	7.62[g]	5.08[j]
August	14.75	1.04	22.27	7.62[d]	7.62[h]	2.54[k]
September	9.98	4.24	14.98	0	0	0
October	7.79	12.92	4.14	0	0	0

[a] Irrigation applied to irrigated plots only and were 2.54 cm in quantity, unless otherwise specified.

[b] Irrigation applied June 23, 2006.

[c] Irrigation applied July 6 (1.27 cm inch only), 13, 20, 30, 2006.

[d] Irrigation applied August 3, 10, 18, 2006.

[e] Irrigation applied May 25, 2007. All plots received overhead irrigation on May 30, 2007.

[f] Irrigation applied June 1, 12, 20, 27, 2007.

[g] Irrigation applied July 5, 12, 26, 2007

[h] Irrigation applied August 2, 9, 16, 2007

[i] Irrigation applied June 2, 12, 19, 24, 2008.

[j] Irrigation applied July 2, 18, 2008.

[k] Irrigation applied August 8, 2008.

Appendix Table 3. Elemental amount (kg/ha) in vegetation by vegetation-free area (VFW) in irrigated (irr.) and nonirrigated (nonirr.) conditions, Clayton, NC, 2007 and 2008.

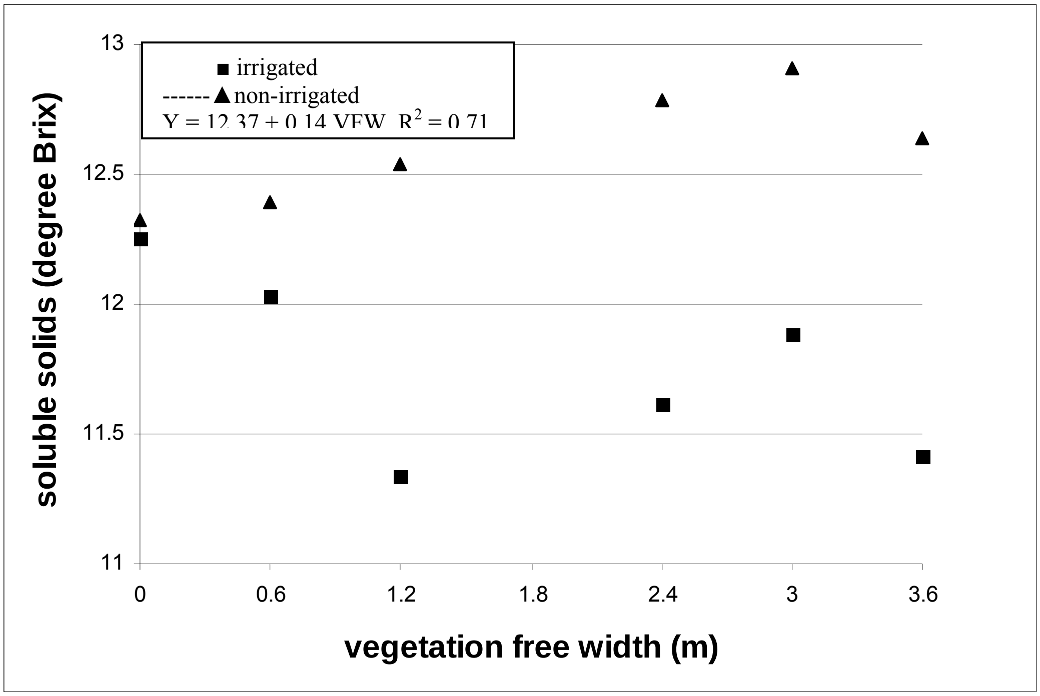
VFW (m)	N		P		K		Ca		Mg	
	irr.	nonirr.	irr.	nonirr.	irr.	nonirr.	irr.	nonirr.	irr.	nonirr.
	kg/ha									
0	22.5	18.0	4.6	3.1	23.2	18.3	8.5	5.2	3.9	2.6
0.6	17.2	15.5	3.9	2.9	19.5	17.2	6.8	5.1	3.4	2.5
1.2	11.0	14.3	2.6	2.9	13.1	16.1	4.3	4.4	2.3	2.5
2.4	6.9	7.1	1.7	1.3	8.2	8.5	2.8	2.8	1.4	1.3
3.0	2.8	3.2	0.7	0.7	3.6	3.9	1.2	1.1	0.6	0.6
3.6	N/A									
LSD(0.05)[a]	6.0	8.5	2.0	1.7	8.6	NS	2.1	2.2	1.4	1.2

[a] Means within a column are different according to Fisher's Protected LSD at P = 0.05.

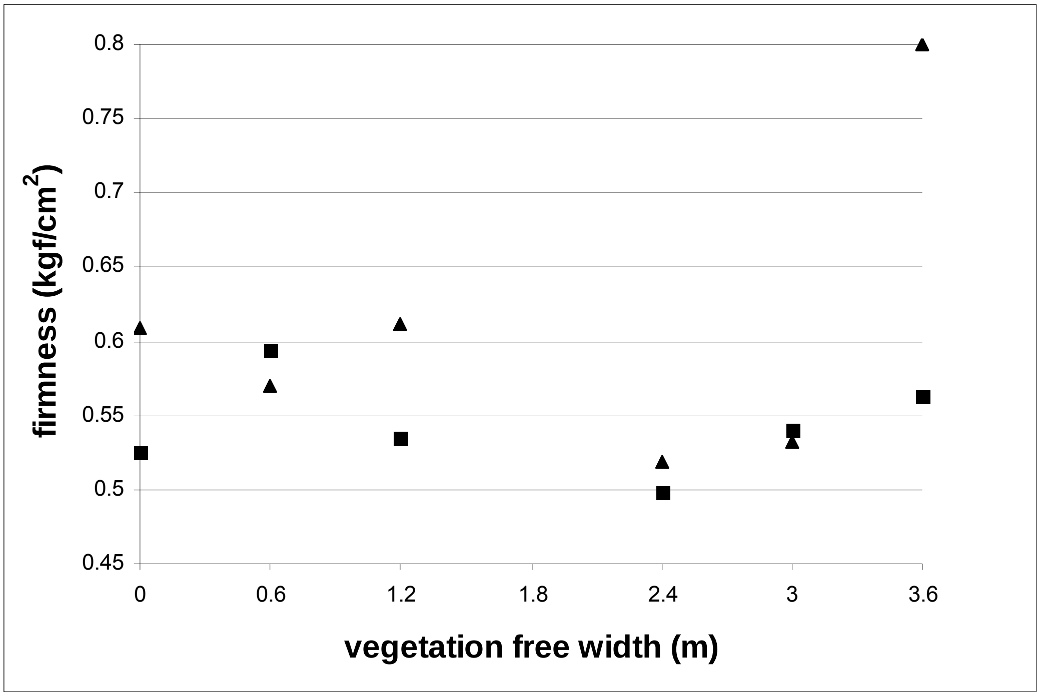
Appendix Table 4. Elemental amount (kg/ha) in vegetation by vegetation-free area (VFW) in irrigated (irr.) and nonirrigated (nonirr.) conditions, Jackson Springs, NC, 2007 and 2008.

VFW (m)	N		P		K		Ca		Mg	
	irr.	nonirr.	irr.	nonirr.	irr.	nonirr.	irr.	nonirr.	irr.	nonirr.
	kg/ha									
0	21.5	26.8	4.2	3.9	28.4	37.3	9.1	13.3	5.1	6.0
0.6	21.1	16.7	4.0	2.6	23.4	25.1	8.8	8.7	4.7	3.9
1.2	11.1	15.0	2.1	2.1	13.0	21.4	4.9	6.8	2.4	3.1
2.4	7.1	9.6	1.4	1.3	9.9	14.3	3.1	4.2	1.8	1.9
3.0	3.9	3.6	0.7	0.5	5.1	4.9	1.6	1.6	0.8	0.7
3.6	N/A									
LSD(0.05)[a]	7.8	10.8	1.9	1.5	10.4	17.2	3.2	5.2	2.2	2.4

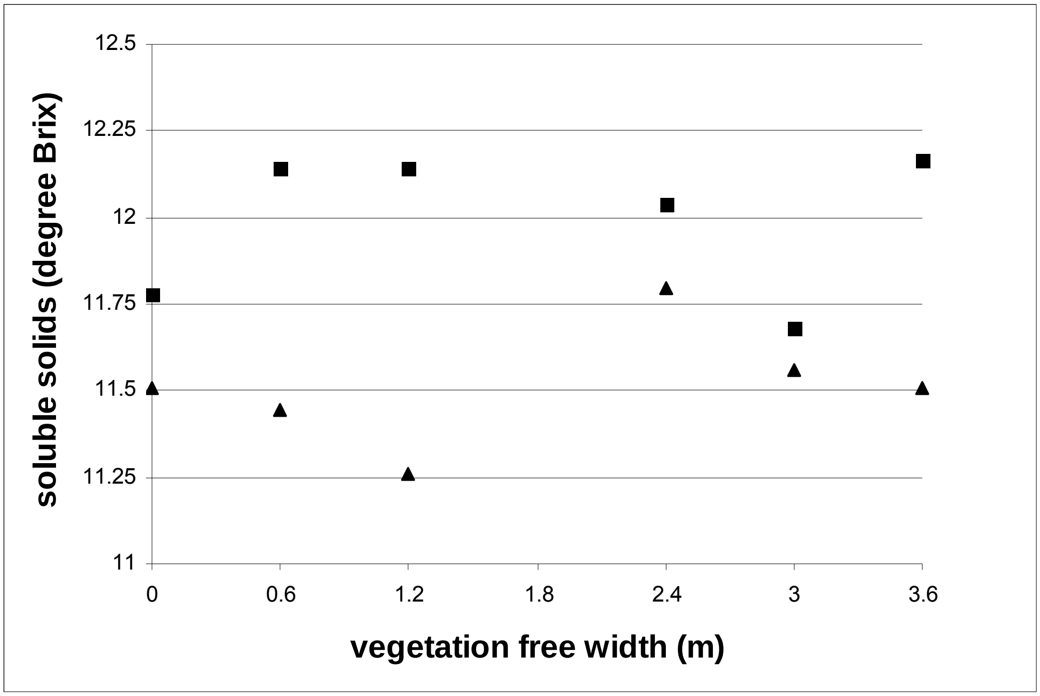
[a] Means within a column are different according to Fisher's Protected LSD at P = 0.05.



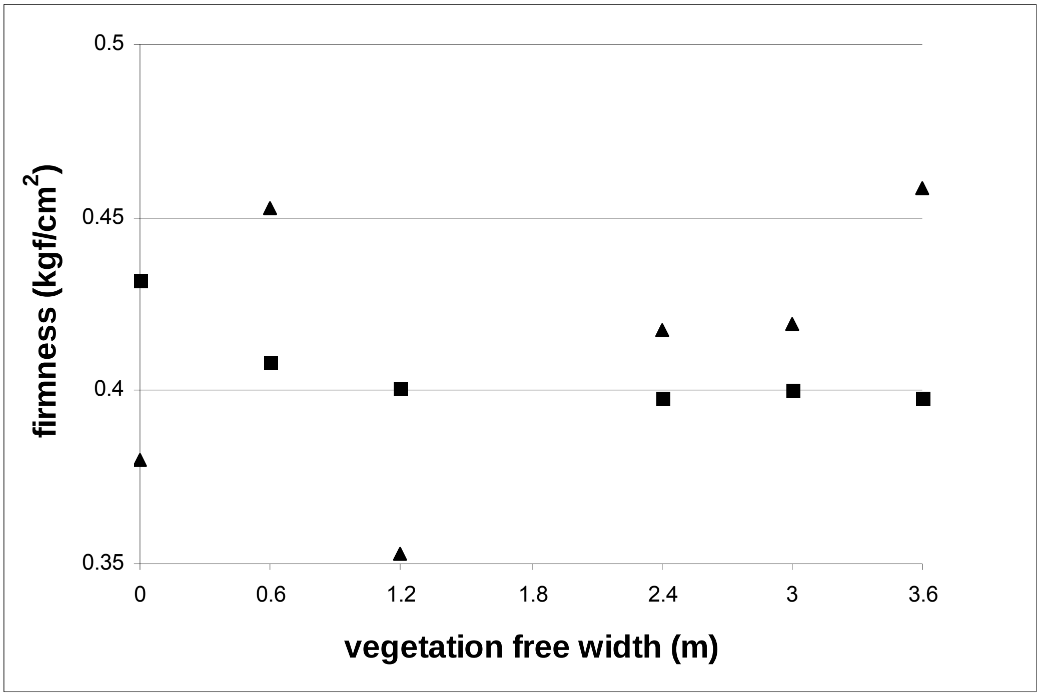
Appendix Figure 1. Effect of irrigation and vegetation - free width (VFW) on fruit soluble solids in fruit harvested July 24, 2008, Jackson Springs, NC.



Appendix Figure 2. Effect of irrigation and vegetation - free width (VFW) on fruit firmness of fruit harvested July 24, 2008, Jackson Springs, NC. (nonirrigated = ▲, irrigated = ■.)



Appendix Figure 3. Effect of irrigation and vegetation - free width (VFW) on fruit soluble solids in fruit harvested July 23, 2008, Clayton, NC. (nonirrigated =▲, irrigated = ■.)



Appendix Figure 4. Effect of irrigation and vegetation - free width (VFW) on fruit firmness of fruit harvested July 23, 2008, Clayton, NC. (nonirrigated =▲, irrigated = ■.)