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PRELIMINARY EVALUATION OF NONSYNTHETIC HERBICIDES FOR WEED MANAGEMENT IN ORGANIC ORANGE PRODUCTION

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Abstract. **A method of using cover crops for suppression of weeds in the row middles of organically grown oranges is being developed. However, weed control within tree rows is currently accomplished by cultivation, which is time consuming and tedious. Alternative weed management methods are being sought that would be less labor intensive and equally or more effective than cultivation. The objectives were to compare the efficacy of three nonsynthetic, postemergence, contact herbicides (Alldown, Matran 2, and Xpress) with that of corn gluten meal applied preemergence, and flaming for weed control in organic citrus production. Also of interest was whether weed control could be improved by a pretreatment of mowing or tillage. The response with mowing and no pretreatment differed from the response with tillage. The most effective treatment with mowing and no pretreatment was flaming with 97% control 1 week after application (WAA) and declining to 79% by 3 WAA. Alldown and a 20% concentration of Matran 2, provided better than 70% weed control within the first week, but decreased to less than 60% by 3 WAA. With tillage as a pretreatment, corn gluten meal, 20% Matran 2, and flaming provided the best weed suppression of 68 to 75%, during the 5 weeks after application. Inconsistent results obtained with Xpress may be due to separation of the component oils from other ingredients in the product.**

Organic production is one of the fastest growing components of U.S. agriculture (USDA, 2002). With the rapid increase in production area, there is a pressing need for development of production methods and recommendations that are pertinent to organic production systems. Organic growers have identified cost-effective weed control as the most important production constraint (Walz, 1999). Currently, little or no information is available on alternative methods for weed control and/or evaluation of herbicides that are approved for organic production systems. With 6,056 acres in 2001 (USDA, 2002), citrus (*Citrus* spp.) is one of the more important crops grown organically in Florida. A method of using cover crops for suppression of weeds in citrus row middles is being developed (Linares et al., 2003). However, weed control within the tree rows is currently accomplished by cultivation, which is time consuming, tedious, and may also damage the root systems of the trees. Alternative weed management methods are being sought that would be less labor intensive and equally or more effective than cultivation.

Some nonsynthetic herbicidal materials are now available, the ingredients of which have been reviewed by the Organic Materials Review Institute (OMRI) and approved for use in certified organic production (Table 1). OMRI does not evaluate products for efficacy, but simply ensures that their constituents meet the requirements of the National Organic Program (OMRI, 2003). Matran 2™ and Xpress™ contain the essential oils of thyme and/or clove, which are eligible active ingredients for use in formulating minimum risk pesticide products and so are exempt from registration by the US Environmental Protection Agency. Alldown™ and Ground Force™ (a more recent addition to the OMRI list that was not evaluated in this study) claim citric acid and garlic as their active ingredients and these are also approved for use in minimum risk herbicides. These two herbicides also list vinegar (acetic acid) as among their "other ingredients". Acetic acid is considered a minimal risk inert ingredient but is not a permitted active ingredient for minimum risk herbicides (USEPA, 2000).

USDA scientists have demonstrated that vinegar at 10 to 20% acetic acid concentration gave 80 to 100% weed control and was more effective than 5% acetic acid (the concentration in food use vinegars) (Comis, 2002). However, because acetic acid at these concentrations does not qualify as minimum risk pesticide, it cannot be marketed or recommended

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Table 1. Summary of active ingredients, product concentrations used in treatments, and treatment codes used on figures.

Product	Active ingredients	Concentration used (%)	Treatment code	Product source or manufacturer
Control	None	None	CHK	N/A
Alldown	Citric acid (5%), garlic (0.2%)	Undiluted	AD	Summerset Products, Inc.
Ground Force[z]	Citric acid (10%), garlic (0.2%)	—	—	Abby Laboratories, Inc.
Matran 2	Clove oil (45.6%)	10	M1	EcoSMART Technologies
		15	M2	
		20	M3	
Xpress	Thyme (10.4%) and clove (10.1%) oils	8	X1	BioHumaNetics, Inc.
		12	X2	
		16	X3	
Bioweed	Corn gluten meal (98%)	granular/soil applied	CGM	Environmental Factor
Flame torch	N/A	None	FLM	Flame Engineering, Inc.

[z]Ground Force is OMRI approved but was not used in this study.

by extension personnel for herbicidal use until it has been registered as a pesticide by the USEPA.

Pretreatments of mowing or tillage were included in the study because the labels of two of the postemergence products (Matran 2 and Xpress) state that effectiveness decreases as weeds mature, and also because a third preemergence product (corn gluten meal) is effective only on germinating seedlings (Christians, 1991). The objective of the study was to compare the efficacy of three OMRI-listed postemergence contact herbicides, corn gluten meal, and flaming for weed control when applied to areas mowed or tilled to stimulate new growth or to a natural weed infestation that received no pretreatment.

Materials and Methods

The experiment was conducted on certified organic land at the Plant Science Research and Education Unit in Citra, Florida, on an area adjacent to the organic orange grove with the aim of including a range of weed species representative of those that occur in the grove. The experimental design was a split plot with main plot pretreatments of mowing and tillage and a natural weed infestation (no pretreatment), arranged in a randomized complete block with 4 replications. On 25 Sept. 2003, weeds in main plots were either mowed to approximately 4 inches, disked to completely incorporate weeds, or left with a natural infestation.

Weed control treatments were applied to the subplots in a completely randomized manner. The ten subplot treatments consisted of Alldown (undiluted) (SummerSet Products, Inc., Bloomington, Minn.), Matran 2 (EcoSMART Technologies, Franklin, Tenn.) as 10, 15, and 20% sprays, Xpress (BioHumaNetics, Inc., Chandler, Ariz.), as 8, 12, and 16% sprays, corn gluten meal (CGM) (Bioweed, Environmental Factor, Oshawa, Ontario) at 0.2 kg m^{-2}, flaming, and a nontreated check (Table 1). Flaming was done with a hand-held propane torch (Flame Engineering, Inc., LaCrosse, Kans.) and nonsynthetic herbicides were applied using knapsack sprayers. The OMRI-listed surfactant ThermX-70 (Cellucon, Inc., Strathmore, Calif.) was included with Matran 2 and Xpress treatments at 0.14 L ha^{-1}. Subplot size was 3 m × 3 m with 1.5 m between subplots and 3-m alleys between main plots to reduce the possibility of herbicide drift. Herbicidal sprays were applied at 468 L ha^{-1}. CGM was applied by hand two weeks after the main plot pretreatments on 10 Oct. with care taken to remove any weeds that had germinated or sprouted in the tilled plots. The experiment was then overhead irrigated to activate the CGM and to stimulate weed germination and growth in the other plots. All other subplot treatments were applied one week later on 17 Oct. when bahiagrass (*Paspalum notatum* Fluegge) was approximately 10 cm tall and Florida pusley (*Richardia scabra* L.) was 2.5-5 cm tall.

Efficacy and persistence of weed control were evaluated 4, 7, 20, and 35 d after the foliar applications using the 0 to 100% rating system in which 0 indicates no control, 50% moderate weed control, and 100% complete weed destruction (Frans et al., 1986). Data were analyzed using the Mixed and Regression procedures of SAS/STAT software, Version 8 (SAS System for Windows, SAS Institute, Inc., Cary N.C.).

Results and Discussion

The primary weed species were tropical spiderwort (*Commelina benghalensis* L.), Florida pusley (*Richardia scabra* L.), bahiagrass (*Paspalum notatum* Fluegge), mexicantea (*Chenopodium ambrosioides* L.), and southern sida (*Sida acuta* Berm. f.). The tilled plots had predominantly bahiagrass regrowth and germinating Florida pusley. There was a significant interaction between main plot treatments, subplot treatments and time ($P < 0.05$). This was primarily due to a differential response with tillage compared with mowing and natural weed infestation (no pretreatment). Therefore, the data for mowed pretreatment and no pretreatment were analyzed together and tillage data were analyzed separately.

Weed control with the mowing pretreatment and no pretreatment was 35% and 40%, which were not statistically different. The response to the subplot treatments differed with time of evaluation ($P < 0.05$). The most effective weed control treatment was flaming, which gave 97% control within the first week of application (Fig. 1) and by 2 weeks later control was 79% and still significantly better than all of the other weed control treatments. Susceptibility of weeds to flaming depends on the size of the plants, thickness of leaves, and whether growing points are protected (Ascard, 1995). Larger plants require larger doses of propane and plants with protected growing points recover after a single treatment.

Injury with Xpress occurred more rapidly (data not shown) and weed control was more effective with the 8% concentration than with the higher concentrations of Xpress (Fig. 1). This was unexpected and could possibly be due to insufficient shaking of the product prior to dispensing. The label

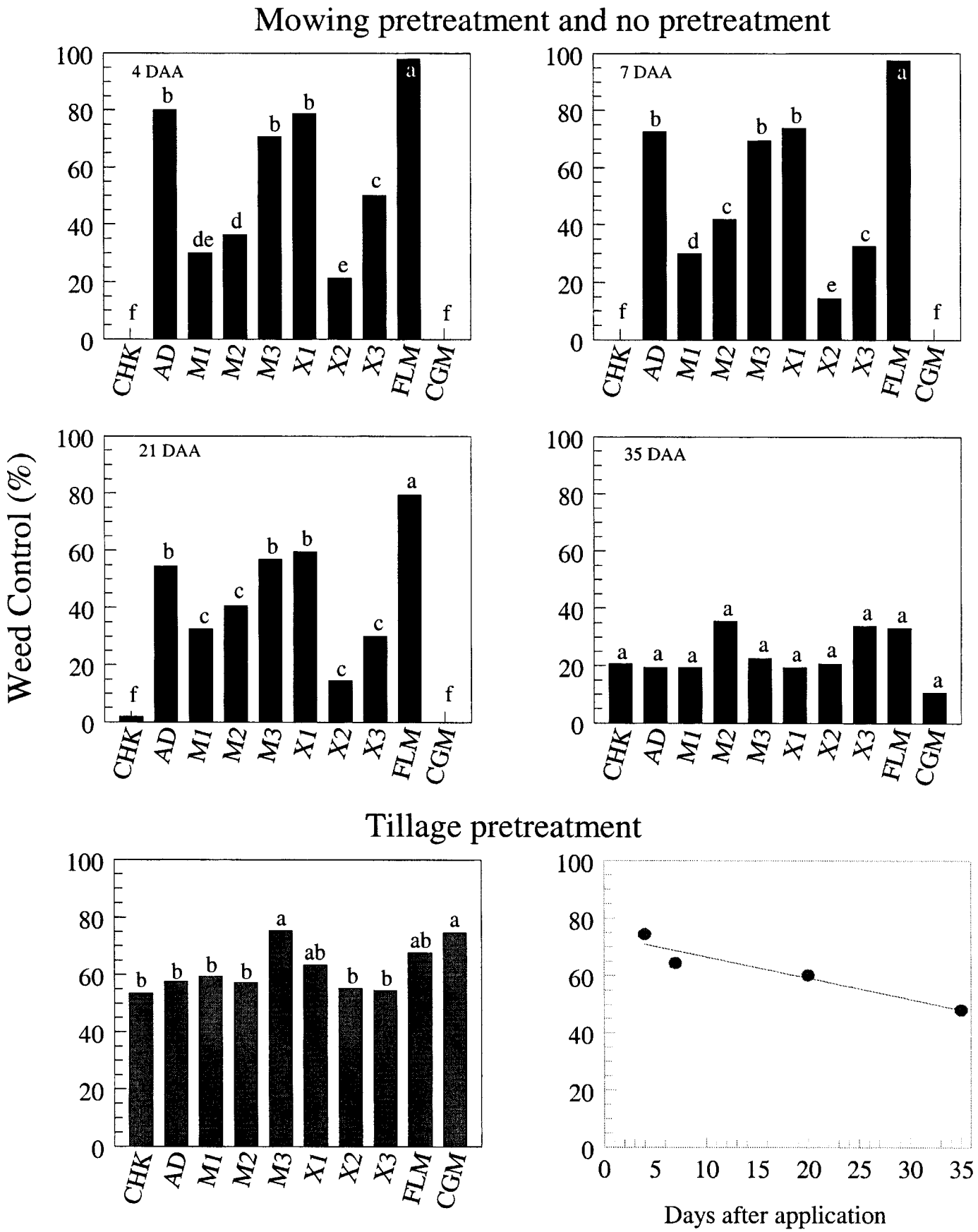

Fig. 1. Weed suppression with nonsynthetic herbicides, corn gluten meal and flaming following a mowing pretreatment and no pretreatment 4, 7, 21, and 35 days after spray and flame applications (DAA), and weed suppression following a tillage pretreatment. Mean separation was done using the lsmeans/pdiff option of Proc Mixed or linear regression. Linear decline in suppression of weed regrowth over time with nonsynthetic herbicides, corn gluten meal and flaming following tillage: $y = -0.74x + 74$, $R^2 = 0.9$.

states that the product should be shaken prior to use and that constant tank agitation is needed to ensure a homogenous spray mixture. The oils in this product were not formulated into an emulsion as was the case with Matran 2. The lowest concentration spray was prepared first and may have received a higher proportion of the active ingredients. Alternatively, if the oils are not miscible, the 8% Xpress treatment may have received a higher proportion of less miscible yet more active ingredients of the product. Clove oil was shown to cause more injury to johnsonsongrass than thyme oil (Tworkoski, 2002). The high level of control obtained with the flawed 8% rate suggests potential for control that could be realized with improved formulation of the herbicide to minimize such errors.

Within 4 d of application weed control with Alldown and the 20% concentration of Matran 2 was 80% and 71%, respectively, with all other treatments providing moderate to poor control (Fig. 1). By 3 weeks after application control with Alldown and 20% Matran 2 had declined to moderate levels of 54% and 57%, respectively. By 5 weeks after application weed suppression with all herbicidal treatments had declined to less than 36% and were not significantly different from the control and the CGM treatments in which summer annual weeds had begun to undergo senescence.

With the disking pretreatment the main effects of herbicidal treatment and time of evaluation were significant ($P < 0.05$) and their interaction was not significant. Therefore, Fig. 1 shows the effect of herbicidal treatments averaged over all times of evaluation. Matran 2 at 20%, flaming and CGM were the most effective with statistically similar weed suppression of 68% to 75%. Moderate weed suppression from 53% to 60% was obtained with all other treatments including the check. Tillage contributed considerably to weed suppression obtained with the subplot treatments since control in the nontreated check was 53%. No improvement in weed control was obtained with Alldown and the lower rates of Matran 2. Four days after application (DAA), weed control averaged over all herbicidal treatments was 75% and declined linearly to 48% 5 weeks after application ($y = 74 - 0.74$, $R^2 = 0.9$ where y is percent weed control for x ranging from 4 to 35 DAA).

Ferguson (2003) attributed poor control with the nonsynthetic herbicides to fall application to large weeds at the end of their growing season. Two of the manufacturers recommend application to actively growing weeds of up to 10 cm tall. Our use of tillage and irrigation resulted in germination and active growth of bahiagrass and Florida pusley. However, the small enhancement of control over that provided by tillage alone may not justify the cost of application. Since these are contact herbicides, several applications of the more active products may serve to better suppress the multiple flushes of weeds that generally arise following tillage and to more effectively suppress perennial weeds such as the bahiagrass that can resprout from subsurface perennating organs.

The herbicidal treatments and flaming appear to give better and longer lasting weed suppression with tillage as a pretreatment than with a pretreatment of mowing or no pretreatment. This suggests that reapplication of the herbicides and flaming would need to be done less frequently when an initial tillage pretreatment is utilized.

Essential oils from clove, thyme, summer savory, and cinnamon have previously been demonstrated to injure weeds at a concentration of 1%. However, concentrations of 5 and 10% and complete coverage were needed to completely kill plants (Tworkoski, 2002). It may be possible to improve the efficacy of the nonsynthetic herbicides by ensuring the concentration of the oils in the sprays are 5 to 10%, by use of appropriate adjuvants to ensure proper dispersal of the oils in the spray, and by using a sufficient spray volume to ensure complete coverage of sprayed plants.

These results are preliminary since they are based on just one experiment. Within this limitation it can be concluded that older, larger weeds, such as those present with the mowing pretreatment and no pretreatment, are more effectively controlled and for a longer duration with flaming than with recommended rates of nonsynthetic herbicides. The nonsynthetic herbicides may be best utilized in a stale seed-bed approach: following tillage as a pretreatment to control larger mature weeds, a herbicidal spray such as 20% concentration of Matran 2 should be applied to the young newly emerged weeds. CGM applied preemergence was also effective in suppressing weed germination. A follow-up study is in progress to further assess the efficacy of a tillage pretreatment with subsequent nonsynthetic herbicide application and the duration of control that can be obtained with this approach. Xpress will be reevaluated with proper attention to product and spray agitation.

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