Fertilizer Placement and Herbicide Rate Affect Weed Control and Crop Growth in Containers[1]

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Abstract

Three experiments were conducted in Oregon and Mississippi to evaluate the effect of fertilizer placement and rate of herbicide application on weed control and crop growth. In Expt. 1, Osmocote 18N–2.6P–10.0K (18–6–12) controlled release fertilizer (CRF) was applied at 12 g (0.4 oz) per container (#1) either topdressed, incorporated, or dibbled (placed under the liner prior to potting); and OH2 (pendimethalin + oxyfluorfen) was applied at 0, 28, 56, or 112 kg/ha (0, 25, 50, or 100 lbs/A). Containers were overseeded with common groundsel (*Senecio vulgaris*). In Expt. 2, Osmocote 17N–3.0P–10.1K (17–7–12) CRF was applied at 18 g (0.6 oz) per container using the same placement methods as Expt. 1; and Rout (oryzalin + oxyfluorfen) was applied at 0, 28, 56, or 112 kg/ha (0, 25, 50, or 100 lbs/A). A hand-weeded check was also included, and containers were overseeded with prostrate spurge (*Chamaesyce prostrata*). In Expt. 3, containers were fertilized with either 12 g (0.4 oz) of Apex 20N–4.3P–8.4K (20–10–10) CRF or 14 g (0.5 oz) of Apex 17N–2.2P–9.2K (17–5–11) CRF using similar fertilizer placement methods; and Snapshot 2.5TG (isoxaben + trifluralin) was applied at 0, 84, or 168 kg/ha (0, 75, or 150 lb/A). Containers were overseeded with creeping woodsorrel (*Oxalis corniculata*). Weed control improved with increasing herbicide rate. Across the three experiments, dibbling CRFs with no herbicide resulted in 85 to 97% weed control, while topdressing resulted in 19 to 85% and incorporating resulted in 55 to 88% control. With herbicides, dibbling fertilizer resulted in 89 to 99% weed control while topdressing resulted in 82 to 90% and incorporating 81 to 98%. Dibbling fertilizer resulted in greater shoot growth (growth index) of azalea (*Rhododendron* 'Stewartsonian'), holly (*Ilex crenata* 'Compacta'), lavender (*Lavandula* ×*intermedia* 'Grosso'), and wintercreeper euonymus (*Euonymus fortunei* 'Emerald Gaiety'). In Expt. 3, incorporating CRFs resulted in higher root ratings than dibbling in lavender and euonymus. Though measurable differences in root and shoot growth were observed in all experiments, differences were economically unimportant.

Index words: dibble, topdress, incorporate, controlled release fertilizer.

Species used in this study: azalea (*Rhododendron* 'Stewartsonian'); holly (*Ilex crenata* 'Compacta'); lavender (*Lavandula* ×*intermedia* 'Grosso'); wintercreeper euonymus (*Euonymus fortunei* 'Emerald Gaiety').

Herbicides used in this study: Ornamental Herbicide 2 (pendimethalin + oxyfluorfen), *N*-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine + 2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl)benzene; Rout (oryzalin + oxyfluorfen), 4-(dipropylamino)-3,5-dinitrobenzenesulfonamide +2-chloro-1-(3-ethoxy-4- nitrophenoxy)-4-(trifluoromethyl)benzene; Snapshot 2.5TG (isoxaben + trifluralin), *N*-[3-(1-ethyl-1-methylpropy1)-5-isoxazoly1]-2,6-dimethoxybenzamide + 2,6-dinitro-*N*,*N*-dipropyl-4-(trifluoromethyl)benzenamine.

Significance to the Nursery Industry

Nursery growers rely on preemergence herbicides for weed control. Even when applied correctly, preemergence herbicides sometimes fail to provide adequate control. Herbicide failure is likely a result of cultural and environmental factors that either compromise the integrity of the herbicidal barrier over the substrate surface, or accelerate herbicide degradation. Herbicides can also fail because the weed has some tolerance to the herbicide applied. Data herein indicated that controlled release fertilizer (CRF) placement influences weed control with herbicides. Dibbling fertilizers (placement of the fertilizer below the liner rootball while potting) reduced germination of common groundsel (*Senecio vulgaris*) and prostrate spurge (*Chamaesyce prostrata*), and reduced subsequent growth of these species and creeping woodsorrel (*Oxalis corniculata*). Dibbling fertilizer reduced weed establishment and growth across herbicide rates compared to topdressing or incorporating. Dibbling CRFs resulted in excellent weed control at reduced herbicide rates, suggesting herbicide rates could be reduced with changes in fertilizer management. Generalizing across three experiments, dibbling fertilizer resulted in similar crop shoot growth compared to topdressing CRFs, and slightly improved growth compared to incorporating. Understanding how cultural practices like fertilizer placement affect weed control with commonly used herbicides will help growers manage their crops and weed control program.

Introduction

Successful weed management is necessary to produce saleable container crops. Weed control in container production is achieved primarily through use of preemergence herbicides in conjunction with some hand-weeding. Preemergence herbicides are expensive and are not 100% effective. To improve weed control, growers and weed scientists often evaluate new herbicides, higher herbicide rates, or different herbicide combinations. However, new herbicides are costly and time consuming to develop; higher herbicide rates will result in increased herbicide costs and potential crop injury; and combining herbicides further complicates application to species where herbicide tolerance is a concern.

Cultural practices and environmental factors influence weed and crop growth. Placement of controlled release fertilizers (CRFs) changes the spatial availability of nutrients in containers, and thus could affect weed growth. Fertilizer

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placement in fields affected weed growth in several cropping systems. Everaarts (8) reported that banding fertilizers near the crop in sandy loam or loamy sand soils resulted in reduced weed growth compared to broadcast applications. Banding fertilizers below drilled wheat seed (*Triticum aestivum*) reduced grass weed growth compared to broadcast surface applications in some tillage systems (5). Similar results were observed in littleseed canarygrass (*Phalaris minor*) (1).

In container production, CRFs are commonly applied by one of three placement methods: topdressing (applying CRFs on the surface of the substrate after potting), incorporating (mixing CRFs into the substrate prior to potting), or dibbling (placing CRFs just below the liner rootball while potting). Fertilizer placement affects crop growth in containers. Meadows and Fuller (15) reported dibble placement of Osmocote 18N–2.6P–10.0K (18–6–12) and 17N–3.0P–10.1K (17–7–12) resulted in faster plant 'green-up' and superior plant quality compared to topdressing and incorporation. In a separate but similar study, Meadows and Fuller (16) reported dibbling and topdressing CRFs to provide superior plant quality compared to incorporating for three azaleas ('Formosa', 'Daphne Salmon', and 'Fielder's White'), cleyera (*Cleyera japonica*), gardenia (*Gardenia jasminoidies* 'Mystery'), and dwarf yaupon holly (*Ilex vomitoria* 'Nana'). A similar study reported dry weight of holly (*Ilex crenata* 'Green luster') fertilized with 8.9 kg/m^3 (1.5 lbs/yd^3) of Osmocote 18N–2.6P–10.0K (18–6–12) to be greater when dibbled or topdressed compared to incorporated, although there were no differences between placement methods when higher N rates were used (1.8 kg/m^3 (3 lb N/yd^3)). Broschat and Moore evaluated crop and weed growth as a result of fertilizer placement in ten tropical plants (4). Dibbling (authors used the term 'layering'), compared to topdressing and incorporating, resulted in similar or greater shoot and root growth among all species except areca palm where incorporating provided superior growth. Dibbling resulted in reduced weed growth compared to topdressing among four of the species, but no difference among the other six.

Fertilizer placement also affects seedling establishment. Seed require available nutrients for establishment and subsequent growth. For example, begonia seed require dilute liquid feed immediately after germination because small seed size results in low nutrient reserve in the seed, and leaching of nutrients below the top 0.6 cm (0.25 in) of the seed flat may cause severe stunting of recently germinated seedlings (2). Physiological tradeoffs prevent most plants from adapting to environments of high and low nutrient availability. Most agricultural weeds are at one end of this adaptive continuum, in that they generally outcompete other crops in high nutrient environments but compete poorly in low nutrient environments (13). Bark is the primary component used in outside container production. Bark substrates are inherently low in available nutrients (12). Without a fertilizer source, weed seedling establishment and growth would be limited. When CRFs are used as the sole source of nitrogen (N), phosphorus (P), and potassium (K) in containers, placement (topdressed, incorporated, or dibbled) should affect the level of available nutrients on the container surface, thus affecting weed seedling establishment and subsequent growth.

Little research has addressed the effects of cultural practices on weed growth and herbicide effectiveness in container production. The objective of this research was to determine the effect of fertilizer placement on weed seedling establishment and growth in container crops.

Materials and Methods

Experiment 1. The first experiment was conducted at the North Willamette Research and Extension Center (NWREC) in Aurora, OR. Azaleas (*Rhododendron* 'Stewartsonian') were potted on April 30, 2002, in 3.7 liter (#1) containers with Douglas fir bark amended with 0.9 kg/m (1.5 lbs/yd^3) Micromax (Scotts Co., Marysville, OH) micronutrients. Treatment design was a 3 × 4 factorial, with 3 fertilizer placement methods and 4 herbicide rates. Osmocote 18N–2.6P–10.0K (18–6–12; Scotts Co.) CRF was applied at potting at 12 g (0.4 oz) per container either topdressed, incorporated, or dibbled. Topdressed fertilizers were placed on the container surface, incorporated fertilizers were premixed into the bark just prior to potting, and dibbled fertilizers were placed immediately beneath the root ball of azalea liners, 8 cm (3.1 in) below the container surface. Azaleas were selected for uniformity from a larger group and were approximately 19 cm (7.5 in) tall and 18 cm (7 in) wide at potting. On May 7, 2002, Ornamental Herbicide 2 (OH2, oxyfluorfen + pendimethalin; Scotts Co.) was applied at 0, 28, 56, or 112 kg/ha (0, 25, 50, or 100 lbs/A). Herbicides were applied with a handheld shaker. Applications were followed immediately by 1.3 cm (0.5 in) of irrigation, and containers were overhead irrigated with 1.3 cm/day thereafter.

Approximately 60 common groundsel (*Senecio vulgaris*) seed per container were applied May 8, 2002. Data collected included weed counts 1, 3, 5, and 8 weeks after herbicide treatment (WAT), weed height of the tallest common groundsel seedling in each container 3, 5, and 8 WAT, weed control ratings on a scale from 0 to 100 (visual estimation of the percent of container surface not covered by weeds) 5 and 8 WAT, weed shoot fresh weight (SFW) and dry weight (SDW) 8 WAT, azalea quality rating on a scale from 1 to 10 (where 1 = poor quality and 10 = excellent quality) 8 WAT, and azalea growth index [(height + width + width) ÷ 3] 8 WAT. Data were subjected to analysis of variance, regression analysis, and means were separated with Duncan's multiple range test ($\alpha = 0.05$). Weed counts were square root transformed prior to analysis; however, actual values are reported in tables and text. The experiment was arranged in a completely randomized design with 8 single pot replications per treatment combination.

Experiment 2. Expt. 2 was conducted similarly to Expt. 1 with the following exceptions. The experiment was conducted at the Truck Crops Branch Experiment Station in Crystal Springs, MS. Holly (*Ilex crenata* 'Compacta') were potted on May 18, 2002, in pinebark:sand (8:1 by vol) medium amended with 3.0 kg/m^3 (5 lb/yd^3) of dolomitic limestone and 0.9 kg/m^3 (1.5 lb/yd^3) of Micromax (Scotts Co.) micronutrients. Rout (oxyfluorfen + oryzalin; Scotts Co.) was applied May 19, 2002, using the same rates applied in Expt. 1 with the addition of a hand-weeded check. Osmocote 17N–3.0P–10.1K(17–7–12) CRF was applied at 18 g (0.6 oz) per container; and was placed 7.5 cm (3.0 in) below the container surface for the dibbled treatments. Containers were overseeded with 20 prostrate spurge (*Chamaesyce prostrata*) seed per container. Data collected included prostrate spurge counts 4 and 8 WAT, weed control ratings 8 WAT, weed SDW 12 WAT, and holly growth index 12 WAT.

Table 1. **Effect of fertilizer placement and herbicide rate on common groundsel (*Senecio vulgaris*) growth in containers (Expt. 1).**

Treatment	Weed number[z] 3 WAT[y]	Weed number[z] 8 WAT	Weed height (mm) 8 WAT
Feritlizer placement			
Topdressed	14.3a[x]	19.8a	243.0a
Incorporated	10.4b	10.7ab	190.1a
Dibbled	10.4b	7.1b	54.2b
OH2[w] (kg/ha)			
0	19.1	29.0	252.9
28	12.8	9.7	166.6
56	10.7	7.8	166.0
112	4.4	3.5	64.2
	L***	L**	L**
Main effects			
Fertilizer placement	*	*	***
Herbicide rate	***	***	***
Interaction	NS	NS	NS

[z]Weed numbers were square root transformed prior to analysis, actual values are presented.

[y]Weeks after herbicide treatment.

[x]Means with different letters are significantly different, separated by Duncan's Multiple Range test ($\alpha = 0.05$).

[w]Ornamental Herbicide 2 (Scotts Co., Marysville, OH).

L and NS represent linear and nonsignficant rate response, respectively.

*, **, and *** represent significance where $P \leq 0.05$, 0.01, and 0.001.

Experiment 3. Expt. 3 was conducted at the NWREC with methods similar to those used in Expt. 1 with the following exceptions. Lavender (*Lavandula ×intermedia* 'Grosso') and euonymus (*Euonymus fortunei* 'Emerald Gaeity') were potted June 26, 2002. At the time of planting, lavender were approximately 6.5 cm (2.6 in) tall and 5 cm (2.0 in) wide, and euonymus were approximately 13 cm (5.1 in) tall and 10.5 cm (4.1 in) wide. Treatment design was a 2 × 3 × 3 factorial with 2 fertilizer types, 3 fertilizer placements, and 3 herbicide rates. Containers were fertilized with either 12 g (0.4 oz) of Apex 20N–4.3P–8.4K (20–10–10; Simplot Turf and Horticulture, Lathrop, CA) CRF (8 to 9 month release) or 14 g (0.5 oz) of Apex 17N–2.2P–9.2K (17–5–11) CRF (12 to 14 month release). Rates differed between CRF types to supply the same quantity of N. Dibbled fertilizers were placed 5.5 cm (2.2 in) below the container surface among lavender, and 6.0 cm (2.4 in) below the container surface among euonymus. Snapshot 2.5TG (isoxaben + trifluralin; Dow Agrosciences, Indianapolis, IN) was applied at 0, 84, or 168 kg/ha (0, 75, or 150 lb/A). Containers were overseeded each with 10 creeping woodsorrel (*Oxalis corniculata*) seed. Data collected included weed counts 4 and 6 WAT, weed control ratings 6 and 10 WAT, weed SFW and SDW 10 WAT, lavender and euonymus growth index 10 WAT, and lavender and euonymus root ratings 16 WAT. The experiment was arranged in a completely randomized design with five single pot replications per species per treatment combination; species were randomized separately.

Results and Discussion

Experiment 1. Fertilizer placement and herbicide rate affected common groundsel establishment and growth. There were no interactions between fertilizer placement and herbicide rate with respect to weed numbers (Table 1). Weed numbers decreased linearly with increasing herbicide rate throughout the experiment. At 3 and 8 WAT, weed numbers were higher in topdressed containers compared to dibbled. In other research, OH2 provided excellent control of common groundsel when fertilizers were incorporated in year 1, and complete control the following year when apparently little supplemental fertilizer was applied (a single application of 7.8 ml of Sta-Green 20N–2.2P–8.4K (20–5–10; Sta-Green Plant Food Co., Sylacauga, AL)) (9). Work by Derr (6) seems to contradict our findings in that he reported 0 common groundsel germination 12 WAT in topdressed containers, though it was not disclosed how many seed were applied in that study. Similarly, Hood et al. (11) reported excellent common groundsel control in topdressed containers with the recommended rate of Rout (112 kg/ha (100 lb/A)) though that study overseeded 10–12 seed per container, which likely resulted in less weed pressure than our study. Hepburn et al. (10) demonstrated that greater seed numbers result in greater weed pressure and increased weed germination.

Weed height was measured as a non-destructive gauge of weed growth. Throughout the study, fertilizer placement affected weed height, with weeds tallest in topdressed containers and shortest in dibbled containers (Table 1). Weed height decreased linearly with increasing herbicide rate throughout the study. Differences in weed height are likely due to lower nutrient availability along the container surface in dibbled verse topdressed containers, and increasingly stunted root systems with increasing herbicide rate.

CRF placement and herbicide rate interacted to affect weed control ratings. By 8 WAT, weed control in topdressed and incorporated containers increased linearly with increasing herbicide rate (and quadratically for topdressed containers) (Table 2). In topdressed and incorporated containers, the rec-

Table 2. **Effect of fertilizer placement and herbicide rate on common groundsel (*Senecio vulgaris*) control in containers (Expt. 1).**

OH2[y] rate (kg/ha)	Topdressed	Incorporated	Dibbled
	4 WAT[z]		
0	34[x]	80	97
28	82	92	98
56	87	88	98
112	98	98	100
	L***Q***	L*	NS
	8 WAT		
0	19[w]	55	85
28	65	79	89
56	75	71	95
112	86	92	97
	L***Q***	L***	NS

[z]Weeks after herbicide treatment.

[y]Ornamental Herbicide 2 (Scotts Co., Marysville, OH).

[x]$LSD_{0.05} = 13$, calculated with Fisher's protected LSD test to compare treatment means 4 WAT.

[w]$LSD_{0.05} = 18$, calculated with Fisher's protected LSD test to compare treatment means 8 WAT.

L, Q, and NS represent linear, quadratic, and nonsignficant rate response, respectively.

*, **, and *** represent significance where $P \leq 0.05$, 0.01, and 0.001.

Table 3. Effect of fertilizer placement and herbicide rate on common groundsel (*Senecio vulgaris*) shoot fresh weight[z] (g) in containers (Expt. 1).

OH2[y] (kg/ha)	Topdressed	Incorporated	Dibbled
0	39.2[x]	21.2	7.0
28	17.3	10.9	5.1
56	12.5	17.3	1.3
112	6.2	2.4	0.1
	L***Q**	L***	NS

[z]Shoots harvested 8 weeks after herbicide treatment.

[y]Ornamental Herbicide 2 (Scotts Co., Marysville, OH).

[x]$LSD_{0.05}$ = 10.0, calculated with Fisher's protected LSD test.

L, Q, and NS represent linear, quadratic, and nonsignficant rate response, respectively.

*, **, and *** represent significance where P ≤ 0.05, 0.01, and 0.001.

ommended herbicide rate (112 kg/ha (100 lb/A)) provided acceptable control (86 and 92%, respectively) while less than the recommended rate provided poor control. Weed control in containers where CRFs were dibbled did not respond to herbicide rate, and averaged 91.5% control across herbicide rates. Even when no herbicide was used in these containers, weed control was acceptable (>90%).

Weed SFW and SDW were highly correlated (r = 0.98) and thus only SFW is presented (Table 3). Fertilizer placement and herbicide rate interacted to affect weed SFW. In topdressed or incorporated containers, weed SFW decreased linearly with increasing herbicide rate. For both of these fertilizer placement methods, weed SFWs were sufficiently low in containers with the recommended herbicide rate, however, weed growth was unacceptably high with lower herbicide rates. Contrary to this, weed SFW in containers where CRFs were dibbled did not respond to herbicide rate, primarily because weed SFWs were low in all containers regardless of herbicide rate. These data indicate that lower herbicide rates can be used if CRFs are dibbled and are the only source of nutrition.

Overall, dibbling fertilizers reduced weed establishment compared to topdressing, and weeds that established in dibbled containers grew slower and were smaller. Limited weed establishment and growth in containers where CRFs were dibbled is likely the result of low available nutrition on the container surface.

Incorporating CRFs reduced azalea growth index by 9% compared to dibbling and 11% compared to topdressing (Table 4). Azalea growth index increased linearly with increasing herbicide rate. Differences were small, not obvious by casual observation, and only revealed after statistical analysis. Across fertilizer placement methods, weed control also increased with increasing herbicide rate, suggesting competition from common groundsel resulted in reduced azalea growth. Berchielli-Robertson et al. (3) reported competition from container weeds reduced crop growth. Dibbling and topdressing CRFs resulted in higher quality ratings than incorporating, which concurs with Meadows and Fuller (15) who reported higher quality ratings of three azalea cultivars from dibbling compared to incorporating.

Experiment 2. No parameter was affected by interaction between herbicide rate and fertilizer placement (Table 5). Dibbled containers had fewer weed numbers 4 and 8 WAT compared to those topdressed or incorporated. Similar to Expt. 1, weed number decreased linearly and quadratically with increasing herbicide rate 4 and 8 WAT.

By 8 WAT, weed control in containers where fertilizers were dibbled remained high (>90%), while control in containers that were either topdressed or incorporated dropped below commercially acceptable levels. The Rout label recommends reapplication intervals not be less than 12 weeks. However, when CRFs were topdressed or incorporated, control was at best marginal by only 8 WAT. In Expts. 1 and 2, incorporation generally resulted in numerically greater, though statistically similar, weed control compared to topdressing (summarizing across all measure weed parameters). Previous research supports these observations. In two separate experiments evaluating Rout (among other products) for prostrate spurge control (both using *Euphorbia humistrata*), Ruter and Glaze (17) reported 86 and 96% control 8 and 12 WAT, respectively, after incorporating CRFs; while Whitwell and Kalmowitz (18) reported 52 and 59% control of prostrate spurge 8 and 12 WAT after topdressing CRFs. Fertilizer placement may explain some of the discrepancy between results in these two studies.

Weed SDW was 56 and 61% less in containers where CRFs were dibbled compared to topdressed and incorporated, respectively. Weed SDW decreased linearly and quadratically with increasing herbicide rate.

Holly growth index was greater in dibbled containers than topdressed or incorporated, though differences were not commercially important. Growth index increased linearly with increasing herbicide rate. Similar to Expt. 1, increased growth index was likely a result of reduced weed pressure in containers with higher herbicide rates.

Experiment 3. Fertilizer type had no effect on any weed control parameter except weed control 10 WAT (data not pre-

Table 4. Effect of fertilizer placement and herbicide rate on azalea growth index (Expt. 1).

Treatment	Growth[z] index (cm)	Quality[y] rating
Fertilizer placement		
Topdressed	33.0a[x]	6.7a
Incorporated	29.3b	5.5b
Dibbled	32.0a	7.0a
Ornamental Herbicide 2 (kg/ha)		
0	29.8	6.1
28	31.9	6.5
56	31.7	6.0
112	32.2	7.0
	L*	L*Q*
Main effects		
Fertilizer placement	***	***
Herbicide rate	*	**
Interaction	NS	*

[z]Growth index = (height + width + width) / 3.

[y]Quality rating on a scale from 1 to 10 where 1 = poor quality and 10 = high quality.

[x]Means with different letters are significantly different, separated by Duncan's Multiple Range test (α = 0.05).

L, Q, and NS represent linear, quadratic, and nonsignficant rate response, respectively.

*, **, and *** represent significance where P ≤ 0.05, 0.01, and 0.001.

Table 5. Effect of fertilizer placement and herbicide rate on spurge (*Chamaesyce prostrata*) growth in containers (Expt. 2).

Treatment	Weed number[z] 4 WAT[w]	Weed number[z] 8 WAT	Control (%) 8 WAT	Weed SDW[y] 12 WAT	Holly[x] growth index (cm)
Feritlizer placement					
Topdressed	2.0a[v]	1.2a	85b	6.4a	8.9b
Incorporated	1.8a	0.9a	88ab	7.2a	8.5b
Dibbled	0.9b	0.5b	93a	2.8b	9.7a
Handweed	0.0	0.0	100	0.0	9.4
Ornamental Herbicide 2 (kg/ha)					
0	3.2	1.6	69	11.4	8.7
28	1.8	0.8	94	4.9	9.1
56	1.0	0.8	94	4.5	8.7
112	0.3	0.4	99	1.1	9.3
	L***Q*	L***Q*	L***Q***	L***Q**	L*
Main effects					
Fertilizer placement	***	**	*	***	***
Herbicide rate	***	***	***	***	**
Interaction	NS	NS	NS	NS	NS

[z]Weed numbers were square root transformed prior to analysis, actual values are presented.
[y]Shoot dry weight (g).
[x]Growth index = (height + width + width) / 3.
[w]Weeks after herbicide treatment.
[v]Means with different letters are significantly different, separated by Duncan's Multiple Range test (α = 0.05).
L and NS represent linear and nonsignficant rate response, respectively.
*, **, and *** represent significance where P ≤ 0.05, 0.01, and 0.001.

sented). Weed control in containers fertilized with 17N–2.2P–9.2K (17–5–11, 12 to 14 month release) was greater than those fertilized with 20N–4.3P–8.4K (20–10–10, 8 to 9 month release) (90.3 vs. 81.9%, p = 0.0115). This is likely the result of increased available nutrients from 20N–4.3P–8.4K (20–10–10), which has a more rapid release rate.

Fertilizer placement did not affect weed numbers (Table 6). This result is different from the first two experiments where dibbling fertilizers reduced weed numbers compared to topdressing. Similar to the first two experiments, weed numbers decreased linearly with increasing herbicide rates.

By 6 WAT, weed control was greater in dibbled containers compared to topdressed, though weed control was high regardless of placement method. While fertilizer placement method did not affect weed establishment (weed numbers), those that did establish in dibbled containers grew poorly,

Table 6. Effect of fertilizer placement and herbicide rate on creeping woodsorrel (*Oxalis corniculata*) control (Expt. 3).

Treatment	Weed number[z] 4 WAT[x]	Weed number[z] 6 WAT	Weed control 6 WAT	Weed control 10 WAT	Weed SFW[y] (g)
Fertilizer placement					
Topdress	3.3a[w]	3.2a	95b	80b	14.9a
Incorporate	3.6a	3.5a	97ab	81b	12.9a
Dibble	3.0a	3.1a	99a	98a	6.7b
Snapshot rate (kg/ha)					
0	4.2	4.2	95	76	13.2
84	3.3	3.2	98	90	11.2
168	2.3	2.4	98	93	10.4
	L***	L***	NS	L***	NS
Main effects					
Placement method	NS	NS	*	***	***
Herbicide rate	***	***	NS	***	NS
Interaction	NS	NS	NS	*	NS

[z]Weed numbers were square root transformed prior to analysis, actual values are presented.
[y]Shoot fresh weight (g).
[x]Weeks after herbicide treatment.
[w]Means with different letters are significantly different, separated by Duncan's Multiple Range test (α = 0.05).
L and NS represent linear and nonsignficant rate response, respectively.
*, **, and *** represent significance where P ≤ 0.05, 0.01, and 0.001.

Table 7. **Creeping woodsorrel (*Oxalis corniculata*) control ratings[z] affected by herbicide rate and fertilizer placement measured 10 weeks after herbicide application (Expt. 3).**

Snapshot 2.5TG (kg/ha)	Topdress	Incorporate	Dibble
0	66[y]	65	97
84	90	81	99
168	84	96	99
	L***Q*	L***	NS

[z]Ratings on a scale from 0 to 100, where 0 = no control and 100 = complete control.

[y]$LSD_{0.05}$ = 14, calculated with Fisher's protected LSD test.

L and NS represent linear and nonsignficant rate response, respectively.

*, **, and *** represent significance where P ≤ 0.05, 0.01, and 0.001.

thus control ratings in those containers were higher. By 10 WAT, weed control was affected by an interaction between placement method and herbicide rate, and thus are reported in a separate table to better present the interaction (Table 7). Weed control increased linearly and quadratically with increasing herbicide rate in topdressed containers. Among topdressed containers, weed control was poor when no herbicide or the recommended rate (168 kg/ha (150 lb/A)) was used and marginal when ½ the recommended rate was used. Weed control in incorporated containers increased with increasing herbicide rate, with only the recommended rate providing acceptable control. Similar to Expt. 1, weed control in dibbled containers was excellent regardless of herbicide rate.

Lavender growth index and root ratings fertilized with Apex 20N–4.3P–8.4K (20–10–10) were higher than those fertilized with 17N–2.2P–9.2K (17–5–11) (Table 8). Though not significant, a similar trend was observed with euonymus. While weed control was reduced slightly with the 17N–2.2P–9.2K (17–5–11) formulation 10 WAT (data not shown), crop growth also was reduced. This suggests that CRF formulations used in this study are not an acceptable method for improving weed control.

Dibbling increased shoot growth (growth index) of lavender and euonymus compared to incorporation; however, it also reduced root ratings compared to incorporation in both species. The authors noted prior to recording root ratings and growth indices, all plants appeared to be marketable (with respect to root and shoot systems), and there were no obvious treatment effects Analysis of the data indicated statistical differences, though not economically important differences. Root ratings of euonymus decreased linearly with increasing herbicide rate, though again, not economically important. These data concur with those of Broschat and Moore (4), in that root and shoot growth was similar or greater with dibbling CRFs compared to topdressing or incorporating (except areca palm).

Plants require 13 mineral nutrients for adequate growth and development, with N, P, and K required in the highest amounts (14). Dibbling CRFs removes N, P, and K from the container surface. A common characteristic of weeds evaluated in this study, and weeds in container production in general, is their small seed size (13). When fertilizers are dibbled, small weed seeds with little nutrient reserves would have difficulty accessing fertilizers below the container surface.

Table 8. **Fertilizer type, fertilizer placement, and herbicide rate affect growth of lavender and euonymus (Expt. 3).**

	Lavender		Euonymus	
Treatment	Growth index[z]	Root rating[y]	Growth index	Root rating
Fertilizer type				
17N–2.2P–9.2K (17–5–11)	11.6b[x]	4.7b	19.8a	4.4a
20N–4.3P–8.4K (20–10–10)	13.9a	5.8a	20.9a	4.8a
Fertilizer placement				
Topdress	12.1b	4.6b	21.7a	5.3a
Incorporate	12.1b	6.2a	18.4b	4.8a
Dibble	14.0a	5.0b	20.9a	3.6b
Snapshot (kg/ha)				
0	12.9	5.4	20.5	5.2
84	12.8	5.4	20.1	4.4
168	12.5	5.0	20.4	4.2
	NS	NS	NS	L**
Main effects				
Fertilizer type (F)	***	***	NS	NS
Placement method (P)	***	***	***	***
Herbicide rate (H)	NS	NS	NS	**
F*P	***	***	NS	NS
H*P	NS	NS	NS	NS
F*H	*	NS	NS	NS
F*H*P	NS	NS	*	NS

[z]Growth index = (height + width + width) / 3.

[y]Root rating on a scale from 1 to 10, where 1 = 10% coverage of root/container interface and 10 = 100% coverage.

[x]Means with different letters are significantly different, separated by Duncan's Multiple Range test (α = 0.05).

L and NS represent linear and nonsignficant rate response, respectively.

*, **, and *** represent significance where P ≤ 0.05, 0.01, and 0.001.

It is also possible topdressing CRFs affects herbicide activity. Topdressing CRFs results in high levels of N on the container surface. Increased N levels results in increased microbial activity and microbial degradation of herbicides (7). This, along with severe nutrient deficiency of weed seedlings, are likely the primary reasons for differences in weed control with respect CRF placement.

In conclusion, data herein suggest that topdressing CRFs results in reduced weed control especially when lower than recommended herbicide rates are used. Results were generally similar across two geographical regions, using three different herbicides and three different weed species. Dibbling CRFs increased weed control compared to topdressing and incorporating, and resulted in acceptable weed control even when no herbicides were used. Dibbling fertilizers is a cultural practice that can be adopted by most nursery production systems to reduce weed pressure without adversely affecting crop growth.

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