Weed Control Strategies for Field Grown Herbaceous Perennials[1]

James B. Calkins, Bert T. Swanson, and Debra L. Newman[2]
Department of Horticultural Science, University of Minnesota
1970 Folwell Avenue, St. Paul, MN 55108

Abstract

Fourteen herbicides or herbicide combinations, wood chip mulch, chipped rubber tire mulch, and newspaper mulch were evaluated for weed control efficacy and phytotoxicity using 12 species of herbaceous perennials under field growing conditions. The effect of herbicide application time was monitored by applying herbicides to dormant and actively growing plants. Herbicide and mulch treatments were compared to weeded and non-weeded controls. Herbicide phytotoxicity was dependent on age and species of herbaceous perennial and time of herbicide application. Herbicide injury was generally greater for young plants compared to established plants and phytotoxicity was usually reduced when herbicides were applied to dormant rather than actively growing plants. Injury was sometimes greater when herbicides were applied in early spring compared to applications made after complete herbaceous perennial emergence. Injury to young shoots that had emerged prior to the earliest possible time that herbicides could be applied in the spring was probably involved. Applying herbicides in the fall may avoid such injury. Mulching field grown perennials with wood chips provided the most effective weed control and often the best quality plants. With the exceptions of *Hemerocallis* 'After Dark' and *Phlox maculata* 'Omega', the herbaceous perennials evaluated were tolerant of most of the herbicides applied. Several herbicides, including Balan 2.5G at 3.36 kg ai/ha (3.0 lb ai/A), Snapshot 80DF at 4.48 kg ai/ha (4.0 lb ai/A), and Stomp 60WDG at 4.48 kg ai/ha (4.0 lb ai/A), demonstrated potential for weed control in herbaceous perennial production systems and landscape plantings. Goal 1.6EC at 1.68 kg ai/ha (1.5 lb ai/A) and Ronstar 50WP at 3.92 kg ai/ha (3.5 lb ai/A) were often phytotoxic when applied to herbaceous perennials.

Index words: pre-emergence herbicides, post-emergence herbicides, mulches, application time, wood chips, rubber tire chips, efficacy, phytotoxicity.

Herbicides used in this study: Balan (benefin), *N*-butyl-*N*-ethyl-2,6-dinitro-4-(trifluoromethyl) benzenamine; Fusilade (fluazifop-P-butyl), Butyl (R)-2-[4-[[5-trifluoromethyl)-2-pyridinyl]oxy] phenoxy]propanoate; Gallery (isoxaben), *N*-[3-(1-ethyl-1-methylpropyl)-5-isoxazolyl]-2,6-dimethoxybenzamide; Goal (oxyfluorfen), 2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl)benzene; Pennant (metolachor), 2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methylethyl)acetamide; Ronstar (oxadiazon), 3-[2,4-dichloro-5-(1-methylethoxy)phenyl]-5-(1,1-dimethylethyl)-1,3,4-oxadiazol-2-(3H)-one; Surflan (oryzalin), 4-(dipropylamino)-3,5-dinitrobenzenesulfonamide; Snapshot DF (isoxaben + oryzalin); Stomp (pendimethalin), *N*-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine; Vantage (sethoxydim), 2-[1-(ethoxyimino)butyl-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one; and Rout GS (oxyfluorfen + oryzalin).

Species used in this study: Narrow-leaved plantain lily (*Hosta lancifolia* Engl.); gayfeather (*Liatris spicata* (L.) Willd.); 'After Dark' daylily (*Hemerocallis* L. 'After Dark'); 'Young Love' daylily (*Hemerocallis* L. 'Young Love'); 'Steve' siberian iris (*Iris sibirica* L. 'Steve'); 'Gypsy Eyes' miniature dwarf bearded iris (*Iris* L. 'Gypsy Eyes'); 'Singing Angel' miniature dwarf bearded iris (*Iris* L. 'Singing Angel'); 'Willowwood' asiatic lily (*Lilium* L. 'Willowwood'); 'Felix Crouse' peony (*Paeonia* L. 'Felix Crouse'); 'Omega' wild sweet william (*Phlox maculata* L. 'Omega'); little bluestem (*Schizachyrium scoparium* (Michx.) Nash); blue fescue (*Festuca ovina* var. *glauca* (Lam.) W.D.J. Koch).

Significance to the Nursery Industry

Increased demand for herbaceous perennials and subsequent increased production and landscape use of herbaceous perennials has fostered interest in improved weed control strategies for herbaceous perennial plantings. Common methods of weed control in herbaceous perennial plantings include cultivation, hand weeding, mulching, and to a limited extent, herbicides. Cultivation and hand weeding are repetitive and costly. The few herbicides labeled for use on herbaceous perennials are generally only effective for short periods and are often only marginally effective. Information regarding tolerance of herbaceous perennials to herbicides is expanding, but limited. Results indicate that a hardwood wood chip mulch and several herbicides that provide effective weed control in woody species have potential for use in herbaceous perennial production systems and landscape plantings. The precocious nature of herbaceous perennial emergence in early spring under field conditions in the upper midwest dictates that herbicide applications be made in late fall after plants have become dormant. Many of the herbicides evaluated were not phytotoxic when applied to emerged plants.

Introduction

In response to high profit potential and increasing demand for herbaceous perennials, herbaceous perennial production is a fast growing sector within the sphere of nursery production. Landscape use of herbaceous perennials continues to increase and production continues to expand both in numbers of growers and species grown. Even though production acreages are generally small, high plant densities make weed

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[2]Post-Doctoral Research Associate, Professor, and Junior Scientist, respectively.

control tedious, labor intensive, and costly. Storage organs just below the soil surface and shallow rooting are common among herbaceous perennial species making cultivation a potentially damaging weed control practice. Alternative weed control measures, including the use of herbicides, could reduce weed control costs; however, little information regarding the tolerance of herbaceous perennials to herbicides is available and few herbicides are labelled for use in herbaceous perennial production systems and landscape plantings. Considerable research has investigated herbicides for use on woody nursery crops while research involving field grown, herbaceous perennials for landscape use has been limited (1, 2, 4, 19, 23). Most herbicide research with herbaceous perennial species has focused on a limited number of species produced for cut flower production (9, 10, 11, 21). Some research has evaluated herbicides for use in bulb production (12, 20). Although general references regarding the use of mulches for weed control can be found, most apply to home garden and landscape use and focus on inorganic mulches such as black plastic or landscape fabrics (3, 8, 17, 18, 22). Sheets of newspaper and shredded newspapers have been used for weed control with varying degrees of success in the production of vegetables (7, 14), strawberries (5); soybeans (14), and woody (15, 24) and herbaceous (15) perennials. No references regarding the use of rubber tire chips as a mulch have been found in the literature. This research was initiated in response to the lack of information regarding herbicide tolerance and weed control options in herbaceous perennial plantings. Objectives were to determine the practicality, weed control efficacy, phytotoxicity, and cost effectiveness of current herbicide technology and several mulches for weed control in herbaceous perennial production systems and landscape plantings. Weed control and phytotoxicity data are presented in this paper.

Materials and Methods

Twelve pre-emergent and two post-emergent herbicide treatments and three mulch treatments (Table 1) were selected for comparison to weeded (cultivated) and non-weeded controls for weed management in field grown herbaceous perennials. Most of the herbicides evaluated are registered for use on turf or woody landscape species and all have provided good weed control in previous research within the UM TRE (Teaching, Research, and Extension) Nursery Program. Busy production schedules coupled with unpredictable weather often precludes the proper timing of herbicide applications. To address this concern and investigate the effects of herbicide application timing, herbicides were applied at two different times: pre- and post-emergence.

Twelve species of herbaceous perennials (Table 2) were planted 0.31 m (1 ft) apart in rows 0.61 m (2 ft) apart in a field plot (St. Paul Agricultural Experiment Station, St. Paul, MN; Waukegan silt loam, fine-silty, mixed, mesic, Typic Hapludoll, pH 6.9, 4.3% organic matter; USDA hardiness zone 4) during August and September. A split-plot experimental design with 3 blocks was used (species = whole plots). Each treatment/species/application time combination was replicated 3 times and there were three plants of each species/plot. During the first week of November plants were covered with 15–20 cm (6–8 in) of straw for winter protection; mulch was removed the following spring (early April). Pre-emergence herbicide applications were made as soon as weather and field conditions were favorable. Post-emergence applications were made in mid June. Liquid herbicide treatments were applied with a N_2-pressurized, back-pack sprayer calibrated to apply 2.8 liters (0.75 gal) of water/4.5 m^2 (50 ft^2) treatment area at 207 kPa (30 PSI) of pressure. Three passes/treatment were made with a 1.22 m (4 ft) boom with

Table 1. Weed control treatments evaluated for use in herbaceous perennial field production systems.

Treatment (chemical name)	Rate (kg ai/ha)	Rate (lb ai/A)
Controls		
Weeded	—	—
Non-weeded	—	—
Pre-emergent herbicides		
Balan 2.5G (benefin)	3.36	3.0
Gallery 75WDG (isoxaben)	1.12	1.0
Gallery 75WDG (isoxaben) + Surflan 4AS (oryzalin)[z]	1.12 + 3.36	1.0 + 3.0
Goal 1.6EC (oxyfluorfen)	1.68	1.5
Pennant 5G (metolachor)	3.36	3.0
Ronstar 2G (oxadiazon)	3.92	3.5
Ronstar 50WP (oxadiazon)	3.92	3.5
Rout GS (oxyfluorfen/oryzalin)	2.24/1.12	2.0/1.0
Snapshot 80DF (isoxaben/oryzalin)	4.48	4.0
Stomp 3.3EC (pendimethalin)	4.48	4.0
Stomp 60WDG (pendimethalin)	4.48	4.0
Surflan 4AS (oryzalin)	3.36	3.0
Post-emergent herbicides		
Fusilade 2000 (fluazifop)	1.12	1.0
Vantage [formerly Poast] (sethoxydim)	0.211	0.188
Mulches		
Newspaper mulch	4 sheets thick	4 sheets thick
Rubber tire chip mulch	8–10 cm	3–4 in
Wood chip (hardwood) mulch	10–15 cm	4–6 in

[z]Tank mixed isoxaben plus oryzalin is the same combination of active ingredients found in the product Snapshot 80DF.

Table 2. **Herbaceous perennial species used to evaluate weed control options for herbaceous perennial field production systems.**

Botanical name—common name	Propagule
Festuca ovina var. *glauca*—Blue Fescue	seeded plugs
Hemerocallis 'Young Love'—'Young Love' Daylily	divisions
Hemerocallis 'After Dark'—'After Dark' Daylily	divisions
Hosta lancifolia—Narrow-leaved Plantain Lily	divisions
Iris sibirica 'Steve'—'Steve' Siberian Iris	divisions
Iris 'Gypsy Eyes'—'Gypsy Eyes' Miniature Dwarf Bearded Iris	divisions
Iris 'Singing Angel'—'Singing Angel' Miniature Dwarf Bearded Iris	divisions
Liatris spicata—Gayfeather	corms
Lilium 'Willowwood'—'Willowwood' Asiatic Lily	bulbs
Paeonia 'Felix Crouse'—'Felix Crouse' Peony	divisions
Phlox maculata 'Omega'—'Omega' Wild Sweet William	rooted cuttings in plugs
Schizachyrium scoparium—Little Bluestem	seeded plugs

four Teejet #11003 nozzles (Spraying Systems Co., Wheaton, IL). Granular herbicides were broadcast using a hand held shaker. All herbicide treatments were applied to weed free plots. The three mulches (wood chips, rubber tire chips, and newspaper) were applied immediately after planting. Treatments were repeated for two additional years.

Weed population and herbaceous perennial performance data were collected in early to mid August each year. Herbicide efficacy was based on weed count data and a survey of weed species present. Phytotoxicity evaluations were based on plant quality ratings (5 = excellent, 4 = good, 3 = fair, 2 = poor, 1 = unsalable, 0 = dead) as determined by three independent judges. Plant mortality was also recorded. Reduction in size or quality compared to weeded control plants was considered when plants were rated for injury.

Results and Discussion

Weed control efficacy. Weeds typically present in non-weeded control plots included black nightshade (*Solanum nigrum* L.), common groundsel (*Senecio vulgaris* L.), common lambsquarters (*Chenopodium album* L.), common purslane (*Portulaca oleracea* L.), Canada thistle [*Cirsium arvense* (L.) Scop.], cottonwood (*Populus deltoides* Bartr. ex Marsh.), dandelion (*Taraxacum officinale* Weber in Wiggers), prostrate knotweed (*Polygonum aviculare* L.), prostrate pigweed (*Amaranthus blitoides* S. Wats.), pineappleweed [*Matricaria matricarioides* (Less.) C.L. Porter], smallflower galinsoga (*Galinsoga parviflora* Cav.), redroot pigweed (*Amaranthus retroflexus* L.), rough hawksbeard (*Crepis biennis* L.), shepherd's-purse [*Capsella bursa-pastoris* (L.) Medicus], velvetleaf (*Abutilon theophrasti* Medicus), bristly foxtail [*Setaria verticillata* (L.) Beauv.], barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.], large crabgrass [*Digitaria sanguinalis* (L.) Scop.], quackgrass [*Andropyron repens* (L.) Beauv.], witchgrass (*Panicum capillare* L.), and yellow foxtail [*Setaria lutescens* (Weigel.) Hubb.]. All treatments reduced weed densities compared to the non-weeded control (Table 3). Even the least effective weed control treatments reduced weed numbers by a minimum of 29% for the pre-emergence applied treatments and 76% for the post-emergence applied treatments, respectively. The most prevalent weed species was common groundsel which appeared to be quite tolerant of most herbicides especially when weather conditions were cool and wet. Germination of this species continues throughout the growing season as long as moisture is adequate. Although newspaper mulch showed potential for controlling weeds, it was abandoned because of problems keeping it in place especially during dry, windy weather. Similar problems have been reported by other researchers (5, 15).

Wood chip mulch, Rout GS, Snapshot 80DF, and tank mixed Gallery 75WDG + Surflan 4AS provided the best weed control, respectively, reducing weed numbers by 93% to 99% compared to non-weeded controls (Table 3). When the active ingredients isoxaben and oryzalin were applied in combination (Snapshot 80DF, Gallery 75WDG + Surflan 4AS), weed control was significantly better than that provided by either compound alone (Gallery 75WDG, Surflan 4AS). Weed populations for the rubber tire chip mulch treatment were initially reduced compared to the non-weeded control; however, numbers of warm season weeds increased in the tire chips over time. Although the weed species mix was different, full season weed control provided by the tire chip mulch resulted in an average of 73% fewer weeds/m^2 than for the non-weeded control plots. Reductions in weed densities associated with the rubber tire chip mulch were comparable to those provided by many of the herbicides evaluated. Increased prevalence of warm season weed species including common purslane (*Portulaca oleracea*) and large crabgrass (*Digitaria sanguinalis*) probably resulted from the black color of the rubber tire chips and associated increases in surface soil temperature.

Reliance on cultivation for weed control in herbaceous perennial plantings was sometimes detrimental to plant quality (Tables 4 and 5). Early spring cultivation was most likely to reduce plant quality perhaps in response to damage to tender shoots, surface roots, and crown tissue. Injury to such tissues just prior to emergence and the period of rapid growth would likely have a stronger influence on plant growth than injury after the spring growth flush. Reductions in plant quality associated with cultivation would be most problematic for herbaceous perennial species having shallow root systems and storage structures, such as rhizomes and fleshy roots, near the soil surface.

Herbicide phytotoxicity/plant quality. Except for *Phlox maculata*, which was very sensitive to herbicides, plant mortality was not correlated with weed control treatment (data not shown). Tolerance of herbaceous perennials to pre- and post-emergence applied herbicides was species, and in some cases cultivar, specific (Tables 4 and 5). Reductions in quality were often associated with reductions in size and plant density. In general, herbicide tolerance was high for all species except *Hemerocallis* 'After Dark' and *Phlox maculata* 'Omega'.

Blue fescue (*Festuca ovina* var. *glauca)*, a semi-evergreen species depending on snowcover, was tolerant of all herbi-

Table 3. Weed density (weeds/m²) for 19 weed control treatments evaluated for field grown herbaceous perennials.

Herbicide/weed control treatment	Pre-emergence application			Post-emergence application		
	Broadleaves	Grasses	Total	Broadleaves	Grasses	Total
Controls						
Weeded	—	—	—	—	—	—
Non-weeded	122.8a[z]	68.0a	190.8a	148.4a	115.1a	263.5a
Pre-emergent herbicides						
Balan 2.5G	54.8c	7.7d	62.5cd	54.1b	10.1c	64.2b
Gallery 75WDG	9.8f	12.8c	22.6f	5.3f	16.2bc	21.5def
Gallery 75WDG + Surflan 4AS[y]	7.7f	1.7e	9.4f	16.9de	2.7cd	19.6def
Goal 1.6EC	24.7e	1.7e	26.4ef	6.7ef	1.4d	8.1ef
Pennant 5G	25.2e	2.0e	26.2ef	20.4d	6.7cd	27.1cde
Ronstar 50WP	35.0d	0.6e	35.6def	9.8ef	2.0cd	11.8ef
Rout GS	3.5f	2.1e	5.6f	2.4f	0.6d	3.0f
Ronstar 2G	31.4de	4.1de	35.5def	21.5d	3.7cd	25.2de
Snapshot 80DF	5.2f	3.2de	8.4f	1.5f	4.0cd	5.5ef
Stomp 3.3EC	131.5a	4.8de	136.3b	36.8c	1.6d	38.4cd
Stomp 60WDG	77.1b	7.0d	84.1c	46.4b	1.9cd	48.3bc
Surflan 4AS	76.7b	1.7e	78.4c	29.3cd	5.2cd	34.5cd
Post-emergent herbicides						
Fusilade 2000[x]	—	—	—	—	—	—
Vantage[x]	—	—	—	—	—	—
Mulches						
Newspaper mulch[w]	—	—	—	—	—	—
Rubber tire chip mulch[v]	37.1d	21.0b	58.1cde	37.1c	21.0b	58.1b
Wood chip mulch[v]	2.3f	0.2e	2.5f	2.3f	0.2d	2.5f

[z]Treatment means within columns separated by Duncan's Multiple Range Test, $p = 0.05$.

[y]Tank mixed isoxaben plus oryzalin is the same combination of active ingredients found in the product Snapshot 80DF.

[x]Fusilade 2000 and Vantage applied post-emergence only; phytotoxicity data only.

[w]Newspaper treatment abandoned because of management problems.

[v]Rubber tire and wood chip mulch treatments present season long; weed counts used in both pre- and post-emergence application weed control comparisons.

cides applied pre-emergence, except Gallery 75WDG + Surflan 4AS, and was injured by post-emergence applied Snapshot 80DF, Goal 1.6EC, and Rout GS (Table 4).

Quality of *Hemerocallis* 'Young Love' plants was equal to or better than that for control plants for all weed control treatments. Application time had no effect on phytotoxicity except for Ronstar 50WP which reduced quality of *Hemerocallis* 'Young Love' when applied post-emergence (Table 4). *Hemerocallis* 'After Dark', a less vigorous cultivar with broader foliage, was more variable in its response to herbicide treatment and more sensitive to herbicides in general than 'Young Love'; this was especially true when herbicides were applied post-emergence (Table 4). Post-emergence applied Stomp 3.3EC reduced *Hemerocallis* 'After Dark' quality dramatically compared to the same herbicide applied pre-emergence. Stomp 3.3EC was not phytotoxic to the cultivar 'Young Love'. In addition to greater herbicide sensitivity, the cultivar 'After Dark' was more negatively influenced by weed competition than 'Young Love' perhaps because of its less vigorous nature. These results highlight the potential for variability among cultivars regarding herbicide tolerance and the importance of herbicide screening for newly released cultivars. The wood chip mulch treatment resulted in the highest quality plants for the herbicide sensitive cultivar 'After Dark'.

Narrow-leaved plantain lily (*Hosta lancifolia*) was tolerant of all herbicides except for Ronstar 50WP, which reduced plant quality when applied pre-emergence (Table 4). All herbicides reduced quality of *Hosta* compared to the controls when applied post-emergence except for Balan 2.5G, Stomp 60WDG, Surflan 4AS, Fusilade 2000, and Vantage. Although safe when applied to dormant *Hosta*, herbicide treatments that contained the active ingredient isoxaben (Gallery 75WDG, tank mixed Gallery 75WDG + Surflan 4AS, and Snapshot 80DF) were considerably more phytotoxic when applied post-emergence. Stomp 3.3EC, Ronstar 50WP, and Goal 1.6EC were more phytotoxic when applied to *Hosta* post-emergence. The wood chip mulch, rubber tire chip mulch, and Balan 2.5G treatments resulted in high quality *Hosta* plants. The timing of Balan 2.5G, Stomp 60WDG, and Surflan 4AS applications had no effect on *Hosta* quality.

Quality of *Iris sibirica* 'Steve' was low for the rubber tire mulch treatment (Table 4). Ronstar 50WP and Surflan 4AS also reduced *Iris sibirica* quality when applied post-emergence. Balan 2.5G resulted in the highest quality plants compared to all other post-emergence herbicide treatments.

Quality determinations for the miniature dwarf bearded iris (*Iris* 'Gypsy Eyes' and 'Singing Angel') were somewhat confounded by leaf diseases and iris borer (*Macronoctua onusta* Grote) activity and subsequent bacterial and fungal attack. Foliage of these two varieties tended to emerge very early in the spring and was typically present at the time of pre-emergence herbicide application. This young foliage was apparently susceptible to herbicide injury since plant quality for *Iris* 'Singing Angel' (Table 5) was low for most pre-emergence herbicide applications. The wood chip and rubber tire mulch treatments resulted in high quality plants. Quality also remained high for the Balan 2.5G treatment. Herbicide tox-

Table 4. **Visual quality ratings (5 = excellent; 0 = dead) for 6 of 12 herbaceous perennial species used to evaluate pre- and post-emergence applied herbicides and mulches as weed control strategies for use in herbaceous perennial field production systems.**

Herbicide/weed control treatment	*Festuca ovina* var. *glauca*	*Hemerocallis* 'After Dark'	*Hemerocallis* 'Young Love'	*Hosta lancifolia*	*Iris sibirica* 'Steve'	*Iris* 'Gypsy Eyes'
Pre-emergence application						
Controls						
Weeded	4.3abc[z]	3.2abc	3.4d	3.7abcd	3.4de	2.6bcd
Non-weeded	4.3abc	2.9abcd	3.9abc	3.6abcde	4.7ab	2.3bcde
Pre-emergent herbicides						
Balan 2.5G	4.6ab	3.0abcd	4.2a	3.8abc	4.6abc	2.6bcd
Gallery 75WDG	3.9bcd	2.6bcde	3.9abc	4.0ab	4.2abcd	1.9cde
Gallery 75WDG + Surfaln 4AS	3.4d	3.0abcd	3.7bcd	4.2a	3.4de	1.5e
Goal 1.6EC	3.6cd	1.6f	3.5cd	3.0cde	4.2abcd	1.5e
Pennant 5G	4.2abc	2.6bcde	3.7bcd	3.4bcde	3.7bcde	1.7de
Ronstar 2G	4.3abc	2.1def	3.7bcd	2.8def	3.7bcde	1.8de
Ronstar 50WP	4.2abc	2.5cdef	3.9abc	2.4f	3.3de	1.5e
Rout GS	3.8cd	1.8f	3.5cd	2.9def	4.2abcd	2.9abc
Snapshot 80DF	4.8a	2.3cdef	4.2a	3.4bcde	3.8bcde	1.9cde
Stomp 3.3EC	4.6ab	3.8a	4.1ab	3.9ab	4.9a	2.4bcde
Stomp 60WDG	3.9bcd	3.1abc	3.7bcd	3.2cde	4.6abc	2.9abc
Surflan 4AS	3.7cd	2.8bcd	3.5cd	3.5abcde	3.8bcde	1.4e
Mulches						
Rubber tire chip mulch	4.0bcd	2.4cdef	3.8abcd	4.1ab	2.9e	3.2ab
Wood chip mulch	3.9bcd	3.5ab	3.4d	4.1ab	3.6cde	3.7a
Post-emergence application						
Controls						
Weeded	3.9ab[z]	3.3ab	3.0cd	3.2bcd	3.7abcde	3.5abc
Non-weeded	3.9ab	2.0c	3.0cd	3.4ab	3.6abcde	3.0abcde
Pre-emergent herbicides						
Balan 2.5G	4.3a	2.5abc	3.1bcd	3.8ab	4.6a	3.4abc
Gallery 75WDG	3.5abcd	1.7c	3.4abc	2.8cd	3.0cde	3.3abc
Gallery 75WDG + Surflan 4AS	3.3bcd	2.7abc	3.9a	2.8cd	4.1abc	2.4de
Goal 1.6EC	2.7de	2.3bc	2.8cd	2.5d	3.2cde	2.9bcde
Pennant 5G	4.0ab	2.3bc	3.4abc	2.8cd	4.0abcd	2.7cde
Ronstar 2G	4.0ab	3.3ab	3.3abc	3.0bcd	3.3bcde	3.6ab
Ronstar 50WP	3.8ab	1.7c	2.5d	2.5d	2.6e	3.4abc
Rout GS	2.1e	2.2bc	2.9cd	2.8cd	3.3bcde	2.7cde
Snapshot 80DF	2.8cde	3.0ab	3.2abcd	2.9cd	3.9abcd	3.0abcde
Stomp 3.3EC	4.0ab	1.8c	3.5abc	2.4d	3.1cde	3.7a
Stomp 60WDG	3.6abc	2.3bc	3.3abc	3.5ab	3.7abcde	3.1abcd
Surflan 4AS	4.0ab	2.0c	3.3abc	3.4ab	1.7f	3.2abc
Post-emergent herbicides						
Fusilade 2000	3.5abcd	2.6abc	3.8ab	3.4ab	3.5abcde	1.7f
Vantage	3.9ab	2.5abc	3.4abc	3.2bcd	4.4ab	2.3e
Mulches						
Rubber tire chip mulch	4.0ab	2.4abc	3.8ab	4.1a	2.9de	3.2abc
Wood chip mulch	3.9ab	3.5a	3.4abc	4.1a	3.6abcde	3.7a

[z]Treatment means within columns and application times separated by Duncan's Multiple Range Test, p = 0.05.

icity was usually less severe for post-emergence herbicide applications. Mature foliage may have been less susceptible to damage or perhaps the presence of foliage reduced exposure of exposed rhizomes to herbicides thereby reducing phytotoxic effects. *Iris* 'Gypsy Eyes' was apparently less susceptible to attack by iris borer so plant quality was generally higher (Tables 4 and 5). Phytotoxicity for 'Gypsy Eyes' was similar to that reported for 'Singing Angel'.

Gayfeather (*Liatris spicata*) was tolerant of all herbicides except for Goal 1.6EC applied pre-emergence (Table 5). Quality of *Liatris* was also reduced compared to control plants for the wood chip mulch treatment; perhaps a consequence of delayed emergence and growth in response to cooler soil temperatures for this warm season species. Regardless of application time, quality of *Liatris* was high when treated with Balan 2.5G, Gallery 75WDG + Surflan 4AS, Pennant 5G, Ronstar 50WP and Stomp 60WDG. Of the species included in the research, *Liatris* was most tolerant of Ronstar 50WP regardless of when it was applied.

Lilium 'Willowwood' was tolerant of all herbicides except Ronstar 50WP and Goal 1.6EC which caused severe injury (stunting) when applied pre-emergence (Table 5). Goal 1.6EC applied post-emergence also reduced *Lilium* quality as did Gallery 75WDG. The injury observed for post-emergence applied Goal 1.6EC was severe, but localized, and consisted of deformation and browning of the foliage at the

Table 5. **Visual quality ratings (5 = excellent; 0 = dead) for 6 of 12 herbaceous perennial species used to evaluate pre- and post-emergence applied herbicides and mulches as weed control strategies for use in herbaceous perennial field production systems.**

Herbicide/weed control treatment	*Iris* 'Singing Angel'	*Liatris* spicata	*Lilium* 'Willowwood'	*Paeonia* 'Felix Crouse'	*Phlox maculata* 'Omega'	*Schizachyrium scoparium*
Pre-emergence application						
Controls						
Weeded	2.6bc[z]	4.2abcd	4.1abc	2.5c	3.0ab	3.2bcd
Non-weeded	2.6bc	3.9cde	3.9abcd	3.9a	3.5a	4.0a
Pre-emergent herbicides						
Balan 2.5G	3.9a	4.6ab	3.4def	3.3abc	2.6bc	3.5abc
Gallery 75WDG	2.8bc	3.8de	4.5a	2.9bc	2.2c	2.9cd
Gallery 75WDG + Surflan 4AS	1.4d	4.0bcd	3.6cdef	3.5ab	0.5e	3.6abc
Goal 1.6EC	2.2bcd	2.9g	0.9g	3.3abc	1.4d	1.9e
Pennant 5G	2.6bc	4.5abc	3.8bcde	4.1a	0.7e	3.2bcd
Ronstar 2G	2.3bcd	3.7ef	3.3ef	3.9a	3.0ab	2.7d
Ronstar 50WP	2.1bcd	4.4abc	3.0f	1.4d	3.0ab	4.2a
Rout GS	2.7bc	3.4efg	3.6cdef	4.2a	2.8bc	2.9cd
Snapshot 80DF	2.3bcd	4.1abcd	3.9abcd	3.5ab	0.7e	3.9ab
Stomp 3.3EC	2.4bcd	3.7ef	3.9abcd	3.8ab	2.3c	3.6abc
Stomp 60WDG	2.0cd	4.7a	4.1abc	3.7ab	1.0de	3.6abc
Surflan 4AS	3.1ab	4.1abcd	3.7cde	3.3abc	0.8de	4.1a
Mulches						
Rubber tire chip mulch	3.9a	3.7ef	4.4ab	3.5ab	2.4bc	3.6abc
Wood chip mulch	3.9a	3.1fg	4.0abcd	3.7ab	2.3c	2.9cd
Post-emergence application						
Controls						
Weeded	2.4d[z]	3.2bcde	3.9abc	3.2bcdef	3.2abc	2.9bcde
Non-weeded	3.5ab	2.6e	3.6bcd	2.3f	2.4bcde	2.7bcde
Pre-emergent herbicides						
Balan 2.5G	4.0a	3.7abc	4.4ab	2.8def	2.9abcd	2.9bcde
Gallery 75WDG	3.0bc	2.7de	2.9d	4.3ab	2.4bcde	2.6cde
Gallery 75WDG + Surflan 4AS	2.6cd	3.3bcde	3.3cd	3.6abcde	3.4ab	3.6ab
Goal 1.6EC	3.0bc	2.7de	2.8d	2.9def	2.1de	2.4de
Pennant 5G	3.6ab	3.6abcd	3.4cd	4.1abc	2.2cde	2.8bcde
Ronstar 2G	2.6cd	3.5abcde	4.7a	3.3bcde	2.6abcd	3.0abcd
Ronstar 50WP	4.1a	3.4bcde	4.8a	1.1g	3.0abcd	2.0e
Rout GS	3.3abc	3.6abcd	3.7bcd	3.2bcdef	2.0de	2.5de
Snapshot 80DF	2.9bcd	2.6e	3.7bcd	4.5a	1.5e	3.0abcd
Stomp 3.3EC	3.7ab	2.7de	3.7bcd	3.9abcd	2.0de	2.9bcde
Stomp 60WDG	4.1a	3.1bcde	3.7bcd	3.6abcde	2.2cde	3.9a
Surflan 4AS	2.4d	3.0cde	3.7bcd	2.9def	2.7abcd	3.5abc
Post-emergent herbicides						
Fusilade 2000	2.5cd	4.4a	3.4cd	2.6ef	3.0abcd	2.1de
Vantage	4.0a	4.0ab	3.2cd	3.1cdef	3.5a	2.9bcde
Mulches						
Rubber tire chip mulch	3.9a	3.7abc	4.4ab	3.5abcde	2.4bcde	3.6ab
Wood chip mulch	3.9a	3.1bcde	4.0abc	3.7abcde	2.3cde	2.9bcde

[z]Treatment means within columns and application times separated by Duncan's Multiple Range Test, p = 0.05.

growing tip at the time of herbicide application. Some plants resumed normal growth subsequent to herbicide application while others never recovered. Whether or not the growing point was killed was likely the determining factor.

Paeonia 'Felix Crouse' was tolerant of all herbicides except for Ronstar 50WP (Table 5). Injury caused by Ronstar 50WP applied post-emergence was manifested as a permanent scorched appearance of the foliage. *Paeonia* was very sensitive to weed competition as evidenced by reduced quality for non-weeded control plants.

Of the 12 species evaluated, *Phlox maculata* 'Omega' was most herbicide sensitive (Table 5). All herbicides, except for Ronstar 2G, Ronstar 50WP, Balan 2.5G, and Rout GS, reduced quality of *Phlox* when applied pre-emergence. Phytotoxicity resulting from post-emergence applied treatments was more variable, but all herbicides still reduced plant quality except for Ronstar 2G, Ronstar 50WP, Fusilade, and Vantage. Whether applied pre- or post-emergence, Snapshot 80DF was the most phytotoxic herbicide for *Phlox*. Mulch treatments also reduced quality for *Phlox* compared to control plants. Based on the response to herbicides observed, *Phlox* might serve as an indicator species for herbicide phytotoxicity screening. If *Phlox* is not injured by a particular herbicide, other herbaceous perennials are also likely to be tolerant. Injury to *Phlox* was often observed, however, for herbicides that did not injure other herbaceous perennial species. Interestingly, *Phlox* exhibited tolerance to Ronstar 50WP which often injured other herbaceous perennial species.

Little bluestem (*Schizachyrium scoparium*) quality was reduced by Goal 1.6EC and Ronstar 2G applied pre-emergence (Table 5). Little bluestem also responded negatively to cultivation. The wood chip mulch may have also reduced plant quality by delaying emergence and growth of this warm season prairie species. The rubber tire chip mulch, which would tend to increase soil temperature, had the opposite effect.

Timing of herbicide application was important regarding herbicide phytotoxicity. The pre-emergence herbicide applications were sometimes more phytotoxic than post-emergence applications. Some of the herbaceous perennials had initiated growth prior to the time that the pre-emergence herbicide applications could be applied in the spring. This tender, succulent growth may have been injured when the herbicides were applied. For this reason it may be better to apply pre-emergent herbicides in the fall after plants have become dormant to avoid injury to early spring growth. Rout GS was more likely to be phytotoxic when applied post-emergence. Perhaps when applied to emerged plants this granular product became lodged within the foliage and caused injury.

The two post-emergent, grass specific herbicides, Fusilade and Vantage, did not reduce plant quality compared to the controls (Tables 4 and 5). This result was somewhat surprising since grasses and other monocots (e.g. *Lilium*) might have been expected to be injured by such products. Other studies have reported variable effects of grass specific, post-emergent herbicides on grasses (6, 13, 16) while the sensitivity of broadleaved monocots has not been specifically addressed in the literature.

No one herbicide appears to be acceptable for use on all herbaceous perennial species. However, most of the herbicides evaluated in this research appear to have potential for weed control in herbaceous perennials. Balan 2.5G, Stomp 60WDG, and Snapshot 80DF were usually non-phytotoxic regardless of when applied. Stomp 3.3EC applied pre-emergence and Ronstar 2G, Surflan 4AS, Pennant 5G, and Gallery 75WDG + Surflan 4AS applied post-emergence were also typically non-phytotoxic. Of these, Snapshot 80DF provided the best weed control: 8.4 weeds/m^2 when applied pre-emergence and 5.5 weeds/m^2 when applied post-emergence compared to 190.8 weeds/m^2 and 263.5 weeds/m^2 for the respective controls (Table 3). Only Rout GS provided better weed control, but Rout GS was more likely to be phytotoxic especially when applied post-emergence. Goal 1.6EC and Ronstar 50WP were often phytotoxic and are not recommended for general use on herbaceous perennials. *Iris* appears to be relatively intolerant of post-emergence applied Surflan 4AS. Herbicide phytotoxicity was species and cultivar dependent and additional species specific research is needed before general recommendations can be made. New herbicide technology should also be evaluated for use in herbaceous perennials.

Evaluation of herbicides in this research does not imply the herbicides are labelled for use on herbaceous perennial species. Herbicide labels are routinely updated and expanded regarding rates of application and species of plants to which the herbicide may be applied. Always read the label before applying any herbicide.

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