EFFECTIVE NON-TRADITIONAL WEED CONTROL IN CONTAINER-GROWN NURSERY CROPS

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EFFECTIVE NON-TRADITIONAL WEED CONTROL IN CONTAINER-GROWN NURSERY CROPS

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EFFECTIVE NON-TRADITIONAL WEED CONTROL IN CONTAINER-GROWN

NURSERY CROPS

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Ben Mack Richardson, son of Jerry Mack Richardson and Alfa Jane Richardson and brother of Luke, Ruthann, Joy, Clay and Mark Richardson, was born on January 19, 1979 in Centre, Alabama. After graduating from Cherokee County High School in 1997, he attended Gadsden State Community College. From there he decided to attend Auburn University to pursue a degree in horticulture, which was the industry in which he had grown up, in his family's greenhouses, Dixie Green. He worked as an intern at Iseli Nursery in Boring, Oregon in 2001 and Chapel Valley Landscape Company in Baltimore, Maryland in 2002. He received a bachelor of science degree in horticulture in 2002.

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THESIS ABSTRACT

EFFECTIVE NON-TRADITIONAL WEED CONTROL IN CONTAINER-GROWN NURSERY CROPS

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A series of experiments were conducted to evaluate container nursery crop tolerance and oxalis control with postemergence applied diuron as influenced by timely overhead irrigation. Intent was to identify an interval between application and irrigation that may reduce crop injury without compromising oxalis control. Diuron was applied at a common rate of 1.0 lb ai/A to oxalis and two nursery crops (*Camellia sasanqua* 'Alabama Beauty' camellia, and *Rhododendron indicum* 'G.G. Gerbing', azalea). Treatments consisted of irrigation at 1, 2, 4, 8, 12, 24, or 48 hr after application. Oxalis control was equivalent whether treated plants were irrigated within either 1 hr or 48 hr after application. Camellia exhibited no visible injury regardless of treatment. Azaleas exhibited diuron-induced injury, however injury was reduced if plants were irrigated within 1 hr of diuron application. ^{14}C-diuron was used to determine the absorption rate of foliar-applied diuron into oxalis, camellia and azalea. Absorption by oxalis was relatively

rapid, and reached a maximum (~68% of applied) within 8 hr after application. Camellia and azalea absorbed a smaller percentage of the amount applied, and absorption was more protracted over time compared to oxalis. Azalea absorbed slightly more than camellia. Diuron has potential for use as an over-the-top application for postemergence oxalis control and timely irrigation has the potential to reduce injury to sensitive crops.

Another set of experiments were conducted to evaluate fresh pine bark nuggets for cool season weed control (oxalis and bittercress) in 11 and 27 L (3 and 7 gal) containers. In October 2004, gardenias were seeded with oxalis, and crapemyrtle with bittercress in 27 L (7 gal) containers. In March 2005, oakleaf hydrangeas were seeded with oxalis and ternstroemia with bittercress in 11 L (3 gal) containers. Treatments consisted of mulch applied at depths of 0, 3.8, and 7.62 cm (0, 1.5 and 3.0 in.), and seeded either before or after mulch application. A separate group of treatments were included similar to the above except that a granular preemergence herbicide was applied after mulch application. Growth of crapemyrtle and ternstroemia were similar regardless of mulch depth. With gardenia and oakleaf hydrangea growth differences existed but there was not a consistent trend with any of the treatments. Season long weed control was obtained in all treatments that included 7.62 cm (3 in.) mulch depth.

The final series of experiments evaluated fresh pine bark nuggets for warm season weed control (spurge and eclipta) in 27 L (7 gal) containers. In 2004 lilac chaste tree were seeded with spurge and dwarf burford holly were seeded with eclipta. In 2005, natchez crapemyrtle were seeded with spurge and willowleaf cotoneaster were seeded with eclipta. Treatments consisted of mulch applied at depths of 0, 3.8, and 7.6 cm (0, 1.5, 3.0 in.), and seeded either before or after mulch application. A separate group of treatments were included similar to the above except that a granular preemergence herbicide, flumioxazin (Broadstar 0.25G) (Valent. Walnut Creek, CA) was applied at 0.40 kg ai/ha (0.375 lb aia or 150 lb product/A) after mulch application. Growth of all species was similar except dwarf burford and cotoneaster where non- mulch treatments were slightly smaller. Season long weed control was obtained in all treatments that included mulch at 7.6 cm (3 in.) depth.

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CHAPTER I

INTRODUCTION AND LITERATURE REVIEW

As man began to cultivate land to produce crops, undesirable plants began to grow among the crops which would reduce growth and yield. In modern times, those noxious plants became to be known as "weeds". Weeds are considered to be plants that are not valued where they are growing and tend to compete with desirable plant species. Originally, weed control was obtained by mechanical means but early in the 1900's chemical controls became available.

Postermergence Oxalis Control with Diuron: Minimizing Crop Injury with Timely Irrigation

Herbicides were developed making weed control more effective and more efficient. These chemicals were proficient at killing weeds; however the crops were also susceptible to being injured. Herbicides were discovered and developed to control only specific weed species, making it possible to apply herbicides directly onto crops with little risk of crop injury while still providing excellent weed control. Other herbicides were discovered and developed which controlled only monocots while others would only control broadleaf species. These were considered 'selective' herbicides. Introduced in 1945, one of the first selective herbicides was 2,4-D which was used to control broadleaf weeds which were growing amongst grasses (32, 41). This introduction prompted chemical companies to develop both postemergence and preemergence chemicals for selective weed control. Generally, postemergence herbicides were applied to the shoots of weeds and foliar absorbed. Preemergence herbicides were typically applied to soil or substrate surface forming a chemical barrier. Most often, preemergence herbicides have low solubility and reside in the soil for months where they are taken up by roots or young expanding shoots of seedling weeds.

In the past, agronomic, forestry and railway industries were the predominant users of herbicides, therefore herbicide research primarily focused on those industries. In recent years nursery production has increased and the ideal growing conditions provide by nurseries are very conducive to weed infestations. Weeds thrive within the high moisture and nutrient rich environment associated with nurseries, leading to an increased use and need for herbicides (1, 19). With such an increase in nursery operations and increased demand for herbicides that can be used on nursery crops, chemical companies are now marketing to nursery growers, as well.

Weeds in nurseries not only reduce growth of nursery crops (9, 18) but reduce sales because of customer demand for weed free plants. Preemergence herbicides and hand weeding are the two primary methods of weed control in container nursery crops (21). Dinitroanilines (DNA's) (prodiamine, oryzalin, pendimethalin), diphenyl ether (oxyfluorfen) and oxadiazon are some of the most effective herbicides for production of container grown nursery crops due to there long half-life and low solubility (20). Most growers use a combination of chemicals with different modes of action, therefore controlling several weed species with one application (5). In nursery production systems preemergence herbicides are typically applied every three to four months and provide excellent control (20, 27). During winter months, mid December through early March in Alabama, crops are covered with over-wintering material or placed in an over-wintering cold frame structure with plastic sheeting over the top. Herbicides can not be applied when crops are covered for over-wintering because of concerns of crop injury due to the volatility of most commonly used preemergence herbicides. Therefore, during over-wintering, preemergence herbicides have typically lost effectiveness due to dissipation and decomposition of the chemical barrier (21). This can also be a problem in summer when spring applied preemergence begin to loose control, making it important to monitor weeds and reapply herbicide before weeds begin to germinate or infestations could occur (36). Even the best preemergence herbicide programs generally do not provide complete control and supplemental hand weeding is usually required (24). Due to increasing labor costs growers are seeking alternatives to hand weeding (21). Postemergence-active herbicides applied “over-the top” of container-grown nursery crops would provide a labor-saving option.

Traditionally, growers would accept this type of application only if it provided broad-spectrum weed control combined with no crop injury. Many herbicides used successfully in agronomic crops are not suitable for nursery crops due to excessive crop injury however tolerance is species dependent (3, 7) Due to increased labor costs, many growers are now willing to accept some crop injury provided it is limited to the early portion of the crop cycle and the crop rapidly recovers. The ability of postemergence-applied herbicides to control a single weed species with minimal nursery crop injury has been previously demonstrated in recent studies. Sulfentrazone was used to successfully control nutsedge and several other broadleaf weed species (12). Liriope, daylily, fraxinus, euonymus and crataegus were all treated with sulfentrazone at recommended rate. Fraxinus, euonymus and crataegus were very tolerant while liriope and daylily were severely injuried. Image (imazaquin) was shown to provide excellent nutsedge control while injuring only a few crop species (36,37). Isoxaben (Gallery 75DF), which is typically used as a preemergence herbicide, has been shown to effectively control bittercress (*Cadamine hirsuta*) when applied postemergence with no crop injury (3,4). Altland *et al.* reported an interaction between bittercress size and rate of isoxaben applied, 1.12 kg ai/ha (1.0 lb ai/A) provided excellent control of small non-flowering bittercress. However, 2.24 kg ai/ha (2.0 lb ai/A) was required to control large, flowering bittercress. This study is in compliance with other work showing weeds are generally easier to control when small and non-flowering (14) making it important to apply herbicide as soon as weeds begin to emerge to avoid multiple applications.

Oxalis is a cool-season perennial weed common in the southeast and has been identified as being difficult to control by many growers (21). Due to the ideal growing conditions provided in container nursery production systems, oxalis can be a problem year round (13). Recent studies demonstrated that postemergence-applied diuron (Direx 4L) provided excellent control of oxalis. Simpson *et al*. (30) applied diuron without a surfactant at rates ranging from 0.14 to 1.12 kg ai/ha (0.125 to 1.0 lb ai/A) to container grown: camellia (*Camellia japonica* 'Pink Icicle'), liriope (*Liriope muscari* 'Big Blue') and spirea (*Spiraea* x *bumalda* 'Anthony Waterer'). Diuron caused no more than slight injury, while providing at least 74% oxalis control. In subsequent studies, diuron (surfactant added) was applied to three different sizes of oxalis, i.e. small 3 to 9 cm (1.2-3.5 in) tall, medium (13 to 15 cm 5.1-5.9 in) tall, and large 20 to 30 cm (7.9-11.8 in) tall.

Control was at least 90% regardless of oxalis size with rates of $\geq$ 0.56 kg/ha (0.5 lb ai/A). Ahrens *et al.* and Barolli *et al.* (2,8) applied several commomly used herbicides and various combinations at various rates and diuron at 0.28, 0.56, 1.12 kg ai/ ha (0.25,0.5,1.0 lb ai/ A) to the following crops while actively growing: Japanese painted fern (*Athyrium niponicum* 'Pictum'), creeping juniper (*Juniperus horizontalis* 'Wiltoni'), azalea (*Rhododendron* 'Stewartstonian'), bigleaf hydrangea (*Hydrangea macrophylla* 'Merritts Supreme'), pee gee hydrangea (*Hydrangea paniculata* 'Grandiflora'), bog rosemary (*Andromeda polifolia*), dwarf burning bush (*Euonymus alatus* 'Compactus') and clematis (*Clematis* x *jackmanii*). These researchers noted that overhead irrigation soon after application tended to reduce any diuron-induced crop injury and diuron caused the least injury of all herbicide treatments. This led to our hypothesis that a timely irrigation shortly after application may improve crop tolerance without compromising oxalis control.

Specific objectives of this research were to first determine the ideal time interval between diuron application and irrigation that meet the combined criteria of reducing diuron-induced injury on a sensitive species without compromising oxalis control. A second objective was to monitor the foliar sorption of diuron into oxalis and selected nursery crops using radiotracer techniques (15, 33, 39, 40). Intent was to discover if differential rates of sorption between the target weed and the landscape crop would enhance the potential for weed-crop selectivity through timely irrigation.

Pine Bark Mini-nuggets as Weed Control in Container Nursery Crops

In other studies, a non-chemical alternative for weed control was investigated. Increasing demand for large plant material in the landscape has led to many growers producing more nursery crops in larger containers from 26.5 L to 2271 L (7 gallon to 600 gallon); however weed control practices differ from that used in smaller containers. Hand weeding is an option but increasingly expensive due to increasing labor costs (21, 24). Increased spacing between large containers renders preemergence herbicides inefficient and environmentally unsafe due to excessive non-target loss. Studies conducted by Porter and Parish (29) showed 12% and 23% non-target loss on 4 L containers in hexagonal pot-to-pot configuration and square pot-to-pot configuration, respectively. Gilliam *et al.* (18) reported that when granular preemergence herbicides were applied to 2.8 L container when spaced 8 to 20 cm on center nontarget losses ranged from 51 to 80% per application and nurseries typically make 3 to 5 applications annually.

Oxyfluorfen and oxadiazon are two commonly used preemergence herbicides that are very stable in the upper layer of the substrate surface, with limited risk of leaching (23, 26, 34, 35). However, due to the fact that most nurseries apply 1.3 to 1.8 cm (0.5 to 0.7 in.) overhead irrigation daily (16) herbicides that are not in the container could be transported by irrigation runoff and contaminate surface water. Excessive herbicides in runoff water are environmentally unsafe and could cause crop injury if water is recycled from run-off collection ponds and reapplied to crops through irrigation.

Mulches provide an alternative for weed control in large containers, reducing risk of herbicide contamination to the environment. However, mulches can be expensive, mainly due to the labor associated with applying the mulch to individual containers.

Therefore, products used for mulch must be very inexpensive to reduce grower production costs. Products that would normally be sent to a landfill such as newspaper and waste tires would be excellent material to use as mulch while reducing waste in the landfill (28). Smith *et al*. (31) reported that newspaper pellets at 5cm depth controlled spurge in the landscape for at least 60 days. However wastepaper has been shown to reduce available nitrogen when applied to container surface as mulch (22). Ground rubber tires were used in a separate field study and provide good initial control but weeds gradually began to penetrate the barrier at about 2 months after mulch application (10). Fabric disk have also been used as weed control with limited success due to voids around the edge or along the seam of the disk (6). There were also problems with wind blowing the disks from the container. Shredded tires, recycled newspaper, pole shavings, and kenaf mulch have been evaluated for weed control in large containers (17). Shredded tires and recycled newspaper provided good control but availability and acceptability by customers are limiting factors for use as mulches.

Pine bark mini-nuggets may provide a non-chemical mulch option for growers. Case and Mathers (11) reported good long term weed control in containers with applications of douglas fir and pine bark nuggets in combination with acetochlor at 3.36 kg ai/A (2.5 lbs ai/A), flumioxazin 0.28 kg ai/A (0.25 lb ai/A), or oryzalin at 2.24 kg ai/A (2.0 lbs ai/A) application in containers. Oryzalin and flumioxazin provided no long term control when applied alone, however the pine nuggets provided good control while the douglas fir bark provided the best control. Shredded pine bark and pine bark mini-nugget mulch has provided good weed control in the landscape and is generally accepted by costumers (25). Pine bark is readily available and could be mechanized at potting. Also, hydrophobic properties and low fertility of fresh pine bark mini-nuggets are not conducive for weed establishment. The objective of this study was to evaluate fresh pine bark mini nuggets for long term weed control in large container nursery crops.

Literature Cited

1. Ahrens, J.F. 1966. Trials with dichlobenil and diphenamid for controlling weeds in container nursery stock. Proc. North East Weed Contr. Conf. 20:232-236.

2. Ahrens, J.F., S. Barolli, and R. Gray. 2003. Evaluation of spray-able herbicides for container grown ornamentals. Proc. Northeastern Weed Sci. Soc. 57:36.

3. Altland, J.E., C.H. Gilliam, J.W. Olive, J.H. Edwards, G.J. Keever, J.R. Kessler, and D.J. Eakes. 2000a. Postemergence control of bittercress. J. Environ. Hort.18:23-28.

4. Altland, J.E., C.H. Gilliam, J.W. Olive, J.H. Edwards, G.J. Keever, J.R. Kessler, and D.J. Eakes. 2000b. Effect of bittercress size and gallery rate on postemergence bittercress control. J. Environ. Hort. 18:128-132.

5. Anderson, W.P. 1996. Weed Science: Principles and Applications 3rd Ed. West Pub. Co. St. Paul, MN.

6. Appleton, B.L. and J.F. Derr. 1990. Use of geotextile disks for container weed control. HortScience 25:666-668.

7. Bachman, G., C. Wilson, and T. Whitwell. 1995. Tolerance of containerized plants to the postemergence herbicides, stinger, manage and basagran. J. Environ. Hort. 13:129-132.

8. Barolli, S., J.F. Ahrens, and R. Gray. 2003. Improved methods of applying herbicides in container-grown ornamentals. Proc. Northeastern Weed Sci. Soc. 57:45.

9. Berchielli-Robertson, D.L., C.H. Gilliam, and D.C. Fare. 1990. Competitive effects of weeds on the growth of container-grown plants. Hortscience 25:77-79.

10. Calkins, J.B., B.T. Swanson, and D.L. Newman. 1996. Weed control strategies for field grown herbaceous perennials. J. Environ. Hort. 14:221-227.

11. Case, L.T., H.M. Mathers. 2003. Long term effects of herbicide treated mulches for ornamental weed control. Proc. Northeast. Weed Sc. Soc. 57:118-121.

12. Collins, K.B., R.E. McNiel, and L.A. Weston. 2001. Evaluation of sulfentrazon for weed control and phytotoxicity in field-grown landscape plants. J. Environ. Hort. 19:189-194.

13. Cross, G.B. and W.A. Skroch. 1992. Quantification of weed seed contamination and weed development in container nurseries. J. Environ Hort. 10:159-161.

14. Edmund, R.M., and A.C. York. 1987. Factors affecting postemergence control of sicklepod (*Cassia obtusifolia*) with imazaquin and DPX-F6025: spray volume, growth stage and soil applied alachlor and vernolate. Weed Sci. 35:216-223.

15. Faircloth, W.H., C.D. Monks, M.G. Patterson, G.R. Wehtje. D.P. Delaney, and J.C. Sanders. 2004. Cotton and weed response to glyphosate applied with sulfur –containing additives. Weed Technol. 18:404-411.

16. Fare, D.C., C.H. Gilliam, and G.J. Keever. 1992. Monitoring irrigation at container nurseries. Hort Technol. 2:75-78.

17. File, S., P. Knight, D. Reynolds, C.H. Gilliam, J. Edwards, and R. Harkess. 1999. Alternative weed control options for large container production. SNA 44:501-504.

18. Fretz, T.A. 1972. Weed compition in container grown Japanese holly. HortScience 7:485-486.

19. Fretz, T.A. 1974. Evaluation of experimental herbicides on container-grown nursery stock. Res. Sum. Ohio. Ag. Res. And Dev. Cent. 79:29-32.

20. Gallatino, L.B. and W.A. Skorch. 1993. Herbicide efficacy for production of container ornamentals. Weed Technol. 7:103-107.

21. Gilliam, C.H., W.J. Foster, J.L. Adrain, and R.L. Shumack. 1990. A survey of weed control costs and strategies in container production nurseries. J. Environ. Hort. 8:133-135.

22. Glenn, J.S., C.H. Gilliam, J.H. Edwards, G.J. Keever and P.R. Knight. 2000.Recycled waste paper mulch reduces available container N. J. Environ. Hort. 18:188-191.

23. Horowitz, M. and C.L. Elmore. 1991. Leaching of oxyfluofen in container media. Weed Technol. 5:175-180.

24. Judge, C.A., J.C. Neal, and J.B. Weber. 2004. Dose and concentration responses of common nursery weeds to Gallery, Surflan and Treflan. J. Environ. Hort. 22:106-112.

25. Llewellyn, J., K. Osborne, C. Steer-George, J. West. 2003. Commercially available organic mulches as a weed barrier for container production. Comp. Proc. Intl. Plant Prop. Soc. 53:590-593.

26. Moles, A. and C.E. Whitcomb. 1976. Movement of ronstar in containers as influenced by growing media. Proc. SNA Res. Conf. 21:137.

27. Norcini, J.C., and J.H. Aldrich. 1992. Spotted spurge control and phytotoxicity to daylily from preemergence herbicides. J. Environ. Hort. 10:14-17.

28. Pellet, N.E. and D.A. Heleba. 1995. Chopped newspaper for weed control in nursery crops. J. Environ. Hort. 13:77-81.

29. Porter, W.C. and R.L. Parish. 1993. Nontarget losses of granular herbicide applied to container-grown landscape plants. J. Environ. Hort. 11:143-146.

30. Simpson, C.V., C.H. Gilliam, J.E. Altland, G.R. Wehtje, and J.L. Sibley. 2004. Postemergence *Oxalis* control in container-grown plants. J. Environ. Hort. 22:45-49.

31. Smith, D.R., C.H. Gilliam, J.H. Edwards, D.J. Eakes, and J.D. Williams. 1997. Recycled waste paper as a landscape mulch. J. Environ. Hort. 15:191-196.

32. Timmons, F.L. 1969. A history of weed control in the United States and Canada. Weed Sci. 14:294-307.

33. Wang, C.H., D.L. Willis, and W.D. Loveland. 1975. Radiotracer methodology in the biological environmental and physical sciences. Prentice-Hall Inc. Englewood Cliff, NJ.

34. Wehtje, G.R., C.H. Gilliam, and B.F. Hajek. 1993. Adsorption, desorption, and leaching of oxadiazon in container media and soil. HortScience. 28:126-128.

35. Wehtje, G.R., C.H. Gilliam, and B.F. Hajek. 1994. Adsorption, desorption and leaching of oryzalin in container media and soil. HortScience. 29:824.

36. Wilcut, J.W., C.H. Gilliam, G.R. Wehtje, and D.C. Fare. 1989. Grass control in container grown ornamentals with pre- and postemergence herbicide combinations. HortScience 24:456-459.

37. Wilcut, J.W., C.H. Gilliam, G.R. Wehtje, and D.C. Fare. 1991. Yellow nutsedge control in landscape plants. HortScience 26:159-162.

39. Williams W., G. R. Wehtje, and R. H. Walker. 2003. CGA-363622: Soil behavior and foliar versus root absorption by torpedograss. Weed Technol. 17:366-372.

40. Williams W., G. R. Wehtje, and R. H. Walker. 2004. Quinclorac: Soil behavior and foliar versus root absorption by torpedograss. Weed Technol. 18:404-411.

41. Zimdahl, R.L. 1983. Weed science- a brief historical perspective. Weed Today. 14:10-11.

CHAPTER II

POSTEMERGENCE OXALIS CONTROL WITH DIURON: MINIMIZING CROP INJURY WITH TIMRLY IRRIGATION

Abstract

Experiments were conducted to evaluate container nursery crop tolerance and oxalis control with postemergence applied diuron as influenced by timely overhead irrigation. Intent was to identify an interval between application and irrigation that may reduce crop injury without compromising oxalis control. Diuron was applied at a common rate of 1.0 lb ai/A to oxalis and two nursery crops (*Camellia sasanqua* 'Alabama Beauty' camellia, and *Rhododendron indicum* 'G.G. Gerbing', azalea). Treatments consisted of irrigation at 1, 2, 4, 8, 12, 24, or 48 hr after application. Oxalis control was equivalent whether treated plants were irrigated within either 1 hr or 48 hr after application. Camellia exhibited no visible injury regardless of treatment. Azaleas exhibited diuron-induced injury, however injury was reduced if plants were irrigated within 1 hr of diuron application. ^{14}C-diuron was used to determine the absorption rate of foliar-applied diuron into oxalis, camellia and azalea. Absorption by oxalis was relatively rapid, and reached a maximum (~68% of applied) within 8 hr after application. Camellia and azalea absorbed a smaller percentage of the amount applied, and absorption was more protracted over time compared to oxalis. Azalea absorbed slightly more than

camellia. Diuron has potential for use as an over-the-top application for postemergence oxalis control and timely irrigation has the potential to reduce injury to sensitive crops.

Index Words: *Oxalis stricta*, Direx, herbicide, weed control, container production, nursery crops.

Herbicide used in this study: Direx 4L (diuron), 3-(3, 4-dichlorophenyl)-1, 1-dimethyl urea.

Species used in this study: Camellia (*Camellia sasanqua* 'Alabama Beauty') azalea (*Rhododendron indicum* 'G.G. Gerbing'); and yellow woodsorrel (*Oxalis stricta* L.)

Significance to the Nursery Industry

Postemergence weed control in container grown nursery crops is becoming increasingly important to producers due largely to increasing labor costs. Oxalis or yellow wood sorrel (*Oxalis stricta* L.) is a serious problem in many regions of the United States, especially with container grown crops emerging from winter protection. Previous research has shown that diuron has the potential to control oxalis when applied postemergence over-the-top to dormant camellia (*Camellia japonica* 'Pink Icicle'), liriope (*Liriope muscari* 'Big Blue') and spirea (*Spiraea* x *bumalda* 'Anthony Waterer'). However in some cases slight crop injury resulted from the application of diuron, and injury was more severe with actively growing crops. This research indicated that irrigation at 1 hr after diuron application reduced diuron–induced injury without compromising oxalis control.

Introduction

Preemergence herbicides and hand weeding are the two primary methods of weed control in container nursery crops (7). However, supplemental hand weeding is usually required because preemergence herbicide programs generally do not provide complete control (8). Due to increasing labor costs growers are seeking alternatives to hand weeding. Postemergence-active herbicides applied "over-the top" of container-grown nursery crops would provide a labor-saving option. Traditionally, growers would accept this type of application only if it provided broad-spectrum weed control combined with no crop injury. Due to economic considerations, many growers are now willing to accept some injury provided it is limited to the early portion of the crop cycle and the crop rapidly grows past the injury. The ability of postemergence-applied herbicides to control a single weed species with minimal landscape crop injury has been previously demonstrated. Recent studies have shown isoxaben (Gallery 75DF), which is typically used as a preemergence herbicide, effectively controlled bittercress (*Cadamine hirsuta*) when applied postemergence (1,2).

Oxalis is a cool-season perennial weed common in the southeast and has been identified as being difficult to control by many growers (7). Due to the ideal growing conditions provided in container nursery production systems, oxalis can be a problem year round (5). Recent studies demonstrated that postemergence-applied diuron (Direx 4L) provided excellent control of oxalis. Simpson *et al*. (9) applied diuron without a surfactant at rates ranging from 0.14 to 1.12 kg ai/ha (0.125 to 1.0 lb ai/A) to container grown: camellia (*Camellia japonica* 'Pink Icicle'), liriope (*Liriope muscari* 'Big Blue') and spirea (*Spiraea* x *bumalda* 'Anthony Waterer'). Diuron caused no more than slight injury, while providing at least 74% oxalis control. In subsequent studies, diuron (surfactant added) was applied to three different sizes of oxalis, i.e. small 3 to 9 cm (1.2 to 3.5 in) tall, medium 13 to 15 cm (5.1 to 5.9 in) tall, and large 20 to 30 cm (7.9 to 11.8 in) tall. Control was at least 90% regardless of oxalis size with rates of $\geq$ 0.56 kg/ha (0.5 lb ai/A). Ahrens *et al.* and Barolli *et al.* (3,4) applied diuron to the following crops while actively growing: Japanese painted fern (*Athyrium niponicum* 'Pictum'), creeping juniper (*Juniperus horizontalis* 'Wiltoni'), azalea (*Rhododendron* 'Stewartstonian'), bigleaf hydrangea (*Hydrangea macrophylla* 'Merritts Supreme'), pee gee hydrangea (*Hydrangea paniculata* 'Grandiflora'), bog rosemary (*Andromeda polifolia*), dwarf burning bush (*Euonymus alatus* 'Compactus') and clematis (*Clematis* x *jackmanii*). These researchers noted that overhead irrigation soon after application tended to reduce any diuron-induced crop injury. This led to the hypothesis that a timely irrigation shortly after application may improve crop tolerance without compromising oxalis control.

Specific objectives of this research were to first determine the ideal time interval between diuron application and irrigation that meet the combined criteria of reducing diuron-induced injury on a sensitive species without compromising oxalis control. A second objective was to monitor the foliar sorption of diuron into oxalis and selected landscape crops using radiotracer techniques. Intent was to discover if differential rates of sorption between the target weed and the landscape crop would collaborate the potential for enhanced weed-crop selectivity through timely irrigation.

Materials and Methods

All experiments were conducted at the Paterson greenhouse complex of Auburn University, Department of Horticulture. Oxalis seed were sown in January of 2004 in 7.6

cm (3 in.) containers and thinned to one uniform-sized oxalis per container. The medium used was a 6:1(v:v) pine bark: sand amended per m^3 (yd^3) with 2.9 kg (5 lb) of dolimitic lime, 8.3 kg (14 lb) of Polyon 17N-2.2P-9.13K (Polyon 17-5-11, Pursell Technologies, Sylacauga, AL) and 0.9 kg (1.5 lb) of Micromax (The Scotts Co.). At time of treatment, approximately five weeks after seeding, oxalis plants were 8-12 cm (3.1-4.7 in.) wide and 4-6 cm (1.6-2.4 in.) tall. Diuron was applied at 1.12 kg ai/ha (1.0 lb ai/A) using Direx 4L. Agridex (Bayer CropScience), a non ionic surfactant, was included at 0.25% v:v. Treatments were applied using an enclosed-cabinet, track sprayer (DeVries Manufacturing, Hollandale, MN), equipped with a single 11002 spray tip, and was calibrated to deliver 284 L/ha (30 gal/A). Treatment application was at 7:00 A.M. Immediately after application all plants were transported to a double layer polyethylene greenhouse.

Diruon-treated plants were subsequently irrigated at 1, 2, 4, 8, 12, 24, or 48 hr after application. Irrigation was 0.64 cm (0.25 in), and was accomplished with an overhead impact sprinkler (Rain Bird 2045PJ, Rain Bird Corp., Azusa, CA). Each treatment-irrigation time interval was assigned to 7 single pot replicates. Subsequent to all irrigation treatments, plants were arranged in a completely randomized experimental design. Visual ratings on percent injury were taken at 14, 21 and 28 days after treatment (DAT) on a scale of 0 to 100 where 0 = no injury and 100 = dead plants. At 28 DAT shoot fresh and dry weights were taken for oxalis. This experiment was conducted three times in 2004 with initiation dates of February 23, March 19 and April 6 respectively. There were no differences among experimental repetitions, consequently data were pooled across all three repetitions for further analysis and presentation.

Two container grown nursery crops: *Rhododendron indicum* ‘G.G. Gerbing’ and *Camellia sasanqua* ‘Alabama Beauty’ were used to evaluate crop injury. Azaleas were in 7.6 cm (3 in.) pots and camellias in 10.2 cm (4 in.) pots at time of treatment. Diuron rate, spray volume and irrigation intervals were identical to that previously described for oxalis. Treatments were replicated 7 and 6 times for azalea and camellia, respectively. Visual ratings were taken at 14, 21, 28, and 120 DAT on a scale of 0 to 100 where 0 = no injury and 100 = dead plants. Azaleas were transplanted into 2.8 liter (trade gallon) containers and camellias were transplanted into #1 (1 gallon) containers at 28 DAT. Growth indices were taken for both species at 120 and 240 DAT. Azalea and camellia studies were conducted twice with treatment initiation dates of March 19 and April 6 respectively. Results were consistent among dates; consequently data were pooled for further analysis and presentation.

Plants identical to ones used in the previously-described irrigation timing study were used in a foliar absorption study. Procedures for determining herbicide foliar sorption using radiotracer techniques have been described in more detail elsewhere (6,11,12). This experiment was conducted concomitantly with 2nd and 3rd repetitions of the irrigation timing study, and included oxalis, azalea and camellia. A 0.5-ml (0.017 oz) sub-sample of the spray suspension as previously-described was retained and supplemented with ^{14}C-diuron so that the final concentration of diuron and radioactivity was 3,000 mg/L and 0.2 MBq/2 μl, respectively. Single 2 μl, drops of this ^{14}C-diuron suspension was applied to the target plants, i.e. oxalis, azalea and camellia using a micro applicator. For oxalis, a recently-formed, but fully-expanded leaf was selected. Droplets were applied to the middle leaflet of the selected leaf. For azalea and camellia, mature leaves were selected that were full sized and had been produced during the previously-season's growth. Droplets were applied to the center of the selected leaf, but not on the midvein. For all species, experimental units consisted of individual plants.

Plants treated with ^{14}C-diuron were harvested at the same schedule as used in the previously-described timed irrigation study, i.e. either 1, 2, 4, 8, 12, 24, or 48 hr after treatment. For oxalis, the treated leaflet was removed from the plant and placed into a 20-ml (0.68 oz) scintillation vial which contained 1 ml (0.034 oz) of a water/methanol solution [50:50 (v/v)]. Vial was then agitated with a swirling motion for 30 sec to remove any unabsorbed diuron. After removing the leaflet, 10 ml (0.34 oz) of scintillation fluid was added into the vial in preparation for counting. Treated leaflet was retained, dried at 45° C (113° F) for 24 hr, combusted at 358° C (900° F) in a biological tissue oxidizer, and recovered radioactivity quantified through scintillation spectrometry (10). For each experimental unit, radioactivity from both the wash and the combusted tissue were summed, the portion recovered in the tissue was then expressed as a percentage of this total, which represented the amount of adsorption.

For azalea and camellia, a 1-cm (0.39 in) cork borer was used to remove the site to which the herbicide droplet had been placed. These disks of leaf tissue were treated in a manner identical to that previously described for the treated oxalis leaflet. A completely random design with 6 single-plant replicates for each harvest time was used. The experiment was repeated. Data were subjected to ANOVA using the general linear model procedure in SAS.

Results and Discussion

Oxalis control at 14 DAT was not influenced by any irrigation treatment. Irrigating within 1hr of treatment resulted in similar control to waiting 48 hr after diuron application (Table 1). Oxalis control tended to increase thru 28 DAT, but irrigation timing had no effect on oxalis control. Shoot fresh and dry weights followed similar trends. Overall level of oxalis control observed was lower than that previously reported by Simpson *et al*. (9). Control in their study ranged from 95 to 98% control at 21 DAT while control in this study ranged from 61 to 75% at 21 DAT. A partial explanation may be surfactant efficacy. Surfactant rate was the same for both studies; however, Simpson *et al*. used X-77 while Agridex was used in this study.

Camellia tolerance to diuron was excellent with no visible injury at any time in the study. This is in contrast with previous reports of slight initial diuron injury when applied to ‘Pink Icicle’ camellia; however, plants had completely outgrown injury symptoms by 60 DAT (9). G. G. Gerbing azaleas were actively growing at time of diuron application and were more sensitive to diuron. Injury occurred with all treatments however irrigation 1 hr after diuron application reduced injury 10 to 15 % compared to irrigation 2 hr after diuron application (Table 2). There were no differences in azalea injury at 14, 21 or 28 DAT when irrigated from 8 to 48 hr after diuron application. Similarly there were no differences in azalea injury rating when irrigated 2 to 4 hr after diuron application. No visible injury was evident at 120 DAT. Azalea growth at 120 DAT was similar among the non-treated control and plants that were irrigated 1, 2, 24, and 48 hr after diuron application. At 240 DAT all azaleas had similar growth except those irrigated 24 hr after diuron application, which were slightly smaller. With camellia all plants were similar in size or larger than the non-treated control plants at both 120 and 240 DAT.

The ^{14}C-diuron study revealed that diuron was rapidly absorbed by oxalis reaching near maximum of 68 % at 8 hr after application (Figure 1). Within 1 hr of application, about 35% of the applied diuron had been absorbed. In contrast, foliar absorption was much slower in the landscape plants, and the maximum amount absorbed was less compared to oxalis. Azalea and camellia absorbed only 8% and 5% of the amount applied, respectively. Azalea absorption was slightly greater than camellia. Oxalis, azalea and camellia reached maximum absorption at 48 hr after diuron application with 70, 48 and 32 % absorbed, respectively.

These data show postemergence oxalis control is obtained with irrigation 1 hr after diuron application due to rapid absorption. Azalea injury is likely reduced by irrigation due to slow foliar uptake; therefore, a timely irrigation could remove unabsorbed diuron thus reducing additional absorption. Additional research is needed to evaluate tolerance of diuron and timing of application to nursery crops.

Literature Cited

1. Altland, J.E., C.H. Gilliam, J.W. Olive, J.H. Edwards, G.J. Keever, J.R. Kessler, and D.J. Eakes. 2000. Postemergence control of bittercress. J. Environ. Hort.18:23-28.
2. Altland, J.E., C.H. Gilliam, J.W. Olive, J.H. Edwards, G.J. Keever, J.R. Kessler, and D.J. Eakes. 2000. Effect of bittercress size and gallery rate on postemergence bittercress control. J. Environ. Hort. 18:128-132.
3. Ahrens, J.F., S. Barolli, and R. Gray. 2003. Evaluation of spray-able herbicides for container grown ornamentals. Proc. Northeastern Weed Sci. Soc. 57:36.
4. Barolli, S., J.F. Ahrens, and R. Gray. 2003. Improved methods of applying herbicides in container-grown ornamentals. Proc. Northeastern Weed Sci. Soc. 57:45.
5. Cross, G.B. and W.A. Skroch. 1992. Quantification of weed seed contamination and weed development in container nurseries. J. Environ Hort. 10:159-161.
6. Faircloth, W.H., C.D. Monks, M.G. Patterson, G.R. Wehtje. D.P. Delaney, and J.C. Sanders. 2004. Cotton and weed response to glyphosate applied with sulfur –containing additives. Weed Technol. 18:404-411.
7. Gilliam, C.H., W.J. Foster, J.L. Adrain, and R.L. Shumack. 1990. A survey of weed control costs and strategies in container production nurseries. J. Environ. Hort. 8:133-135.
8. Judge, C.A., J.C. Neal, and J.B. Weber. 2004. Dose and concentration responses of common nursery weeds to Gallery, Surflan and Treflan. J. Environ. Hort. 22:106-112.

9. Simpson, C.V., C.H. Gilliam, J.E. Altland, G.R. Wehtje, and J.L. Sibley. 2004. Postemergence *Oxalis* control in container-grown plants. J. Environ. Hort. 22:45-49.

10. Wang, C.H., D.L. Willis, and W.D. Loveland. 1975. Radiotracer Methodology in the Biological Environmental and Physical Sciences. Prentice-Hall Inc. Englewood Cliff, NJ.

11. W. Williams, G. R. Wehtje, and R. H. Walker. 2003. CGA-363622: Soil behavior and foliar versus root absorption by torpedograss. Weed Technol. 17:366-372.

12. W. Williams, G. R. Wehtje, and R. H. Walker. 2004. Quinclorac: Soil behavior and foliar versus root absorption by torpedograss. Weed Technol. 18:404-411.

Table 2-1. The influence of irrigation timing after diuron application on postemergence oxalis control.

	Oxalis control				
	visual injury (%)			weight (g)	
Irrigation[z] (hr)	14 DAT[y]	21 DAT	28 DAT	SFW	SDW
1	39[x]a[w]	62a	71a	0.48a	0.13a
2	50a	75a	80a	0.23a	0.09a
4	46a	72a	73a	0.46a	0.11a
8	48a	67a	64a	0.62a	0.14a
12	42a	61a	64a	0.58a	0.17a
24	51a	70a	74a	0.36a	0.11a
48	54a	70a	72a	0.37a	0.10a
non-treated	2b	5b	4b	3.34b	0.93b

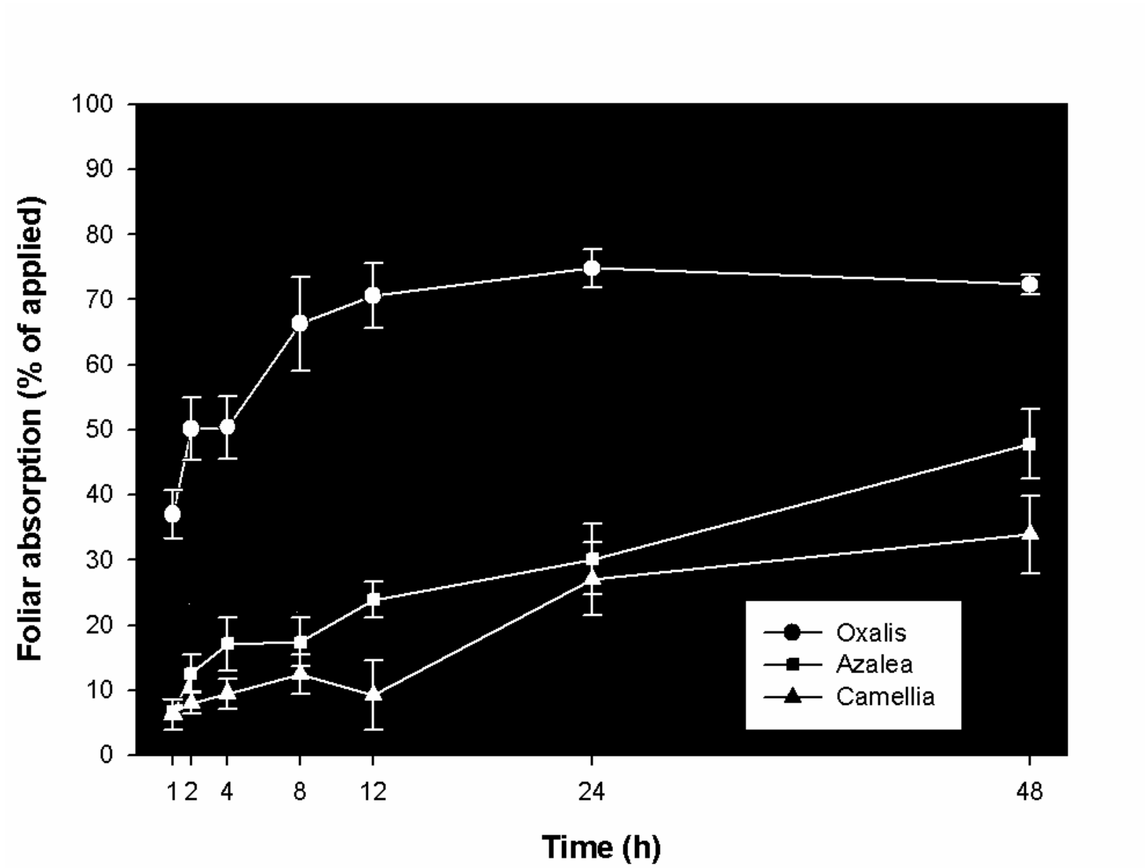
[z] Irrigation timing, hours after diuron application.

[y] DAT= days after treatment, SFW= shoot fresh weight (g), SDW= shoot dry weight(g).

[x] Percent oxalis control, where 0% = no injury and 100% = plant death.

[w] Means within a column followed by the same letter are not significantly different (Duncan's Multiple Range Test: $\alpha = 0.05$).

Figure 2- 1. Foliar absorption of ^{14}C diuron by oxalis, azalea and camellia.



Error bars equal standard deviation of individual means.

CHAPTER III

PINEBARK MINI-NUGGETS PROVIDE EFFECTIVE WEED CONTROL IN NURSERY CROPS GROWN IN LARGE CONTAINERS (COOL SEASON WEEDS)

Abstract

The market for large plants is increasing steadily; however, weed control in large containers present new production problems for growers. Preemergence herbicides are inefficient in large containers due to extensive non-target herbicide loss and hand weeding is expensive. Mulches can provide an alternative. Experiments were conducted to evaluate fresh pine bark nuggets for weed control in 11 and 27 L (3 and 7 gal) containers. In October 2004, gardenias were seeded with oxalis, and crapemyrtle with bittercress in 27 L (7 gal) containers. In March 2005, oakleaf hydrangeas were seeded with oxalis and ternstroemia with bittercress in 11 L (3 gal) containers. Treatments consisted of mulch applied at depths of 0, 3.8, and 7.62 cm (0, 1.5 and 3.0 in.), and seeded either before or after mulch application. A separate group of treatments were included similar to the above except that a granular preemergence herbicide was applied after mulch application. Growth of crapemyrtle and ternstroemia were similar regardless of mulch depth. With gardenia and oakleaf hydrangea growth differences existed but

there were no consistent trends among treatments. Season long weed control was obtained in all treatments that included 7.62 cm (3 in.) mulch depth.

Introduction

Container nursery crops are increasingly valuable compared to agronomic crops in the southeast. However, weeds growing in containers can reduce the value of the crop by reducing growth through competitive effects (2) and reducing salability due to customer demand for weed free crops. Most growers use preemergence herbicides along with supplemental hand weeding to control weeds thus maximizing crop value.

Increasing demand for large plant material in the landscape has led to many growers producing more nursery crops in 27 L up to 2271 L (7 gal up to 600 gal) containers; however weed control practices differ from that used in smaller containers. Hand weeding is increasingly expensive option due to increasing labor costs (7,10). Increased spacing between large containers renders preemergence herbicides inefficient and environmentally unsafe due to excessive non-target loss. Studies conducted by Porter and Parish (14) showed 12% and 23% non-target loss on 3.8L (1 gal) containers in hexagonal pot-to-pot configuration and square pot-to-pot configuration, respectively. Gilliam *et al*. (7) reported similar results in that non-target losses ranged from 51 to 80% when herbicides were applied to 2.8 L (trade gal) containers spaced 18 to 30 cm (7.1 to 11.8 in.) on center. Nurseries typically apply preemergence herbicides 3 to 5 times annually. Oxyfluorfen and oxadiazon are two commonly used preemergence herbicides that are very stable in the upper layer of the substrate surface, with limited risk of leaching (9,12). However, due to the fact that most nurseries apply 1.3 to 1.8 cm (0.5 to 0.7 in.) of overhead irrigation daily (5), herbicides that are not in the container could be transported by irrigation runoff and contaminate surface water. Excessive herbicides in runoff water are environmentally unsafe and could cause crop injury if water is recycled from run-off collection ponds and reapplied to crops through irrigation.

Mulches may provide a non-chemical alternative for weed control in large containers. However, mulches can be expensive, mainly due to the labor associated with application. Therefore, products used for mulch must be inexpensive to reduce grower production costs. Waste products that would normally be sent to a landfill such as newspaper and tires would be excellent material to use as mulch while reducing waste in the landfill (13). Smith *et al*. (15) reported that newspaper pellets at 5 cm (2 in.) depth controlled spurge in the landscape for at least 60 days. However a negative was that waste paper has been shown to reduce available nitrogen when applied to container surface as mulch (8). Ground rubber tires were used in a separate study and provide good initial control but weeds gradually began to penetrate the barrier at about 2 months after mulch application (3). Fabric disks have also been used as weed control with limited success due to voids around the edge or along the seam of the disk (1). Also there are problems with wind blowing the disks from the container. Shredded tires, recycled newspaper, pole shavings, and kenaf mulch have been evaluated for weed control in large containers (6). Shredded tires and recycled newspaper provided good weed control but availability and acceptability by customers are limiting factors for use of these materials as mulches.

Fresh pine bark mini-nuggets may provide a non-chemical mulch option. Low fertility, large particle size and hydrophobic properties of fresh pine bark nuggets are not conducive for weed growth. Case and Mathers (4) reported good long term weed control with douglas fir and pine bark nuggets in combination with acetochlor at 3.36 kg ai/ha (2.5 lbs ai/A), flumioxazin 0.28 kg ai/ha (0.25 lb ai/A), or oryzalin at 2.24 kg ai/ha (2.0 lbs ai/A) application in containers. Oryzalin and flumioxazin provided no long term control when applied alone, however the pine bark mini-nuggets provide good control while the douglas fir bark provided the best control. Shredded pine bark mulch has provided good weed control in the landscape and is generally accepted by costumers (11). Pine bark is readily available and could be mechanized at potting. Also, hydrophobic properties of fresh pine bark mini nuggets are not conducive for weed establishment because of the lack of moisture available to the germinating weed seed. The objective of this study was to evaluate fresh pine bark mini nuggets for long term weed control in nursery crops grown in large containers.

Materials and Methods

These studies were conducted at the Paterson greenhouse complex of Auburn University, Alabama in the fall of 2004 and spring 2005. The substrate was a 6:1 (v:v) pine bark: sand amended per m^3 (yd^3) with 2.9 kg (5 lbs) of dolomitic lime, 8.3 kg (14lb) of Polyon 18-6-12 (Pursell Technologies, Sylacauga, AL) and 0.9 kg (1.5 lbs) of Micromax (Scotts Co., Maryville, OH). All plants were potted to equal depths, approximately 7.62 cm (3 in.) below the top of the container and were irrigated twice with 0.64 cm (0.25 in.) prior to treatment. Three treatments consisted of broadcasting either 25 bittercress (*Cardamine*) or 25 oxalis (*Oxalis stricta*) seed on each container substrate surface followed by application of pine bark mini-nugget mulch which was hand applied at 0, 3.81, and 7.62 cm (1.5 and 3 in.) deep respectively. Particle size distribution of the pine bark mini-nuggets was as follows: 11% between 2.54 and 5.08 cm (1 and 2 in.), 68% between 1.27 and 2.54 cm (0.5 and 1 in.), 14% between 0.64 and 1.27 cm (0.25 and 0.5 in.) and 7% less than 0.64 cm (0.25 in.). Two other treatments consisted of first applying mulch at 3.81 and 7.62 cm (1.5 and 3 in.), then broadcasting the seeds on top of the mulch. These same five treatments were repeated except that a granular preemergence herbicide, flumioxazin (Broadstar 0.25G) (Valent. Walnut Creek, CA) was applied at 0.40 kg ai/ha (0.375 lb aia or 150 lb product/A) after all mulch and seed were present.

Pine bark mini-nuggets were purchased for $16 per cubic yard. Mulch cost per 27 L (7 gal) container was 7 and 15 cents for 3.81 and 7.62 cm (1.5 and 3.0 inch) mulch depths respectively. This study was a completely randomized design with 10 single pot reps per treatment. All plants were placed in full sun under overhead irrigation with 1.27 cm (0.5 inches) of water applied in two daily cycles during the growing season.

In a similar study, gardenia (*Gardenia jasminoides*) were transplanted from 2.8 L (trade gal) containers into 27 L (7 gal) containers on September 27, 2004. On September 30, 2004 the same treatments as previously described were applied to gardenia except 25 oxalis (*Oxalis stricta*) seed were used per container instead of bittercress. In both studies, data collected were weed number per container at 30, 60, 90 and 180 days after treatment (DAT) and percent coverage of container surface of designated weeds at 60, 90, 180 DAT. Shoot fresh weight of weeds and growth indices of crop were taken for each container at 180 DAT. Plants were covered for overwintering from December 23, 2004 until March 1, 2004. Growth indices and general weed coverage were taken on crapemyrtle and gardenia at 180 and 300 DAT. Duncan's multiple range test ($\alpha = 0.5$) was used to separate treatment means.

In spring 2005 a similar mulch study was conducted using oakleaf hydrangea (*Hydrangea quercifolia*) and ternstroemia (*Ternstroemia gymnanthera*). Both crops were transplanted from 10.2 cm (4 in.) containers into 11 L (3 gal) containers on March 16, 2005. All plants were potted 7.6 cm (3 in.) below the top of the container The substrate was a 6:1 (v:v) pine bark: sand amended per m^3 (yd^3) with 2.9 kg (5 lb) of dolomitic lime, 8.3 kg (14 lb) of Polyon 18-6-12 (Pursell Technologies, Sylacauga, AL) and 0.9 kg (1.5 lb) of Micromax (Scotts Co., Maryville, OH). Treatments previously described were applied to crops on March 17, 2005. Oakleaf hydrangea received 25 oxalis seed per container, while the ternstroemia received 25 bittercress seed per container. Plants were placed in a completely randomized design outdoors under 47% shade and received 1.27cm (0.5 in.) daily cyclic overhead irrigation. Data were collected on weed number and % surface coverage of container by designated weed species at 30, 60, 120 and 150 DAT. Growth indices were also taken 150 DAT.

Results and Discussion

Crapemyrtle-Bittercress

Fresh pine bark mini-nuggets provided effective season long weed control for nursery crops grown in large containers. At 90 DAT and 180 DAT bittercress were growing vigorously in the no mulch, no herbicide containers, with 48% and 100% coverage of container surface, respectively and 59.6 g of bittercress dry weight per container at 180 DAT (Table 1). In comparison, no herbicide, 3.8 cm (1.5 in.) of mulch treatment with seeding after mulching, averaged 5% coverage at 90 DAT and increased to 44% coverage of container surface and 33.7 g per container at 180 DAT. No mulch with herbicide provided effective control for about 90 DAT but at 180, control had dissipated as expected. All other treatments provided excellent bittercress control at 90 and 180 DAT . Crapemyrtle growth was similar among treatments at 180 DAT.

After weeding at 180 DAT (April 6, 2005), crapemyrtles were placed in a nursery area for the remainder of the growing season. Plants reached marketable status by 300 DAT. Weed pressure was low throughout the summer due to the crapemyrtles canopy shading the container surface. No herbicides were applied beyond the initial treatment. At 300 DAT weeds covered 16% of the containers surface for the no mulch, no herbicide treatment and 32% coverage for the no mulch, herbicide treatment. There was slight but minimal weed coverage, less than 5% in the 3.8 cm (1.5 in.) of mulch treatments. There were no weeds in the 7.6 cm (3 in.) of mulch treatments at 300 DAT.

Ternstroemia - Bittercress

At 60 DAT bittercress averaged 13% coverage of container surface within the no mulch no herbicide treatment and minimal coverage of 3% in 3.8 cm (1.5 in.) mulch, seeded before, no herbicide treatment (Table 3). At 150 DAT, coverage increased to 40% for the no mulch, no herbicide treatment. The no mulch, with herbicide treatment had 5% coverage at 150 DAT while all other treatments had no bittercress. Ternstroemia growth was not effected by treatment at 150 DAT.

Gardenia- Oxalis

At 90 and 180 DAT, oxalis covered 18.5 and 35 % of container surface, respectively in the no mulch, no herbicide treatment (Table 1). At 180 DAT oxalis shoot dry weight was 12.9 g per container. All other treatments resulted in minimal oxalis growth at 90 and 180 DAT. The combination of mulch plus herbicide provided complete oxalis control 180 DAT. General weed coverage at 300 DAT averaged 71% coverage per container for the no mulch, no herbicide, 56% coverage for no mulch, with herbicide and 24% for 3.8 cm (1.5 in.) of mulch, seeded before mulch with no herbicide. All other treatments with 3.8 cm (1.5 in.) of mulch contained minimal weeds similar to the containers with crapemyrtle. Results are similar for gardenia compared to crapemyrtle in that 7.6 cm (3 in.) of mulch provided excellent weed control.

Gardenia growth was not significantly different among mulch treatments at 180 DAT (Table 2). However at 300 DAT gardenia were significantly smaller in the no mulch no herbicide treatment. The reduced growth was attributed to the excessive amount of weeds in those containers.

Oakleaf Hydrangea – Oxalis

At 60 DAT there was 37% oxalis coverage in the no mulch, no herbicide treatment and a minimal 8% coverage in the 3.8 cm (1.5 in.) mulch, seeded before with no herbicide treatment (Table 3). At 150 DAT oxalis covered an average 65% of container surface within the no mulch no herbicide treatment and 20% in the 3.8 cm (1.5 in.) mulch, seeded before with no herbicide treatment. The no mulch, with herbicide treatment averaged 15% coverage at 150 DAT, as expected. The 7.6 cm (3 in.), seeded after, with no herbicide treatment had 9% coverage, however the oxalis were very small and insignificant. Growth was not effected by treatment at 150 DAT for oakleaf hydrangea.

In summary, these data showed that pine bark mini-nuggets provided excellent control of the two primary cool season weeds in large containers when applied at a 7.6 cm (3 in.) depth, and did not affect crop growth. These results are likely due to the hydrophobic properties of the fresh pine bark, the depth of the mulch and lack of favorable growing conditions for weed germination and growth. The process of applying this type of mulch could easily be mechanized at potting. Fresh pine bark mini-nugget mulch could virtually eliminate the use of herbicides and handweeding in production of nursery crops grown in large containers.

Literature Cited

1. Appleton, B.L. and J.F. Derr. 1990. Use of geotextile disks for container weed control. HortScience 25:666-668.
2. Berchielli-Robertson, D.L., C.H. Gilliam, and D.C. Fare. 1990. Competitive effects of weeds on the growth of container-grown plants. HortScience 25:77-79.
3. Calkins, J.B., B.T. Swanson, and D.L. Newman. 1996. Weed control strategies for field grown herbaceous perennials. J. Environ. Hort. 14:221-227.
4. Case, L.T., H.M. Mathers. 2003. Long term effects of herbicide treated mulches for ornamental weed control. Proc. Northeast. Weed Sci. Soc. 57:118-121.
5. Fare, D.C., C.H. Gilliam, and G.J. Keever. 1992. Monitoring irrigation at container nurseries. Hort Technol. 2:75-78.
6. File, S., P. Knight, D. Reynolds, C.H. Gilliam, J. Edwards, and R. Harkess. 1999. Alternative weed control options for large container production. SNA 44:501-504
7. Gilliam, C.H., W.J. Foster, J.L. Adrain, and R.L. Shumack. 1990. A survey of weed control costs and strategies in container production nurseries. J. Environ. Hort. 8:133-135.
8. Glenn, J.S., C.H. Gilliam, J.H. Edwards, G.J. Keever and P.R. Knight. 2000. Recycled waste paper mulch reduces available container N. J. Environ. Hort. 18:188-191.
9. Horowitz, M. and C.L. Elmore. 1991. Leaching of oxyfluofen in container media. Weed Technology. 5:175-180.

10. Judge, C.A., J.C. Neal, and J.B. Weber. 2003. Dose and concentration responses of common nursery weeds to Gallery, Surflan and Treflan. J. Environ. Hort. 21:43-45.

11. Llewellyn, J., K. Osborne, C. Steer-George, J. West. 2003. Commercially available organic mulches as a weed barrier for container production. Comp. Proc. Intl. Plant Prop. Soc. 53:590-593.

12. Moles, A. and C.E. Whitcomb. 1976. Movement of ronstar in containers as influenced by growing media. Proc. SNA Res. Conf. 21:137.

13. Pellet, N.E. and D.A. Heleba. 1995. Chopped newspaper for weed control in nursery crops. J. Environ. Hort. 13:77-81.

14. Porter, W.C. and R.L. Parish. 1993. Nontarget losses of granular herbicide applied to container-grown landscape plants. J. Environ. Hort. 11:143-146.

15. Smith, D.R., C.H. Gilliam, J.H. Edwards, D.J. Eakes, and J.D. Williams. 1997. Recycled waste paper as a landscape mulch. J. Environ. Hort. 15:191-196.

Table 3- 1: The influence of mulch and BroadStar on bittercress control within container nursery crops.

			2004				2005	
			Bittercress			General[Z]	Bittercress	
			90 DAT[Y]	180 DAT		300 DAT	60 DAT	150 DAT
Herbicide[X]	Seeded[W]	Mulch[V]	% cover[U]	% cover	SDW[T]	% cover	% cover	% cover
No	before	0	48a[S]	100a	59.6a	16b	13a	40a
No	before	1.5	0b	2.5c	3.5c	5cb	2.5b	0b
No	before	3	0b	0c	0c	0c	0b	0b
No	after	1.5	5b	44.2b	33.7b	5cb	0b	0b
No	after	3	0b	1.0c	1.4c	0c	0b	0b
Yes	before	0	2b	8c	3.8c	32a	0b	5b
Yes	before	1.5	0b	0c	0c	0c	0b	0b
Yes	before	3	0b	0c	0c	0c	0b	0b
Yes	after	1.5	0b	0c	0c	0c	0b	0b
Yes	after	3	0b	0c	0c	0c	0b	0b

[Z] General = all weed species, consisting mainly of bittercress, spurge, eclipta and oxalis.

[Y] DAT= days after treatment.

[X] Application of a preemergence herbicide (Broadstar 0.25G 150 lb product/ A).

[W] Timing of seeding compared to mulching, before = seeds under mulch , after = seeds on top of mulch.

[V] Mulch depth in inches.

[U] % cover = percentage of container surface covered by weed species.

[T] SDW = shoot dry weight in grams.

[S] Means within column followed by the same letter are not significantly different (Duncan's Multiple Range Test: $\alpha = 0.05$).

Table 3- 2: The influence of mulch and herbicide on growth of gardenia, crapemyrtle, oakleaf hydrangea and ternstroemia

Treatment			Growth-index[Z]					
			Crapemrytle		Gardenia		Oakleaf Hydrangea	Ternstroemia
Herbicide[Y]	Seeded[X]	Mulch depth[W]	180 DAT	300 DAT	180 DAT	300 DAT	150 DAT	150 DAT
No	before	0	129a[V]	85a	59ab	75c	51ab	37a
No	before	1.5	128a	77a	54b	79bc	51ab	38a
No	before	3	126a	80a	59ab	84ab	52ab	34a
No	after	1.5	126a	82a	56ab	82ab	62a	36a
No	after	3	119a	80a	56ab	80b	56ab	34a
Yes	before	0	131a	80a	55ab	80b	50ab	39a
Yes	before	1.5	129a	88a	60a	84ab	48b	37a
Yes	before	3	121a	79a	56ab	82ab	52ab	34a
Yes	after	1.5	123a	75a	54b	86a	55ab	36a
Yes	after	3	125a	74a	58ab	83ab	55ab	35a

[Z] Growth index = height + 2 perpendicular widths/ 3, taken at 150, 180 and 300 DAT(days after treatment).

[Y] Application of a preemergence herbicide (Broadstar 0.25G 150 lb product/ A).

[X] Timing of seeding compared to mulching, before = seeds under mulch, after = seeds on top of mulch.

[W] Mulch depth in inches.

[V] Means within column followed by the same letter are not significantly different.
(Duncan's Multiple Range Test: $\alpha = 0.05$)

Table 3- 3: Influence of mulch and BroadStar on oxalis control in container nursery crops.

			2004				2005	
			Oxalis			General[Z]	Oxalis	
Treatment			90 DAT[Y]	180 DAT		300 DAT	60 DAT	150 DAT
Herbicide[X]	Seeded[W]	Mulch[V]	% cover[U]	% cover	SDW[T]	% cover	% cover	% cover
No	before	0	18.5a[S]	35a	12.9a	71a	37a	65a
No	before	1.5	0.5b	0.9b	0.9b	24b	7.5b	20b
No	before	3	0b	0b	0b	0b	0b	0b
No	after	1.5	0b	2.5b	1.3b	6	1.0b	5b
No	after	3	0b	1b	0.8b	0b	0b	9b
Yes	before	0	1.5b	2.5b	1.1b	56a	0b	15b
Yes	before	1.5	0b	0b	0b	3b	0b	0b
Yes	before	3	0b	0b	0b	0b	0b	0b
Yes	after	1.5	0b	0b	0b	8b	0b	0b
Yes	after	3	0b	0b	0b	0b	0b	0b

[Z] General = weed species, consisting mainly of bittercress, spurge, eclipta and oxalis.

[Y] DAT= days after treatment.

[X] Application of a preemergence herbicide (Broadstar 0.25G 150 lb product/ A).

[W] Timing of seeding compared to mulching, before = seeds under mulch ,after = seeds on top of mulch.

[V] Mulch depth in inches.

[U] % cover = percentage of container surface covered by weed species.

[T] SDW = shoot dry weight in grams.

[S] Means within column followed by the same letter are not significantly different (Duncan's Multiple Range Test: $\alpha = 0.05$).

CHAPTER IV

PINEBARK MINI-NUGGETS PROVIDE EFFECTIVE WEED CONTROL IN NURSERY CROPS GROWN IN LARGE CONTAINERS (WARM SEASON WEEDS)

Abstract

The market for large plants is increasing steadily; however, weed control in large containers present new production problems for growers. Preemergence herbicides are inefficient in large containers due to extensive non-target herbicide loss and hand weeding is expensive. Mulches can provide an alternative. Experiments were conducted to evaluate fresh pine bark nuggets for weed control in 27 L (7 gal) containers. In 2004 lilac chaste tree were seeded with spurge and dwarf burford holly were seeded with eclipta. In 2005, natchez crapemyrtle were seeded with spurge and willowleaf cotoneaster were seeded with eclipta. Treatments consisted of mulch applied at depths of 0, 3.8, and 7.6 cm (0, 1.5, 3.0 in.), and seeded either before or after mulch application. A separate group of treatments were included similar to the above except that a granular preemergence herbicide, flumioxazin (Broadstar 0.25G) (Valent. Walnut Creek, CA) was applied at 0.40 kg ai/ha (0.375 lb aia or 150 lb product/A) after mulch application. Spurge control was excellent within treatments with 3.8 and 7.6cm (1.5 and 3.0in.) of mulch. Spurge was present in the no mulch, no herbicide treatment at 30 DAT in 2004 and 2005.

The no mulch with herbicide treatment began to grow spurge at 90 DAT. Growth of lilac chaste tree and natchez crapemrytle were similar regardless of mulch depth. Eclipta was present in no mulch no herbicide treatment at 30 DAT. At 90 DAT, no mulch no herbicide treatment and no mulch with herbicide treatment contained 964 grams and 358 grams, respectively. In the 2004 eclipta was present in the 7.6 cm (3 in.) mulch , seeded before, no herbicide treatment; however it was insignificant, averaging 32 grams per container. In 2005 there were no eclipta in any of the treatments containing mulch depths of 3.8 and 7.6cm (1.5 and 3.0in.). Growth was reduced, compared to other treatments for both dwarf burford holly and willowleaf cotoneaster in the no mulch no herbicide treatment. Season long weed control was obtained in all treatments that included mulch at 3.8 and 7.6 cm (1.5 and 3 in.) depth.

Introduction

Container nursery crops are increasingly valuable compared to agronomic crops in the southeast. However, weeds growing in containers can reduce the value of the crop by reducing growth through competitive effects (2) and reducing salability due to customer demand for weed free crops. Most growers use preemergence herbicides along with supplemental hand weeding to control weeds thus maximizing crop value.

Increasing demand for large plant material in the landscape has led to many growers producing more nursery crops in 27 L up to 2271 L (7 gal up to 600 gal) containers; however weed control practices differ from that used in smaller containers. Hand weeding is an increasingly expensive option due to increasing labor costs (7,10). Increased spacing between large containers renders preemergence herbicides inefficient and environmentally unsafe due to excessive non-target loss. Studies conducted by Porter and Parish (14) showed 12% and 23% non-target loss on 3.8 L (1 gal) containers in hexagonal pot-to-pot configuration and square pot-to-pot configuration, respectively. Gilliam *et al*. (7) reported similar results in that nontarget losses ranged from 51 to 80% when herbicides were applied to 2.8 L (trade gal) container spaced 18 to 30 cm (7.1 to 11.8 in.) on center. Nurseries typically apply preemergence herbicides 3 to 5 times annually. Oxyfluorfen and oxadiazon are two commonly used preemergence herbicides that are very stable in the upper layer of the substrate surface, with limited risk of leaching (9,12). However, due to the fact that most nurseries apply 1.3 to 1.8 cm (0.5 to 0.7 in.) daily overhead irrigation (5), herbicides that are not in the container could be transported by irrigation runoff and contaminate surface water. Excessive herbicides in runoff water are environmentally unsafe and could cause crop injury if water is recycled from run-off collection ponds and reapplied to crops through irrigation.

Mulches may provide a non-chemical alternative for weed control in large containers. However, mulches can be expensive, mainly due to the labor associated with application. Therefore, products used for mulch must be inexpensive to reduce grower production costs. Waste products that would normally be sent to a landfill such as newspaper and tires would be excellent material to use as mulch while reducing waste in the landfill (13). Smith *et al*. (15) reported that newspaper pellets at 5cm depth controlled spurge in the landscape for at least 60 days. However, a negative is that wastepaper has been shown to reduce available nitrogen when applied to container surface as mulch (8). Ground rubber tires were used in a separate study and provide good initial control but weeds gradually began to penetrate the barrier at about 2 monthes after mulch application (3). Fabric disk have also been used as weed control with limited success due to voids around the edge or along the seam of the disk (1). Also there are problems with wind blowing the disks from the container. Shredded tires, recycled newspaper, pole shavings, and kenaf mulch have been evaluated for weed control in large containers (6). Shredded tires and recycled newspaper provided good weed control but availability and acceptability by customers are limiting factors for use of these materials as mulches.

Pine bark mini-nuggets may provide a non-chemical mulch option for growers. Low fertility, large particle size and hydrophobic properties of fresh pine bark nuggets are not conducive for weed growth. Case and Mathers (4) reported good long term weed control with Douglas fir and pine bark nuggets in combination with acetochlor at 2.83 kg ai/ha (2.5 lbs ai/A), flumioxazin 0.28 kg ai/ha (0.25 lb ai/A), oryzalin at 2.24 kg ai/ha (2.0 lbs ai/A) application in containers. Oryzalin and flumioxazin provided no long term control when applied alone, however the pine bark mini-nuggets provide good control while the Douglas fir bark provided the best control. Shredded pine bark mulch has provided good weed control in the landscape and is generally accepted by costumers (11). Pine bark is readily available and could be mechanized at potting. Also, hydrophobic properties of fresh pine bark mini nuggets are not conducive for weed establishment because of the lack of moisture and nutrients available to weed seedlings. The objective of this study was to evaluate fresh pine bark mini nuggets for long term weed control in large container nursery crops.

Materials and Methods

These studies were conducted at the Paterson greenhouse complex of Auburn University, Alabama in the summer of 2004 and 2005. Lilac chaste tree (*Vitex agnus-castus* 'Shoal Creek') were transplanted from 2.8 L (trade gal) containers into 27 L (7 gal) containers June 18, 2004 and treated on June 19, 2004. The substrate was a 6:1 (v:v) aged pine bark: sand amended per m^3 (yd^3) with 2.9 kg (5 lb) of dolomitic lime, 8.3 kg (14 lb) of Polyon 18-6-12 (Pursell Technologies, Sylacauga, AL) and 0.9 kg (1.5 lb) of Micromax (Scotts Co., Maryville, OH). All plants were potted to equal depths, approximately 7.62 cm (3 in.) below the top of the container. All plants were irrigated twice prior to treatment. Three treatments consisted of broadcasting 25 spotted spurge (*Euphorbia maculata*) seed on each container substrate surface followed by application of pine bark mini-nugget mulch which was hand applied at 0, 3.81, and 7.62 cm (1.5 and 3 in.) deep respectively. Two other treatments consisted of first applying mulch at 3.81 and 7.62 cm (1.5 and 3 in.), then broadcasting the spurge seeds on top of the mulch. These same five treatments were repeated except that a granular preemergence herbicide, flumioxazin (Broadstar 0.25G) (Valent. Walnut Creek, CA) was applied at 0.40 kg ai/ha (0.375 lb aia or 150 lb product/A) after all mulch and seed were present. Particle size distribution of the pine bark mini-nuggets was as follows: 11% between 2.54 and 5.08 cm (1 to 2 in.), 68% between 1.27 and 2.54 cm (0.5 to 1 in.), 14% between 0.64 and 1.27 cm (0.25 to 0.5 in.) and 7% less than 0.64 cm (0.25 in.). Pine bark mini-nuggets were purchased for $16 per cubic yard. Mulch cost per container was 7 and 15 cents for 3.81 and 7.62 cm (1.5 and 3.0 in.) mulch depths respectively. This study was a completely randomized design with 10 single pot reps per treatment. All plants were placed in full sun under overhead irrigation with 1.27 cm (0.5 in.) of water applied in two cycles daily during the growing season. Data were collected on weed number per container at 30 and 60 days after treatment (DAT). Shoot fresh weight of weeds were collected at 90 DAT. Growth indices of crops were taken 150 DAT.

In a similar study, dwarf burford holly (*Ilex cornuta* 'Dwarf Burford') were transplanted from 2.8 L (trade gal) containers into 27 L (7 gal) containers on June 18, 2004. On June 24, 2004 the same treatments as previously described were applied to dwarf burford holly except 20 eclipta (*Eclipta alba*) seed were used per container instead of spurge. Data collected were weed number per container at 30 and 60 DAT. Shoot fresh weight of weeds were taken for each container at 90 DAT. Growth indices were taken at 150 DAT.

In summer 2005 a similar mulch study was conducted using natchez crapemyrtle (*Lagerstoemia indica* 'Natchez') and willowleaf cotoneaster (*Cotoneaster salicifolius*). Natchez crapemyrtle were transplanted from 10.2 cm (4 in.) containers and cotoneaster from 2.8 L (trade gal) into 27 L (7 gal) containers on May 10, 2005. All plants were potted 7.6 cm (3 in.) below the top of the container. The substrate was a 6:1 (v:v) pine bark: sand amended per m^3 (yd^3) with 2.8 kg (5lb) of dolimitic lime, 8.3kg (14lb) of Polyon 18-6-12 (Pursell Technologies, Sylacauga, AL) and 0.9kg (1.5lb) of Micromax (Scotts Co., Maryville, OH). Treatments previously described were applied to crops on May 11, 2005. The natchez crapemyrtle received 25 spurge seed per container, while the willowleaf cotoneaster received 20 eclipta seed per container. Plants were placed in a completely randomized design outdoors in full sun and received 1.27cm (0.5 in.) cyclic overhead irrigation twice daily. Data were collected on % coverage of container surface at 30 and 60 DAT. Shoot fresh weight of eclipta were taken 90 DAT. Growth indices were also taken 150 DAT. Duncan's multiple range test ($\alpha = 0.5$) was used to separate treatment means.

Results and Discussion

Lilac Chaste Tree - Spurge

Fresh pine bark mini nuggets provided weed control for nursery crops grown in large containers. At 30 and 60 DAT spurge were growing vigorously in the no mulch, no herbicide containers averaging 11 and 6 spurge per container, respectively (Table 1). At 90 DAT the no mulch, no herbicide treatment averaged 1.1 grams shoot fresh weight per container. In comparison, all other treatments contained no spurge throughout the study. Vitex growth was consistent among treatments at 150 DAT (Table 2).

Natchez Crapemyrtle – Spurge

Spurge control in 2005 was similar to control in 2004. In 2005, the no mulch, no herbicide treatment averaged 16 and 83 percent coverage of container surface at 30 and 60 DAT respectively (Table 3). The no mulch with herbicide treatment contained no spurge at 30 DAT however control began to diminish at 60 DAT with 10% coverage per container. Spurge shoot fresh weight at 90 DAT was 143 and 17 grams for no mulch, no herbicide treatment and no mulch, with herbicide treatment respectively. All mulch treatments maintained excellent spurge control. Natchez crapemyrtle growth was not significantly different among treatments (Table 2).

Dwarf Burford Holly - Eclipta

Fresh pine bark mini-nuggets provided excellent eclipta control. The no mulch, no herbicide treatment averaged 4 and 3 eclipta per container at 30 and 60 DAT respectively (Table 1). The no mulch, with herbicide treatment had no eclipta at 30 DAT however at 60 DAT there was an average of 1 eclipta per container. At 90 DAT shoot fresh weight of eclipta was significant in the no mulch, no herbicide treatment and in the no mulch, with herbicide treatment with 964 grams and 358 grams respectively. The 7.6 cm (3 in.) mulch, seeded before, no herbicide treatment did contain some eclipta, 32 g per container, however was not significant. At 150 DAT growth of dwarf burford holly was reduced in the no mulch no herbicide treatment due to the competitive effects of the eclipta (Table 2). All other dwarf burford treatments were similar in growth.

Cotoneaster - Eclipta

Eclipta control in the 2005 study was similar to control in 2004. In 2005, the no mulch no herbicide treatment averaged 11 and 32 percent coverage of container at 30 and 60 DAT, respectively (Table 3). At 90 DAT eclipta shoot fresh weight averaged 326 grams in the no mulch no herbicide treatment. All other treatments contained no eclipta throughout the study. Cotoneaster growth was significantly reduced in the no mulch no herbicide treatment due to the competitive effects of the large population of eclipta.

In summary, these data showed that pine bark mini-nuggets provided excellent control of the two primary warm season weeds in large containers when applied at a 7.6 cm (3 in.) depth, and did not affect crop growth. These results are likely due to the hydrophobic properties of the fresh pine bark, the depth of the mulch and lack of favorable growing conditions for weed germination and growth. The process of applying this type of mulch could easily be mechanized by growers at potting. Fresh pine bark mini-nugget mulch could virtually eliminate the use of herbicides and handweeding in production of nursery crops grown in large containers.

Literature Cited

1. Appleton, B.L. and J.F. Derr. 1990. Use of geotextile disks for container weed control. HortScience 25:666-668.

2. Berchielli-Robertson, D.L., C.H. Gilliam, and D.C. Fare. 1990. Competitive effects of weeds on the growth of container-grown plants. HortScience 25:77-79.

3. Calkins, J.B., B.T. Swanson, and D.L. Newman. 1996. Weed control strategies for field grown herbaceous perennials. J. Environ. Hort. 14:221-227.

4. Case, L.T., H.M. Mathers. 2003. Long term effects of herbicide treated mulches for ornamental weed control. Proc. Northeast. Weed Sci. Soc. 57:118-121.

5. Fare, D.C., C.H. Gilliam, and G.J. Keever. 1992. Monitoring irrigation at container nurseries. Hort Technol. 2:75-78.

6. File, S., P. Knight, D. Reynolds, C.H. Gilliam, J. Edwards, and R. Harkess. 1999. Alternative weed control options for large container production. SNA 44:501-504

7. Gilliam, C.H., W.J. Foster, J.L. Adrain, and R.L. Shumack. 1990. A survey of weed control costs and strategies in container production nurseries. J. Environ. Hort. 8:133-135.

8. Glenn, J.S., C.H. Gilliam, J.H. Edwards, G.J. Keever and P.R. Knight. 2000. Recycled waste paper mulch reduces available container N. J. Environ. Hort. 18:188-191.

9. Horowitz, M. and C.L. Elmore. 1991. Leaching of oxyfluofen in container media. Weed Technol. 5:175-180.

10. Judge, C.A., J.C. Neal, and J.B. Weber. 2003. Dose and concentration responses of common nursery weeds to Gallery, Surflan and Treflan. J. Environ. Hort. 21:43-45.

11. Llewellyn, J., K. Osborne, C. Steer-George, J. West. 2003. Commercially available organic mulches as a weed barrier for container production. Comp. Proc. Intl. Plant Prop. Soc. 53:590-593.

12. Moles, A. and C.E. Whitcomb. 1976. Movement of ronstar in containers as influenced by growing media. Proc. SNA Res. Conf. 21:137.

13. Pellet, N.E. and D.A. Heleba. 1995. Chopped newspaper for weed control in nursery crops. J. Environ. Hort. 13:77-81.

14. Porter, W.C. and R.L. Parish. 1993. Nontarget losses of granular herbicide applied to container-grown landscape plants. J. Environ. Hort. 11:143-146.

15. Smith, D.R., C.H. Gilliam, J.H. Edwards, D.J. Eakes, and J.D. Williams. 1997. Recycled waste paper as a landscape mulch. J. Environ. Hort. 15:191-196.

Table 4- 1: The influence of mulch and herbicides on spurge control within container nursery crops.

Treatment			Spurge 2004			Spurge 2005		
			spurge #[Z]		SFW[Y]	spurge % cover[X]		SFW
Herbicide[W]	Seeded[V]	Mulch[U]	30 DAT[T]	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT
No	before	0	11a[S]	6a	1.1a	16a	83a	143a
No	before	1.5	0b	0b	0b	0b	0b	0c
No	before	3	0b	0b	0b	0b	0b	0c
No	after	1.5	0b	0b	0b	0b	0b	0c
No	after	3	0b	0b	0b	0b	0b	0c
Yes	before	0	0b	0b	0b	0b	10b	17b
Yes	before	1.5	0b	0b	0b	0b	0b	0c
Yes	before	3	0b	0b	0b	0b	0b	0c
Yes	after	1.5	0b	0b	0b	0b	0b	0c
Yes	after	3	0b	0b	0b	0b	0b	0c

[Z] Spurge # = number of spurge per container.

[Y] SFW = shoot fresh weight in grams.

[X] Spurge % cover = percentage coverage of container surface by spurge.

[W] Application of a preemergence herbicide (Broadstar 0.25G 150 lb product/ A).

[V] Timing of seeding compared to mulching, before = seeds under mulch , after = seeds on top of mulch.

[U] Mulch depth in inches.

[T] DAT= days after treatment.

[S] Means within column followed by the same letter are not significantly different (Duncan's Multiple Range Test: $\alpha = 0.05$).

Table 4- 2: The influence of mulch and BroadStar on growth of nursery crops.

			Growth-index[Z] 150 DAT			
			2004		2005	
Herbicide[Y]	Seeded[X]	Mulch depth[W]	Vitex	Dwarf burford	Natchez	Cotoneaster
No	before	0	119a[V]	44b	127a	103b
No	before	1.5	123a	52a	124a	127a
No	before	3	121a	49ab	132a	127a
No	after	1.5	119a	50ab	126a	129a
No	after	3	117a	51ab	136a	129a
Yes	before	0	121a	49ab	128a	129a
Yes	before	1.5	123a	50ab	128a	129a
Yes	before	3	120a	48ab	131a	128a
Yes	after	1.5	121a	49ab	134a	126a
Yes	after	3	119a	51a	129a	128a

[Z] Growth index = height + 2 perpendicular widths/ 3, taken at 150 DAT (days after treatment).

[Y] Application of a preemergence herbicide (Broadstar 0.25G 150 lb product/ A).

[X] Timing of seeding compared to mulching, before = seeds under mulch, after = seeds on top of mulch.

[W] Mulch depth in inches.

[V] Means within column followed by the same letter are not significantly different (Duncan's Multiple Range Test: $\alpha = 0.05$).

Table 4- 3: The influence of mulch and Broadstar on eclipta control within container nursery crops.

			eclipta 2004			eclipta 2005		
Treatment			eclipta #[Z]		SFW[Y]	eclipta % cover[X]		SFW
Herbicide[X]	Seeded[W]	Mulch[V]	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT
No	before	0	4a	3a	964a	11a	32a	326a
No	before	1.5	0b	0c	0c	0b	0b	0b
No	before	3	0b	0c	32c	0b	0b	0b
No	after	1.5	0b	0c	0c	0b	0b	0b
No	after	3	0b	0c	0c	0b	0b	0b
Yes	before	0	0b	1b	358b	0b	0b	0b
Yes	before	1.5	0b	0c	0c	0b	0b	0b
Yes	before	3	0b	0c	0c	0b	0b	0b
Yes	after	1.5	0b	0c	0c	0b	0b	0b
Yes	after	3	0b	0c	0c	0b	0b	0b

[Z] # = number of eclipta weeds per container.

[Y] SFW= shoot fresh weight in grams.

[X] Eclipta % cover = percentage of container surface covered by eclipta.

[W] Application of a preemergence herbicide (Broadstar 0.25G 150 lb product/ A).

[V] Timing of seeding compared to mulching, before = seeds under mulch , after = seeds on top of mulch.

[U] Mulch depth in inches.

[T] DAT= days after treatment.

[S] Means within column followed by the same letter are not significantly different (Duncan's Multiple Range Test: $\alpha = 0.05$).

CHAPTER V

FINAL DISSCUISSION

Postermergence Oxalis Control with Diuron: Minimizing Crop Injury with Timely Irrigation

Oxalis is a cool season weed that is difficult to control. Diuron has been shown to provide excellent postemergence oxalis control with very little crop injury when applied to most nursery crops however there are sensitive crop species. This study focused on reducing crop injury to sensitive crops with timely irrigation. Diuron was applied to oxalis, camellia and azalea. The treatments were irrigation intervals of 1, 2, 4, 8, 12, 24 and 48 hr after diuron application. Foliar absorption was also studied using ^{14}C-diuron which was also applied to oxalis camellia and azalea.

Oxalis control at 14 DAT was not influenced by any irrigation treatment. Irrigating within 1hr of treatment resulted in similar control to waiting 48 hr after diuron application. Oxalis control tended to increase thru 28 DAT, but irrigation timing had no effect on oxalis control. Camellia tolerance to diuron was excellent with no visible injury at any time in the study. This is in contrast with previous reports of slight initial diuron injury when applied to ‘Pink Icicle’ camellia; however, plants had completely outgrown injury symptoms by 60 DAT. G. G. Gerbing azaleas were actively growing at time of diuron application and were more sensitive to diuron. Injury occurred with all treatments however irrigation 1 hr after diuron application reduced injury 10 to 15 % compared to irrigation 2 hr after diuron application. There were no differences in azalea injury at 14, 21 or 28 DAT when irrigated from 8 to 48 hr after diuron application. Similarly there were no differences in azalea injury rating when irrigated 2 to 4 hr after diuron application. No visible injury was evident at 120 DAT. Azalea growth at 120 DAT was similar among the non-treated control and plants that were irrigated 1, 2, 24, and 48 hr after diuron application. At 240 DAT all azaleas had similar growth except those irrigated 24 hr after diuron application, which were slightly smaller. With camellia all plants were similar in size or larger than the non-treated control plants at both 120 and 240 DAT.

The ^{14}C-diuron study revealed that diuron was rapidly absorbed by oxalis reaching near maximum of 68 % at 8 hr after application. Within 1 hr of application, about 35% of the applied diuron had been absorbed. In contrast, foliar absorption was much slower in the landscape plants, and the maximum amount absorbed was less compared to oxalis. Azalea and camellia absorbed only 8% and 5% of the amount applied, respectively. Azalea absorption was slightly greater than camellia. Oxalis, azalea and camellia reached maximum absorption at 48 hr after diuron application with 70, 48 and 32 % absorbed, respectively.

These data show postemergence oxalis control is obtained with irrigation 1 hr after diuron application due to rapid absorption. Azalea injury is likely reduced by irrigation due to slow foliar uptake; therefore, a timely irrigation could remove unabsorbed diuron thus reducing additional absorption. Additional research is needed to evaluate tolerance of diuron and timing of application to nursery crops.

Pine Bark Mini-Nuggets as Weed Control in Container Nursery Crops

Fresh pine bark mini-nugget mulch was used as weed control in nursery crops grown in large containers. Treatments consisted of seeding weeds before or after mulch was applied, for four weed species (oxalis, bittercress, eclipta, spurge). Mulch was applied at 0, 3.8, 7.6 cm (0, 1.5 and 3 in.) depths in container grown nursery crops.

These studies showed that fresh pine bark mini-nuggets provided effective season long weed bittercress control for nursery crops grown in large containers. In the 2004 study, bittercress was seeded into 27 L (7 gal) crapemyrtle. At 90 DAT and 180 DAT bittercress were growing vigorously in the no mulch, no herbicide containers, with 48% and 100% coverage of container surface, respectively. In comparison, no herbicide, 3.8 cm (1.5 in.) of mulch treatment with seeding after mulching, averaged 5% coverage at 90 DAT and increased to 44% coverage of container surface and 33.7 g per container at 180 DAT. No mulch with herbicide provided effective control for about 90 DAT but at 180, control had dissipated as expected. All other treatments provided excellent bittercress control at 90 and 180 DAT . Crapemyrtle growth was similar among treatments at 180 DAT. There were no weeds in the 7.6 cm (3 in.) of mulch treatments at 300 DAT.

In the 2005 bittercress was seeded into 11 L (3 gal) ternstroemia. At 60 and 150 DAT bittercress coverage for the no mulch, no herbicide treatment was 13% and 40% respectively. However, unlike the 2004 study, there was minimal bittercress in all other treatments. At 150 DAT the no mulch with herbicide had 5% coverage as expected due to decomposition of the herbicide. In the 2005 study all mulch treatments provided excellent bittercress control.

In 2004, oxalis were seeded into 27 L (7 gal) gardenia. At 90 and 180 DAT, oxalis covered 18.5 and 35 % of container surface, respectively in the no mulch, no herbicide treatment. All other treatments resulted in minimal oxalis growth at 90 and 180 DAT. The combination of mulch plus herbicide provided complete oxalis control 180 DAT. General weed coverage at 300 DAT averaged 71% coverage per container for the no mulch, no herbicide, 56% coverage for no mulch, with herbicide and 24% for 3.8 cm (1.5 in.) of mulch, seeded before mulch with no herbicide. All other treatments with 3.8 cm (1.5 in.) of mulch contained minimal weeds similar to the containers with crapemyrtle. Results are similar for gardenia compared to crapemyrtle in that 7.6 cm (3 in.) of mulch provided excellent weed control.Gardenia growth was not significantly different among mulch treatments at 180 DAT. However at 300 DAT gardenia were significantly smaller in the no mulch no herbicide treatment. The reduced growth was attributed to the excessive amount of weeds in those containers.

In the 2005 study, oxalis were seeded in 11 L (3 gal) oakleaf hydrangea. At 60 and 150 DAT oxalis coverage was 37% and 65% respectively. However unlike the 2004 study oxalis was growing in the 3.8 cm (1.5 in.) mulch, no herbicide, seeded before mulch treatment. Coverage was 8% and 20% at 60 and 150 DAT respectively. Like the 2004 study, the no mulch, with herbicide had coverage of 15% at 150 DAT. All other treatments provide excellent oxalis control.

These studies also showed that fresh pine bark mini nuggets provided warm season weed control for nursery crops grown in large containers. In 2004, spurge were seeded in 27 L (7 gal) vitex. At 30 and 60 DAT spurge were growing vigorously in the no mulch, no herbicide containers averaging 11 and 6 spurge per container, respectively. In comparison, all other treatments contained no spurge throughout the study. Vitex growth was consistent among treatments at 150 DAT.

Spurge control in 2005 was similar to control in 2004. In 2005, the no mulch, no herbicide treatment averaged 16 and 83 percent coverage of container surface at 30 and 60 DAT respectively. The no mulch with herbicide treatment contained no spurge at 30 DAT however; unlike the 2004 study, control began to diminish at 60 DAT with 10% coverage per container. All mulch treatments maintained excellent spurge control. Natchez crapemyrtle growth was not significantly different among treatments.

In 2004 eclipta was seeded into 27 L (7 gal) dwarf burford holly. The no mulch, no herbicide treatment averaged 4 and 3 eclipta per container at 30 and 60 DAT respectively. The no mulch, with herbicide treatment had no eclipta at 30 DAT however at 60 DAT there was an average of 1 eclipta per container. The 7.6 cm (3 in.) mulch, seeded before, no herbicide treatment did contain some eclipta, 32 g per container, however was not significant. At 150 DAT growth of dwarf burford holly was reduced in the no mulch no herbicide treatment due to the competitive effects of the eclipta. All other dwarf burford treatments were similar in growth.

Eclipta control in the 2005 study was similar to control in 2004. In 2005, eclipta was seeded into 27 L (7gal) cotoneaster. The no mulch no herbicide treatment averaged 11 and 32 percent coverage of container at 30 and 60 DAT, respectively. All other treatments contained no eclipta throughout the study. Cotoneaster growth was alsosignificantly reduced in the no mulch no herbicide treatment due to the competitive effects of the large population of eclipta.

In summary, these data showed that pine bark mini-nuggets provided excellent control of the two primary cool season and two primary warm season weeds in large containers when applied at a 7.6 cm (3 in.) depth, and did not affect crop growth. These results are likely due to the hydrophobic properties of the fresh pine bark, the depth of the mulch and lack of favorable growing conditions for weed germination and growth. The process of applying this type of mulch could easily be mechanized at potting. Fresh pine bark mini-nugget mulch could virtually eliminate the use of herbicides and handweeding in production of nursery crops grown in large containers.

BIBLIOGRAPHY

Ahrens, J.F. 1966. Trials with dichlobenil and diphenamid for controlling weeds in container nursery stock. Proc. North East Weed Contr. Conf. 20:232-236.

Ahrens, J.F., S. Barolli, and R. Gray. 2003. Evaluation of spray-able herbicides for container grown ornamentals. Proc. Northeastern Weed Sci. Soc. 57:36.

Altland, J.E., C.H. Gilliam, J.W. Olive, J.H. Edwards, G.J. Keever, J.R. Kessler, and D.J. Eakes. 2000a. Postemergence control of bittercress. J. Environ. Hort.18:23-28.

Altland, J.E., C.H. Gilliam, J.W. Olive, J.H. Edwards, G.J. Keever, J.R. Kessler, and D.J. Eakes. 2000b. Effect of bittercress size and gallery rate on postemergence bittercress control. J. Environ. Hort. 18:128-132.

Anderson, W.P. 1996. Weed Science: Principles and Applications 3rd Ed. West Pub. Co. St. Paul, MN.

Appleton, B.L. and J.F. Derr. 1990. Use of geotextile disks for container weed control. HortScience 25:666-668.

Bachman, G., C. Wilson, and T. Whitwell. 1995. Tolerance of containerized plants to the postemergence herbicides, stinger, manage and basagran. J. Environ. Hort. 13:129-132.

Barolli, S., J.F. Ahrens, and R. Gray. 2003. Improved methods of applying herbicides in container-grown ornamentals. Proc. Northeastern Weed Sci. Soc. 57:45.

Berchielli-Robertson, D.L., C.H. Gilliam, and D.C. Fare. 1990. Competitive effects of weeds on the growth of container-grown plants. Hortscience 25:77-79.

Calkins, J.B., B.T. Swanson, and D.L. Newman. 1996. Weed control strategies for field grown herbaceous perennials. J. Environ. Hort. 14:221-227.

Case, L.T., H.M. Mathers. 2003. Long term effects of herbicide treated mulches for ornamental weed control. Proc. Northeast. Weed Sc. Soc. 57:118-121.

Collins, K.B., R.E. McNiel, and L.A. Weston. 2001. Evaluation of sulfentrazon for weed control and phytotoxicity in field-grown landscape plants. J. Environ. Hort. 19:189-194.

Cross, G.B. and W.A. Skroch. 1992. Quantification of weed seed contamination and weed development in container nurseries. J. Environ Hort. 10:159-161.

Edmund, R.M., and A.C. York. 1987. Factors affecting postemergence control of sicklepod (*Cassia obtusifolia*) with imazaquin and DPX-F6025: spray volume, growth stage and soil applied alachlor and vernolate. Weed Sci. 35:216-223.

Faircloth, W.H., C.D. Monks, M.G. Patterson, G.R. Wehtje. D.P. Delaney, and J.C. Sanders. 2004. Cotton and weed response to glyphosate applied with sulfur – containing additives. Weed Technol. 18:404-411.

Fare, D.C., C.H. Gilliam, and G.J. Keever. 1992. Monitoring irrigation at container nurseries. Hort Technol. 2:75-78.

File, S., P. Knight, D. Reynolds, C.H. Gilliam, J. Edwards, and R. Harkess. 1999. Alternative weed control options for large container production. SNA 44:501-504.

Fretz, T.A. 1972. Weed compition in container grown Japanese holly. HortScience 7:485-486.

Fretz, T.A. 1974. Evaluation of experimental herbicides on container-grown nursery stock. Res. Sum. Ohio. Ag. Res. And Dev. Cent. 79:29-32.

Gallatino, L.B. and W.A. Skorch. 1993. Herbicide efficacy for production of container ornamentals. Weed Technol. 7:103-107.

Gilliam, C.H., W.J. Foster, J.L. Adrain, and R.L. Shumack. 1990. A survey of weed control costs and strategies in container production nurseries. J. Environ. Hort. 8:133-135.

Glenn, J.S., C.H. Gilliam, J.H. Edwards, G.J. Keever and P.R. Knight. 2000.Recycled waste paper mulch reduces available container N. J. Environ. Hort. 18:188-191.

Horowitz, M. and C.L. Elmore. 1991. Leaching of oxyfluofen in container media. Weed Technol. 5:175-180.

Judge, C.A., J.C. Neal, and J.B. Weber. 2004. Dose and concentration responses of common nursery weeds to Gallery, Surflan and Treflan. J. Environ. Hort. 22:106-112.

Llewellyn, J., K. Osborne, C. Steer-George, J. West. 2003. Commercially available organic mulches as a weed barrier for container production. Comp. Proc. Intl. Plant Prop. Soc. 53:590-593.

Moles, A. and C.E. Whitcomb. 1976. Movement of ronstar in containers as influenced by growing media. Proc. SNA Res. Conf. 21:137.

Norcini, J.C., and J.H. Aldrich. 1992. Spotted spurge control and phytotoxicity to daylily from preemergence herbicides. J. Environ. Hort. 10:14-17.

Pellet, N.E. and D.A. Heleba. 1995. Chopped newspaper for weed control in nursery crops. J. Environ. Hort. 13:77-81.

Porter, W.C. and R.L. Parish. 1993. Nontarget losses of granular herbicide applied to container-grown landscape plants. J. Environ. Hort. 11:143-146.

Simpson, C.V., C.H. Gilliam, J.E. Altland, G.R. Wehtje, and J.L. Sibley. 2004. Postemergence *Oxalis* control in container-grown plants. J. Environ. Hort. 22:45-49.

Smith, D.R., C.H. Gilliam, J.H. Edwards, D.J. Eakes, and J.D. Williams. 1997. Recycled waste paper as a landscape mulch. J. Environ. Hort. 15:191-196.

Timmons, F.L. 1969. A history of weed control in the United States and Canada. Weed Sci. 14:294-307.

Wang, C.H., D.L. Willis, and W.D. Loveland. 1975. Radiotracer methodology in the biological environmental and physical sciences. Prentice-Hall Inc. Englewood Cliff, NJ.

Wehtje, G.R., C.H. Gilliam, and B.F. Hajek. 1993. Adsorption, desorption, and leaching of oxadiazon in container media and soil. HortScience. 28:126-128.

Wehtje, G.R., C.H. Gilliam, and B.F. Hajek. 1994. Adsorption, desorption and leaching of oryzalin in container media and soil. HortScience. 29:824.

Wilcut, J.W., C.H. Gilliam, G.R. Wehtje, and D.C. Fare. 1989. Grass control in container grown ornamentals with pre- and postemergence herbicide combinations. HortScience 24:456-459.

Wilcut, J.W., C.H. Gilliam, G.R. Wehtje, and D.C. Fare. 1991. Yellow nutsedge control in landscape plants. HortScience 26:159-162.

Williams W., G. R. Wehtje, and R. H. Walker. 2003. CGA-363622: Soil behavior and foliar versus root absorption by torpedograss. Weed Technol. 17:366-372.

Williams W., G. R. Wehtje, and R. H. Walker. 2004. Quinclorac: Soil behavior and foliar versus root absorption by torpedograss. Weed Technol. 18:404-411.

Zimdahl, R.L. 1983. Weed science- a brief historical perspective. Weed Today. 14:10-11.