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# Granular Preemergence Applied Herbicides Influence Annual Bedding Plant Growth[1]

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## Abstract

Three experiments were conducted to evaluate effects of preemergence applied herbicides on annual bedding plants. In experiment 1, five preemergence applied herbicides were evaluated for control of large crabgrass (*Digitaria sanguinalis* L. Scop.) and prostrate spurge (*Euphorbia humistata* Engelm. ex Gray) and phytotoxicity to spring planted herbaceous bedding plants. Dimension 0.5G (dithiopyr) applied at 1.1, 2.2 or 3.4 kg ai/ha (1.0, 2.0, or 3.0 lb ai/A), Southern Weedgrass Control (SWGC) (pendimethalin) 2.68G and Rout 3G (oxyfluorfen + oryzalin) each applied at 1.7, 3.4 or 6.7 kg ai/ha (1.5, 3.0 or 6.0 lb ai/A), Snapshot 2.5TG (trifluralin + isoxaben) applied at 3.4 or 6.7 kg ai/ha (3.0 or 6.0 lb ai/A) and Ronstar 2G (oxadiazon) applied at 4.5 kg ai/ha (4.0 lb ai/A) controlled both weeds up to 60 days after treatment (DAT). Bedding plant tolerance varied with herbicide and application rate. Basil and salvia were sensitive to Snapshot (trifluralin + isoxaben) [6.7 kg ai/ha (6.0 lb ai/A)], while Ronstar (oxadiazon) [4.5 kg ai/ha (4.0 lb ai/A)] injured begonia and impatiens. Species sensitive to Dimension (dithiopyr) at 2.2 or 3.4 kg/ha (2.0 and 3.0 lb ai/A) 60 DAT were begonia, salvia, and nicotiana. Bedding plants sensitive to SWGC (pendimethalin) were celosia and salvia. Rout (oxyfluorfen + oryzalin) was injurious to most species evaluated at 6.7 kg ai/ha (6.0 lb ai/A) and in some cases at 3.4 kg ai/ha (3.0 lb ai/A). In experiments 2 and 3, shoot growth of impatiens, geranium, basil, and ageratum was not affected by any herbicide treatment. However, impatiens root growth was suppressed (30 DAT) with Dimension (dithiopyr), Snapshot (trifluralin + isoxaben), SWGC (pendimethalin) (high rate only), and Ronstar (oxadiazon). Basil root growth was suppressed 15 DAT with Dimension (dithiopyr), Snapshot (trifluralin + isoxaben), and SWGC (pendimethalin); however, all root dry weights were similar to control root dry weights at 30 DAT.

**Index words:** weed control, herbicide, annual bedding plants, begonia, marigold, salvia, celosia, geranium, impatiens, nicotiana, ageratum, basil, root growth.

**Herbicides used in this study:** Rout, [(oxyfluorfen), 2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl)benzene + (oryzalin), 3,5-dinitro-$N_4$,$N_4$-dipropylsulfanil amide]; Southern Weedgrass Control, (pendimethalin), *N*-(1-ethylpropyl)-3,4 dimethyl-2,6-dinitrobenzeneamine; Ronstar (oxadiazon), 3-[2,4-dichloro-5-(methylethoxy) phenyl]-5-(1,1-dimethyl ethyl)-1,3,4-oxadiazol-2-(3*H*)-one; Snapshot, [(trifluralin), 2,6-dinitro-N,*N*-dipropyl-4-(trifluoromethyl)benzenamine + (isoxaben), *N*-[3-(1-Ethyl-1-methylpropyl)-5-isoxazolyl]-2,6-dimethoxy benzamide; Dimension, [dithiopyr, (Monsanto 15179)] (S,S-Dimethyl 2-(difluoromethyl)-4-(2-methylpropyl)-6-trifluoromethyl)-3,5-pyridinedicarbothioate).

**Species used in this study:** Begonia [*Begonia* L. *semperflorens-cultorum* hybrid Group cv. 'Vodka']; 'Blue Danube' Ageratum [*Ageratum houstonianum* Mill. 'Blue Danube']; Flowering Tobacco [*Nicotiana alata* Link & Otto 'Nikki Red']; Marigold [*Tagetes* L. (*patula* x *erecta*) Triploid Hybrid cv. 'Janie Yellow']; Impatiens [*Impatiens wallerana* Hook.f. 'Super Elfin Orchid']; Celosia [*Celosia plumosa* L. 'Apricot Brandy']; Salvia [*Salvia splendens* F. Sellow ex Roem. & Schult 'Fireball']; Geranium [*Pelargonium* x *hortorum* Bailey 'Orbit Red'] and Basil [*Ocimum basilicum* L. 'Spicy Globe'].

## Significance to the Nursery Industry

Dimension (dithiopyr) and Snapshot (trifluralin + isoxaben) have been recently registered for turf and landscape plantings. They may have potential for safe, effective weed control with selected annual bedding plants. In our work, both Dimension (dithiopyr) and Snapshot (trifluralin + isoxaben) were generally non-injurious to ageratum, celosia, impatiens, and marigold, while suppressing growth of basil (trifluralin + isoxaben only), begonia, nicotiana (dithiopyr only), and salvia. No herbicide evaluated was safe at all rates on all annuals. In contrast, begonia and impatiens treated with Ronstar (oxadiazon), one of the least injurious herbicides currently used on landscape plants, exhibited injury symptoms or growth suppression at the recommended label rate during the study. Most preemergence applied herbicides evaluated reduced root growth of impatiens and basil, even though visual foliar injury was not apparent.

## Introduction

Weed control is a serious problem in newly transplanted herbaceous bedding plants. Freshly tilled soil with high nutrient and moisture levels creates an ideal environment for weed seed germination. With the increased use of bedding plants for seasonal color in commercial landscapes; safe, effective, and economical weed management is needed.

Granular applied preemergence herbicides are preferred by landscape contractors for their ease of application (5, 11). Although herbicides can be used to control many weeds, injury to the young transplants may occur (3, 7, 8, 9). Studies indicate various herbicides generally do not injure petunia, ageratum, marigold, or geranium but these same herbicides will injure salvia and impatiens (4, 6) indicating varying degrees of herbicide sensitivity within this diverse group of plant species.

In the past few years several herbicides were developed for use in landscape plantings or turf. Barricade (prodiamine) has little effect on woody species but reduced growth of bedding plants (10). Two other herbicides recently registered for turf or landscape use are Snapshot (trifluralin + isoxaben) and Dimension (dithiopyr). With both of these herbicides, there are limited data on their effects on transplanted bed-

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ding plants. Since these herbicides may impact annual bedding plant beds near the target woody or turf species, information is needed on the effects these herbicides have on annual bedding plants. The objective of this study was to evaluate Dimension (dithiopyr) and Snapshot (trifluralin + isoxaben) efficacy and phytotoxicity on a number of herbaceous landscape species compared to Ronstar (oxadiazon), Rout (oxyfluorfen + oryzalin), and SWGC (pendimethalin).

## Materials and Methods

*Experiment 1.* On June 1, 2.1 $m^2$ (6.9 $ft^2$) plots in a fine-loamy siliceous, thermic Typic Hapudalt soil amended with about 5 cm (2 in) of pinebark, were further amended with ammonium nitrate (34 % N) at 135 kg/ha N (120 lb/A), as per soil test recommendation, and tilled to a depth of 15 cm (6 in). On June 6, uniform transplants (about 10 cm (4 in) in height) of begonia, ageratum, nicotiana, marigold, impatiens, celosia, salvia, geranium, and basil were transplanted and watered in with 1.25 cm (0.5 in) overhead irrigation.

All herbicides were applied over-the-top of the transplanted annuals on June 8 at the following rates: Dimension 0.5G (dithiopyr) was applied at either 1.1, 2.2 or 3.4 kg ai/ha (1, 2, or 3 lb ai/A), Snapshot 2.5TG (trifluralin + isoxaben), SWGC 2.68G (pendimethalin), and Rout 3G (oxyfluorfen + oryzalin), were applied at either 1.7, 3.4 or 6.7 kg ai/ha (1.5, 3, or 6 lb ai/A) and Ronstar (oxadiazon) 2G was applied at 4.5 kg ai/ha (4 lb ai/A). All herbicides were applied with a hand-held shaker and all plots were watered with 2.5 cm (1.0 in) overhead irrigation immediately following herbicide application and as needed. Half of each plot was overseeded (June 15) with large crabgrass (*Digitaria sanguinalis* L. Scop.) and the other half with prostrate spurge (*Euphorbia humistata* Englem. ex Gray). Weed species other than large crabgrass and prostrate spurge were hand-weeded biweekly. Weedy and hand-weeded controls were included for comparison purposes.

Bedding plant transplants were evaluated for injury 15, 30, and 60 DAT (days after treatment) using a visual rating scale of 1 to 5 where; 1 = no injury; 2 = slight chlorosis, necrosis, or stunting; 3 = moderate to severe chlorosis or necrosis; 4 = defoliation or stem die-back and 5 = dead plant. Only 30 and 60 DAT data are presented in tables.

On July 11 (30 DAT), plant growth indices [(height + width at the widest point + width perpendicular to the widest point)/3], flower number, and shoot dry weights were determined (one plant per experimental unit). On August 9 (60 DAT), all remaining plants were evaluated for growth indices, flower number, and dry weight. Weed number per plot was counted 15, 30, and 60 DAT and weed shoot dry weights were determined 60 DAT.

The experimental design was a randomized complete block with 5 replicates of 3 plants per species. Analysis of variance procedures were conducted on data for each species and significant differences determined using Fisher's Protected LSD at Alpha = 0.05.

*Experiment 2.* On June 20, transplants of impatiens and geranium (same cultivars used in experiment 1) were potted in polyvinyl chloride (PVC) pipe containers 15 cm (6 in) wide by 30 cm (12 in) deep, each with a 10 cm (4 in) by 20 cm (8 in) side viewing window, supported as described by Murdoch et al. (12). The medium consisted of 0.6 cm (0.25 in) screened pinebark:sand (6:1, by vol.) amended on a $m^3$ ($yd^3$) basis with 3 kg (6.5 lb) dolomitic limestone and 0.9 kg (2 lb) micromax (micronutrient).

Herbicide treatments were applied over-the-top of annuals with a hand-held shaker on June 21 and watered immediately with about 1.3 cm (0.5 in) of water. Treatments were applied outdoors prior to placing plants in a double layer polyhouse with 47% shade. Dimension (dithiopyr) at 1.1 or 2.2 kg ai/ha (1, 2 lb ai/A), Snapshot 2.5TG (trifluralin + isoxaben), and Southern Weedgrass Control 2.45G (pendimethalin) at 1.7 or 3.4 kg ai/ha (1.5 or 3 lb ai/A), and Ronstar (oxadiazon) 2G at 4.5 kg ai/ha (4 lb ai/A) were included as treatments with a nontreated control. Beginning June 28, plants were fertilized twice weekly with 500 ml of solution containing 200 ppm N from a 20N-8.8P-16.6K (20-20-20) water soluble fertilizer.

The number of root tips visible in the chamber windows were counted 15 and 30 DAT. Growth indices, shoot (leaves and stems) dry weight, root dry weight (roots occurring outside the original root ball) were determined 30 DAT. Six single plant replicates of each species were used in a completely randomized design. Analysis of variance procedures were conducted on data for each species and significant differences were determined using Fisher Protected LSD mean separation at the 5% level of significance.

*Experiment 3.* Ageratum and basil were evaluated as in experiment 2 with the following exceptions: plants were potted on July 30; treatments were applied on August 1; biweekly fertilization (200 ppm N) began July 30, and Osmocote 18N-2.6P-8.3K (18-6-12) was added to the medium at 3.6 kg/$m^3$ (6 lb/$yd^3$).

## Results and Discussion

*Ageratum.* Only Rout (oxyfluorfen + oryzalin) resulted in significant ageratum injury, 30 DAT, with injury increasing with increasing rates (Table 1). These data concur with other work (8). However, Ronstar (oxadiazon) was the only common herbicide treatment with our study. Rout (oxyfluorfen + oryzalin) injury was characterized by slight necrosis of the younger leaves; however, plants recovered from injury symptoms by 60 DAT. Dimension (dithiopyr), Snapshot (trifluralin + isoxaben), SWGC (pendimethalin), and Ronstar (oxadiazon) were non-injurious to ageratum. At 30 DAT Dimension (dithiopyr) at 2.2 and 3.4 kg ai/ha (2.0 and 3.0 lb ai/A) and Rout (oxyfluorfen + oryzalin) at 6.7 kg ai/ha (6.0 lb ai/A) resulted in shoot dry weights of 16.9, 18.6, and 15.6 grams compared to 32.5 grams for the hand-weeded control. Shoot dry weights were similar among all other treatments 30 DAT and by 60 DAT shoot dry weights for all plants in treatments were equal to or larger than the handweeded control (Table 2). Flowering of ageratum was suppressed 30 DAT with Dimension (dithiopyr) at 2.2 and 3.4 kg ai/ha (2.0 and 3.0 lb ai/A) and Rout (oxyfluorfen + oryzalin) at 6.7 kg ai/ha (6.0 lb ai/A); however, by 60 DAT flower numbers were similar among all treatments (Table 3).

*Basil.* Both Snapshot (trifluralin + isoxaben) (30 and 60 DAT) and Rout (oxyfluorfen + oryzalin) (30 DAT) resulted in increasing plant injury with increasing application rates (Table 1). Snapshot (trifluralin + isoxaben) [6.7 kg ai/ha (6.0 lb ai/A)] injury was characterized by moderate to severe chlorosis visible through 60 DAT.

**Table 1. Phytotoxicity rating of 8 bedding plant species following application of selected granular preemergence applied herbicides.**

| Treatments | Rate (kg ai/ha) | Ageratum | | Basil | | Begonia | | Celosia | | Impatiens | | Marigold | | Nicotiana | | Salvia | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Days after treatment | | | | | | | | | | | | | | | |
| | | 30 | 60 | 30 | 60 | 30 | 60 | 30 | 60 | 30 | 60 | 30 | 60 | 30 | 60 | 30 | 60 |
| Dimension | 1.1 | 1.0 | 1.0 | 1.1 | 1.0 | 1.9 | 2.1 | 1.8 | 1.3 | 1.3 | 1.5 | 1.0 | 1.4 | 1.5 | 1.9 | 1.9 | 2.7 |
| | 2.2 | 1.0 | 1.0 | 1.0 | 1.0 | 2.3 | 2.9 | 1.4 | 1.2 | 1.6 | 1.4 | 1.0 | 1.0 | 1.7 | 1.8 | 2.1 | 3.7 |
| | 3.4 | 1.0 | 1.0 | 1.7 | 1.0 | 3.3 | 4.4 | 1.6 | 1.4 | 1.9 | 1.6 | 1.0 | 1.0 | 2.8 | 4.1 | 1.8 | 3.8 |
| Snapshot | 1.7 | 1.0 | 1.0 | 1.0 | 1.0 | 1.6 | 1.4 | 1.3 | 1.0 | 1.5 | 1.4 | 1.0 | 1.0 | 1.0 | 1.3 | 1.7 | 2.7 |
| | 3.4 | 1.0 | 1.0 | 1.7 | 1.8 | 2.1 | 2.0 | 1.3 | 1.3 | 1.8 | 2.4 | 1.0 | 1.0 | 1.8 | 2.0 | 2.6 | 3.1 |
| | 6.7 | 1.0 | 1.0 | 2.7 | 2.5 | 1.9 | 1.5 | 1.3 | 1.0 | 1.8 | 1.3 | 1.1 | 1.0 | 1.1 | 1.4 | 3.9 | 4.4 |
| Southern | 1.7 | 1.1 | 1.0 | 1.6 | 1.3 | 1.6 | 1.3 | 1.5 | 1.3 | 1.7 | 1.6 | 1.0 | 1.0 | 1.2 | 1.3 | 1.9 | 2.8 |
| Weedgrass | 3.4 | 1.0 | 1.0 | 1.8 | 1.3 | 1.4 | 1.3 | 1.6 | 1.6 | 1.3 | 1.3 | 1.0 | 1.0 | 1.3 | 1.1 | 3.1 | 4.3 |
| Control | 6.7 | 1.4 | 1.0 | 2.2 | 1.0 | 2.5 | 2.6 | 2.4 | 2.9 | 2.7 | 2.7 | 1.6 | 1.4 | 2.1 | 2.1 | 2.0 | 2.8 |
| Rout | 1.7 | 1.9 | 1.0 | 1.5 | 1.0 | 2.3 | 2.3 | 2.7 | 1.7 | 3.7 | 3.9 | 1.8 | 1.0 | 1.9 | 1.6 | 2.1 | 2.7 |
| | 3.4 | 2.2 | 1.0 | 2.0 | 1.4 | 2.7 | 2.7 | 2.7 | 2.3 | 4.5 | 4.4 | 1.9 | 1.0 | 2.5 | 1.6 | 2.6 | 3.4 |
| | 6.7 | 2.8 | 1.0 | 2.4 | 1.3 | 3.0 | 4.3 | 2.8 | 2.8 | 4.8 | 5.0 | 2.1 | 1.0 | 2.9 | 2.4 | 2.8 | 2.2 |
| Ronstar | 4.5 | 1.2 | 1.0 | 1.7 | 1.6 | 2.7 | 3.1 | 2.3 | 1.1 | 2.7 | 2.7 | 1.4 | 1.0 | 1.9 | 1.0 | 1.3 | 2.1 |
| Nontreated | 0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.1 | 1.5 | 1.4 | 1.3 | 1.0 | 1.5 | 1.0 | 1.0 | 1.0 | 1.1 | 1.0 | 2.0 |
| Fisher's Protected LSD (0.05) | | 0.8 | NS[y] | 1.6 | 1.4 | 1.5 | 2.2 | 1.2 | 1.2 | 1.7 | 1.8 | 0.7 | NS | 1.4 | 1.6 | 2.0 | 1.8 |

[z]Phytotoxicity rating scale: 1 = no injury, 2 = slight chlorosis, necrosis, stunting; 3 = moderate to severe chlorosis, necrosis, 4 = defoliation, stem die-back, 5 = dead plant.

[y]NS = nonsignificant at 5% level of significance.

**Table 2. Shoot dry weight of 8 bedding plant species following application of selected granular preemergence applied herbicides.**

| Treatments | Rate (kg ai/ha) | Ageratum | | Basil | | Begonia | Celosia | Impatiens | | Marigold | | Nicotiana | | Salvia |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Days after treatment | | | | | | | | | | | | |
| | | 30 | 60 | 30 | 60 | 60 | 60 | 30 | 60 | 30 | 60 | 30 | 60 | 60 |
| Dimension | 1.1 | 25.4 | 53.5 | 33.5 | 55.5 | 8.3 | 41.9 | 6.9 | 14.2 | 19.7 | 51.1 | 12.1 | 20.6 | 4.3 |
| | 2.2 | 16.9 | 52.3 | 20.8 | 49.8 | 4.2 | 46.9 | 11.4 | 17.8 | 16.6 | 51.5 | 12.8 | 18.3 | 2.1 |
| | 3.4 | 18.6 | 42.3 | 30.1 | 38.6 | 1.5 | 43.2 | 5.5 | 12.9 | 19.8 | 52.9 | 3.4 | 4.9 | 1.5 |
| Snapshot | 1.7 | 30.4 | 48.9 | 32.5 | 56.6 | 10.1 | 35.0 | 10.5 | 15.9 | 17.5 | 41.3 | 25.1 | 32.6 | 4.9 |
| | 3.4 | 29.2 | 49.7 | 29.6 | 46.6 | 9.8 | 36.7 | 10.7 | 10.4 | 20.4 | 56.5 | 21.6 | 28.5 | 5.3 |
| | 6.7 | 31.4 | 57.1 | 16.6 | 24.3 | 10.5 | 38.5 | 11.5 | 12.4 | 19.6 | 47.1 | 22.4 | 26.5 | 1.0 |
| Southern | 1.7 | 24.1 | 58.0 | 35.6 | 50.2 | 11.6 | 32.8 | 10.0 | 15.4 | 17.9 | 48.3 | 20.0 | 28.8 | 5.6 |
| Weedgrass | 3.4 | 26.0 | 59.5 | 25.4 | 38.9 | 12.7 | 27.3 | 12.8 | 14.2 | 16.6 | 54.9 | 16.8 | 26.9 | 1.3 |
| Control | 6.7 | 24.1 | 53.1 | 26.8 | 38.5 | 7.5 | 24.8 | 3.5 | 8.2 | 12.3 | 46.0 | 6.2 | 14.3 | 3.1 |
| Rout | 1.7 | 30.7 | 42.5 | 31.9 | 55.8 | 7.5 | 27.7 | 0.1 | NA | 16.6 | 41.8 | 13.2 | 20.7 | 5.4 |
| | 3.4 | 23.1 | 50.6 | 26.7 | 41.2 | 5.3 | 26.1 | 0.1 | NA | 12.7 | 32.3 | 10.8 | 16.8 | 3.0 |
| | 6.7 | 15.6 | 45.0 | 23.0 | 41.9 | 1.4 | 22.7 | 0.0 | NA | 11.4 | 33.7 | 8.3 | 10.8 | 4.2 |
| Ronstar | 4.5 | 37.5 | 66.1 | 33.9 | 54.2 | 3.1 | 35.4 | 4.4 | 7.5 | 17.3 | 55.2 | 10.2 | 24.7 | 9.1 |
| Handweeded | 0 | 32.5 | 46.8 | 52.0 | 70.1 | 13.9 | 42.3 | 13.0 | 10.8 | 19.3 | 51.4 | 30.1 | 31.4 | 10.5 |
| Fisher's Protected LSD (0.05) | | 13.2 | 10.4 | 13.7 | 11.9 | 4.6 | 18.3 | 10.2 | NS[z] | 7.8 | 10.0 | 11.0 | 10.9 | 4.5 |

[z]NS = nonsignificant at 5% level of significance.

Shoot dry weights were suppressed with all herbicide treatments 30 and 60 DAT compared to hand-weeded plants (Table 2). Only with Snapshot 2.5TG (trifluralin + isoxaben) was there a rate response with decreasing shoot dry weight as the Snapshot (trifluralin + isoxaben) rates increased.

*Begonia*. Herbicide injury was apparent 30 DAT with Dimension (dithiopyr), SWGC (pendimethalin), and Rout (oxyfluorfen + oryzalin). Injury was proportional to rates applied. Ronstar (oxadiazon) also caused severe foliar necrosis (Table 1). Bing (3) reported injury to 'Derby' begonia

30 DAT with the application of Ronstar (oxadiazon) at 4.5 kg ai/ha (4.0 lb ai/A). Sixty DAT begonia exhibited defoliation and stem die-back with high rates of Dimension (dithiopyr) and Rout (oxyfluorfen + oryzalin). Severe necrosis was also observed with plants treated with Ronstar (oxadiazon). Suppressed shoot dry weight and growth indices (data not shown) occurred with Dimension (dithiopyr) and Rout (oxyfluorfen + oryzalin) (all rates), SWGC (pendimethalin) (high rate) and Ronstar (oxadiazon) compared to hand-weeded control (Table 2). Ronstar (oxadiazon) resulted in 78% less shoot dry weight and 51% fewer flowers (Table 3) compared to hand-weeded control.

*Celosia*. Injury occurred with all rates of Rout (oxyfluorfen + oryzalin) 30 DAT (Table 1). Necrosis occurred primarily on the lower portions of the transplants and resulted in the inhibition of secondary branching in that region. Ronstar (oxadiazon) and SWGC (pendimethalin) (high rate), also, resulted in necrosis of the lower portions of celosia. In contrast to these results, Bing and Macksel (4) reported optimum growth of celosia one month after the application of Ronstar (oxadiazon) at 2.2 and 4.5 kg ai/ha (2.0 and 4.0 lb ai/A).

Celosia continued to exhibit foliar necrosis and suppressed shoot dry weight 60 DAT with the highest rates of Rout (oxyfluorfen + oryzalin) and SWGC (pendimethalin). With SWGC (pendimethalin), injury increased with increasing rates. Dimension (dithiopyr) and Snapshot 2.5TG (trifluralin + isoxaben) appeared to be safe on celosia, causing no injury or growth suppression at the rates tested (Tables 1 and 2).

*Geranium*. Geranium was generally tolerant of all herbicides evaluated (data not shown). Slight injury occurred with the highest rate of Dimension (dithiopyr) and Rout (oxyfluorfen + oryzalin) 30 DAT (data not shown); however, by 60 DAT all plants were similar to the control plants. Flower number, growth indices, and shoot dry weight were not affected by herbicide treatment (data not shown). These results concur with those obtained by Fretz et al. (7) where application of Treflan (trifluralin), Surflan (oryzalin), or Ronstar (oxadiazon) were non-injurious to geranium (8).

*Impatiens*. Impatiens were extremely sensitive to Rout (oxyfluorfen + oryzalin); within 30 DAT most plants were dead or severely defoliated (Table 1). Dimension (dithiopyr) (30 DAT), SWGC (pendimethalin) (30 and 60 DAT), and Rout (oxyfluorfen + oryzalin) (30 and 60 DAT) caused greater plant injury with increasing rates. With SWGC (pendimethalin) (highest rate) and Ronstar (oxadiazon) moderate chlorosis occurred 30 DAT and all Rout rates suppressed shoot dry weights (Table 2). Impatiens treated with the highest rate of SWGC (pendimethalin) had fewer flowers than hand-weeded plants (1 vs 13). SWGC (pendimethalin) treated plants (highest rate) had sparse foliage and flowering began later than plants treated with the lower rates of SWGC (pendimetalin) (visual observation). Within 60 DAT, all impatiens except those treated with Rout (oxyfluorfen + oryzalin) had similar flower numbers (Table 3).

*Marigold*. Rout (oxyfluorfen + oryzalin) caused slight necrosis 30 DAT which disappeared before 60 DAT. There

**Table 3. Flower number of 7 bedding plant species following application of selected granular preemergence applied herbicides.**

| Treatments | Rate (kg ai/ha) | Ageratum | | Begonia | Celosia | Impatiens | | Marigold | | Nicotiana | | Salvia |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Days after treatment | | | | | | | | | | |
| | | 30 | 60 | 60 | 60 | 30 | 60 | 30 | 60 | 30 | 60 | 60 |
| Dimension | 1.1 | 56 | 138 | 60 | 10 | 17 | 40 | 24 | 71 | 39 | 50 | 14 |
| | 2.2 | 34 | 141 | 39 | 11 | 6 | 31 | 19 | 78 | 26 | 27 | 11 |
| | 3.4 | 37 | 123 | 31 | 10 | 7 | 38 | 23 | 77 | 8 | 9 | 11 |
| Snapshot | 1.7 | 60 | 144 | 62 | 10 | 8 | 27 | 23 | 53 | 79 | 79 | 11 |
| | 3.4 | 69 | 121 | 75 | 9 | 19 | 34 | 24 | 82 | 90 | 68 | 13 |
| | 6.7 | 66 | 145 | 59 | 9 | 12 | 30 | 20 | 72 | 55 | 62 | 9 |
| Southern | 1.7 | 60 | 138 | 104 | 8 | 8 | 36 | 18 | 76 | 39 | 61 | 14 |
| Weedgrass | 3.4 | 51 | 155 | 93 | 7 | 18 | 26 | 22 | 83 | 35 | 53 | 8 |
| Control | 6.7 | 51 | 150 | 69 | 7 | 1 | 24 | 14 | 72 | 4 | 30 | 10 |
| Rout | 1.7 | 58 | 117 | 59 | 8 | — | — | 15 | 63 | 36 | 41 | 13 |
| | 3.4 | 56 | 121 | 48 | 7 | — | — | 17 | 59 | 20 | 38 | 10 |
| | 6.7 | 30 | 117 | 11 | 5 | — | — | 21 | 53 | 14 | 17 | 9 |
| Ronstar | 4.5 | 77 | 153 | 48 | 15 | 6 | 28 | 23 | 80 | 24 | 59 | 16 |
| Handweeded | 0 | 81 | 157 | 99 | 11 | 13 | 30 | 25 | 75 | 93 | 70 | 16 |
| Fisher's Protected LSD (0.05) | | 31 | NS[z] | 47 | 7 | 14 | NS | 10 | 30 | 34 | 52 | NS |

[z]NS = nonsignificant at 5% level of significance.

was no significant injury with any herbicide treatment 60 DAT (Table 1).

Marigold flower number was initially suppressed 44% (30 DAT) with SWGC (pendimethalin) (highest rate) but by 60 DAT flower numbers were similar among all treatments (Table 3). Shoot dry weights were suppressed with Rout (oxyfluorfen + oryzalin) 30 DAT (highest rate) and 60 DAT (two highest rates) compared to hand-weeded plants (Table 2). All other herbicide treatments resulted in similar shoot dry weight.

'Gypsy Sunshine' marigold was not injured by Ronstar (oxadiazon) [3.3 kg ai/ha (3 lb ai/A)] one month after application (7); however, other work (8) indicated unacceptable injury on 'Inca Orange', 'Dainty Marietta' and 'Queen Sophia' marigold 30 DAT with the same rate of Ronstar (oxadiazon). These contrasting results indicate marigold sensitivity to Ronstar (oxadiazon) may differ with cultivar selection.

*Nicotiana*. There was a linear response to Dimension (dithiopyr) and SWGC (pendimethalin) (30 and 60 DAT) and Rout (oxyfluorfen + oryzalin) (30 DAT) with respect to plant injury (Table 1). Nicotiana in plots receiving Rout (oxyfluorfen + oryzalin) outgrew the initial injury (moderate to severe chlorosis) by 30 DAT and ratings were similar to controls 60 DAT. Although not compared statistically, Dimension (dithiopyr) injury appeared to increase with each rating. Nicotiana treated with the two lower Dimension (dithiopyr) rates exhibited foliar chlorosis while the highest rate (3.4 kg ai/ha) exhibited severe defoliation and stem dieback by 60 DAT.

Flowering was suppressed initially (30 DAT) with the highest rate of Dimension (dithiopyr) and SWGC (pendimethalin) compared to the hand-weeded plants (8 and 4 vs 47, respectively). Flower number for other treatments were similar to controls (Table 3).

Snapshot (trifluralin + isoxaben) was the only herbicide that did not reduce shoot dry weight of nicotiana with all rates of application. Shoot dry weight (30 DAT) reflects suppression with Dimension (dithiopyr) (all rates), SWGC (pendimethalin) (two higher rates), Rout (oxyfluorfen + oryzalin) (all rates), and Ronstar (oxadiazon) when compared to control (Table 2). Shoot dry weight suppression continued at 60 DAT with Dimension (dithiopyr) (two higher rates), SWGC (pendimethalin) (highest rate), and Rout (oxyfluorfen + oryzalin) (all rates) compared to hand-weeded control plants.

*Salvia*. Only Ronstar (oxadiazon) appeared to be safe for salvia. All other herbicides caused significant plant injury (Table 1) and suppressed shoot dry weight 60 DAT (Table 2). These data concur with other work (10), that demonstrated scarlet salvia (*Salvia splendens* 'Top Red') was not injured by Ronstar (oxadiazon). Gilbert and Johnson (7) reported salvia to be more sensitive to herbicides than five other summer annuals tested.

*Weed Control*. Excellent crabgrass control was achieved with most herbicides at all rates tested (Table 4). Among herbicide treatments, Snapshot 2.5TG (trifluralin + isoxaben) [1.7 kg ai/ha (1.5 lb ai/A)] had ≥ 25.5 plants per plot throughout the test period. This application rate is about one-half

**Table 4. Large crabgrass and prostrate spurge control with selected preemergence applied herbicides.**

| | | Crabgrass | | | | Spurge | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Number | | Dry wt | | Number | | Dry wt | |
| | | Weeds/m²[z] | | (g/m²) | | Weeds/m² | | (g/m²) | |
| | | Days after treatment | | | | | | | |
| Treatments | Rate (kg ai/ha) | 15 | 30 | 60 | 60 | 15 | 30 | 60 | 60 |
| Dimension | 1.1 | 1.0 | 1.5 | 2.3 | 3.5 | 0.4 | 0.0 | 0.2 | 0.0 |
| | 2.2 | 0.2 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.6 | 0.1 |
| | 3.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Snapshot | 1.7 | 25.5 | 33.7 | 26.1 | 80.7 | 6.0 | 8.0 | 9.2 | 37.5 |
| | 3.4 | 4.4 | 5.9 | 6.3 | 11.8 | 0.6 | 0.4 | 1.2 | 2.3 |
| | 6.7 | 1.3 | 1.5 | 1.3 | 3.0 | 0.8 | 1.0 | 1.2 | 0.8 |
| Southern | 1.7 | 5.7 | 6.9 | 5.9 | 43.6 | 1.4 | 0.8 | 1.6 | 3.1 |
| Weedgrass | 3.4 | 3.6 | 4.8 | 1.9 | 19.0 | 1.0 | 0.8 | 1.8 | 3.6 |
| Control | 6.7 | 1.7 | 1.1 | 0.6 | 1.3 | 0.2 | 0.0 | 0.0 | 0.0 |
| Rout | 1.7 | 8.0 | 8.0 | 8.2 | 44.3 | 0.6 | 1.0 | 2.6 | 3.5 |
| | 3.4 | 5.9 | 4.8 | 4.6 | 28.4 | 0.4 | 0.8 | 0.8 | 1.8 |
| | 6.7 | 1.2 | 1.7 | 0.8 | 13.7 | 0.0 | 0.2 | 0.3 | 0.7 |
| Ronstar | 4.5 | 0.4 | 1.3 | 8.0 | 2.9 | 0.0 | 0.2 | 0.2 | 0.1 |
| Non-weeded | — | 176.2 | 171.4 | 177.1 | 207.7 | 43.6 | 61.8 | 41.8 | 26.4 |
| Fisher's Protected LSD (0.05) | | 70.1 | 69.0 | 67.3 | 63.0 | 11.9 | 15.5 | 10.4 | 11.4 |

[z]Plot size = 1.05 m².

**Table 5. Root growth of 'Super Elfin Orchid' impatiens and 'Spicy Globe' basil following application of granular preemergence applied herbicides.**

| Treatments | Rate (kg ai/ha) | Impatiens | | Basil | |
|---|---|---|---|---|---|
| | | Root tip[z] (no.) | Root dry wt[y] (grams) | Root tip (no.) | Root dry wt (grams) |
| | | Days after treatment | | | |
| | | 30 | 30 | 15 | 30 |
| Dimension | 1.1 | 48.1 | 0.23 | 94.4 | 0.25 |
| | 2.2 | 53.4 | 0.15 | 101.4 | 0.30 |
| Snapshot | 1.7 | 63.3 | 0.20 | 77.3 | 0.15 |
| | 3.4 | 44.6 | 0.09 | 44.0 | 0.20 |
| Southern Weedgrass Control | 1.7 | 59.7 | 0.16 | 106.2 | 0.22 |
| | 3.4 | 40.7 | 0.14 | 86.7 | 0.23 |
| Ronstar | 4.5 | 47.0 | 0.14 | 142.9 | 0.15 |
| Non-treated | — | 74.6 | 0.49 | 165.2 | 0.24 |
| Fisher's Protected LSD (0.05) | | 20.1 | 0.09 | 40.6 | NS[x] |

[z]Root tips/100cm$^2$, visible roots in a 10 × 20-cm window in the PVC container.

[y]New roots outside original root ball only.

[x]NS = nonsignificant at 5% level of significance.

the manufacturer's recommended rate and is not acceptable in a commercial landscape setting for grass control. At 1.7 kg ai/ha (1.5 lb ai/A) large crabgrass germination occurred throughout the Snapshot (trifluralin + isoxaben) plots while at the higher rates large crabgrass germination occurred primarily around the base of the transplants; possibly a result of transplants deflecting the herbicide granules during application.

As with crabgrass, excellent prostrate spurge control was also obtained with most herbicide treatments (Table 4). This concurs with previous research (2) with newly planted azaleas where Ronstar (oxadiazon) provided at least 80% control of prostrate spurge. However, prostrate spurge control with the lowest Snapshot (trifluralin + isoxaben) rate was unacceptable with ≥ 6 plants per plot. Spurge shoot dry weight from plots treated with the low rate of Snapshot (trifluralin + isoxaben) [1.7 kg ai/ha (1.5 lb ai/A) were similar to non-weeded plots 60 DAT; however, Snapshot (trifluralin + isoxaben) did effectively suppress prostrate spurge at the two higher rates. The low rate tested is about one-half of the manufacturer's recommended rate.

*Experiment 1.* Results for growth indices were similar to those of shoot dry weight therefore only shoot dry weight data are presented.

*Experiment 2.* Within 30 DAT impatiens root numbers were suppressed with Dimension (dithiopyr) (both rates), Snapshot (trifluralin + isoxaben) and SWGC (pendimethalin) (higher rate of each), and Ronstar (oxadiazon) when compared to non-treated plants (Table 5). Impatiens root dry weights were suppressed with all herbicide treatments compared to non-treated control plants. Roots in the top 2 cm (0.8 in) of the medium were observed to have swollen root tips with Snapshot (trifluralin + isoxaben) and SWGC (pendimethalin). Growth indices and shoot dry weight were similar among all treatments (data not shown). These data concur with the first study where similar growth occurred with the above treatments on impatiens.

Geranium root and shoot growth were not significantly affected with any of the herbicides tested (data not shown). Experiment 1 and other research have shown geranium is tolerant to various herbicides (7, 8). As with impatiens, geranium roots visible in the top 2 cm (0.8 in) of the windows exhibited swelling of root tips with SWGC (pendimethalin) and Snapshot (trifluralin + isoxaben). Vigorous root growth occurred below the top 2 cm (0.8 in) and may account for similar dry weights. Swelling of root tips is a recognized morphological effect of the dinitroanaline herbicides resulting from an inhibition of mitosis and disruption of cell division within the roots (1, 13).

*Experiment 3.* Ageratum growth was not affected by any herbicide treatment (data not shown). Although the field research resulted in growth indices suppression of basil with the herbicides employed in this test 30 DAT, basil growth indices and shoot dry weight were not different from the controls when grown in a pinebark media under greenhouse conditions (data not shown). Increased herbicide adsorption is common in media containing high levels of organic matter (14). This may account for the differing results noted in these tests. Basil root tip number was suppressed with Dimension (dithiopyr), Snapshot 2.5TG (trifluralin + isoxaben), and SWGC (pendimethalin) at both rates 15 DAT (Table 5). Only, Ronstar treated plants had similar root numbers to non-treated plants. Root dry weights were similar among all treatments 30 DAT (Table 5). As with plants in experiment 2, ageratum and basil exhibited swollen root tips in the top 2 cm of the medium with SWGC (pendimethalin) and Snapshot (trifluralin + isoxaben).

This work demonstrates application of granular preemergence herbicides are generally safe on ageratum, celosia, geranium, impatiens, and marigold, while injury or growth suppression occurred with basil (Snapshot (trifluralin + isoxaben) only), nicotiana (Dimension (dithiopyr) only) and salvia. Application of these herbicides to nearby turf or established woody landscape plants should not cause injury to these annual flowering plants. However, our results demonstrate application of preemergence herbicides, especially those containing dinitroanaline herbicides, can result in suppressed root growth of bedding plant transplants. The extent of root suppression varies with herbicide and species tested, most likely depending on the vigor of the root system.

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