HortScience 49(9):1212–1216. 2014.

Springtime Dandelion (*Taraxacum officinale*) Control with Seven Postemergence Herbicides Applied at Three Anthesis Stages

Zane Raudenbush[1,3] **and Steven J. Keeley**[2]

Department of Horticulture, Forestry and Recreation Resources, Kansas State University, 2021 Throckmorton Plant Sciences, Manhattan, KS 66506

Additional index words. 2,4-D, application timing, broadleaf weed control, carfentrazone-ethyl, dicamba, pyraflufen-ethyl

***Abstract*. Although spring is not considered the optimal time for herbicidal control of most cool-season broadleaf weeds in turfgrass, spring applications are often required. Most new postemergence broadleaf herbicides combine several active ingredients, possibly resulting in synergistic, antagonistic, or additive effects. Therefore, as new herbicides become available, information is needed about their performance when applied in the spring. The objective of our study was to determine the effect of spring application timing on dandelion control with seven commercially available postemergence herbicides. Products were applied at their lowest labeled rate for dandelion control at three spring application timings, which coincided with dandelion anthesis stages (pre-, peak-, or post-bloom). A grid was used to determine percent dandelion control at several rating dates. The 2010 site had a denser turfgrass stand with smaller dandelions and was irrigated more frequently compared with the 2011 site. In 2010, all herbicides gave 98% or greater control at 30 days after treatment (DAT) when applied post-bloom; when applied pre- or peak-bloom, control was 80% or greater for all herbicides except for two products applied peak-bloom. At pre- and peak-bloom, products combining a protoporphyrinogen oxidase (PPO) inhibitor with a 2,4-D ester formulation were superior to most other herbicides. When evaluated at the end of the growing season in 2010, all herbicides provided 89% or greater control at all three timings. In 2011, with a less dense turfgrass stand, larger dandelions, and less frequent irrigation, control was more variable and shorter-lived among herbicides. When applied pre-bloom, all products containing 2,4-D provided 87% or greater control 60 DAT. Post-bloom application generally gave similar control to the pre-bloom timing. Peak-bloom application resulted in the poorest overall control at 60 DAT, but products combining a PPO inhibitor with a 2,4-D ester formulation performed better than most other herbicides. By the end of the season, dandelion regrowth caused reduced overall control at all timings, but overall control was poorest when applied at peak-bloom. In summary, peak-bloom applications should be avoided, especially if dandelion pressure is high. Products combining PPO inhibitors with ester forms of 2,4-D were most effective across all spring application timings. Products containing amine forms of 2,4-D may provide effective control if applied pre- or post-bloom.**

Common dandelion (*Taraxacum officinale* Weber) is one of the most widely recognized weeds of turfgrass. It is a simple perennial, forming a basal rosette of leaves and bright yellow flowers (Uva et al., 1997). Dandelions can reproduce through wind-dispersed seeds or from taproot fragments (McCarty et al., 2001). Dandelions are apomictic, so pollination is not needed to produce viable seeds (Uva et al., 1997). The wind-dispersed seeds can travel long distances and infest previously weed-free areas. Mechanical control of dandelion is difficult because the taproot must effectively be removed or destroyed. A study comparing dandelion control with 2,4-D and mechanical treatments found no measure of control was achieved with hand-weeding alone (Mann, 1981). Many turf managers have achieved acceptable dandelion control using selective herbicides (Christians, 2007; Gardner, 2009; Loughner and Nolting, 2010).

Most products used for broadleaf weed control in turfgrass are combination products that contain several active ingredients, which allow turf managers to control a wide array of broadleaf weeds with a single product. However, because the interaction between active ingredients may be additive, synergistic, or antagonistic when combined (Zhang et al., 1995), it is difficult to predict the performance of a new combination herbicide based on the performance of its components applied singly.

Many of the active ingredients found in these products such as 2,4-D, dicamba, mecoprop, clopyralid, fluroxypyr, and triclopyr are in the synthetic auxin class of herbicides (Senseman, 2007). Synthetic auxin herbicides are highly selective because most grasses can inactivate these compounds by conjugation, whereas broadleaf weeds cannot and thus are controlled. In recent years, some products have also included an active ingredient from the PPO-inhibiting class such as pyraflufen-ethyl, carfentrazone-ethyl, or sulfentrazone (Senseman, 2007). These compounds inhibit PPO, an enzyme in chlorophyll synthesis needed for catalyzing the oxidation of protoporphyrinogen IX to protoporphyrin IX (Cobb and Reade, 2010). Inhibition of PPO causes an increase in both triplet and singlet state oxygen, resulting in cellular leakage through lipid peroxidation (Senseman, 2007). One reason PPO inhibitors may be included in tank mixes with synthetic auxin herbicides is to provide more rapid necrosis of foliage. Many researchers have reported acceptable control of perennial broadleaf weeds using such combination products (Haley et al., 1995; Loughner and Nolting, 2010; Olson and Hall, 1988; Reicher and Weisnenberger, 2007; Watschke and Borger, 1999). However, previous research has shown that PPO inhibitors can reduce the efficacy of some non-phenoxy herbicides. Ashigh and Hall (2010) reported reduced glyphosate activity when combined with the PPO inhibitor saflufenacil and hypothesized the rapid contact activity of saflufenacil limited the translocation of glyphosate. Similarly, a study conducted by Breeden and McElroy (2006) found that carfentrazone significantly reduced white clover (*Trifolium repens* L.) control when tank-mixed with foramsulfuron compared with foramsulfuron alone.

Fall is considered the best time for herbicidal control of cool-season perennial broadleaf weeds in turfgrass (Branham, 1990; McCarty et al., 2001; Reicher and Weisnenberger, 2007; Wilson and Michiels, 2003). Branham (1990) posited that herbicidal control in the fall is effective because plants are moving carbohydrate reserves to underground storage structures, which is believed to aid in the movement of xenobiotics to their site of action. However, although fall applications may be optimal, turf managers frequently need herbicidal options in the spring to meet clients' expectations.

Spring herbicide applications coincide with one of three dandelion anthesis stages: pre-bloom, peak-bloom, or post-bloom. To the casual observer, the extent of a dandelion infestation may not be apparent until the flush of bright flowers occurs during the bloom stage. Gray et al. (1973) reported less than one flowering dandelion stem/m^2 in the first 13 weeks of the growing in a home lawn in Kentucky; however, in the fourteenth week (4 to 10 Apr.), flowering increased to 68 stems/m^2. Unfortunately, dandelion control may be reduced if herbicides are applied during the

---

Received for publication 2 Mar. 2014. Accepted for publication 15 July 2014.

[1] Graduate Research Assistant.

[2] Professor.

[3] To whom reprint requests should be addressed; e-mail zane12@ksu.edu.

production of flowers and seeds (Schleicher, 1997). The movement of auxinic herbicides in plants is largely controlled by the physiochemical properties of the herbicide such as pK_a and log K_{ow} values (Cobb and Reade, 2010). Once absorbed into the shoot of a susceptible plant, auxinic herbicides such as 2,4-D ($pK_a = 2.8$) typically exist as a free acid because cellular pH is $\approx$5.0 (Sterling, 1994). The non-ionized 2,4-D molecules can readily pass through the cell membrane and into the phloem. However, phloem pH is higher ($\approx$8.0), and incoming 2,4-D molecules are immediately ionized and essentially "trapped" because anions have reduced membrane permeability (Sterling and Hall, 1997). Once trapped in the phloem, the movement of the 2,4-D anion is passive and primarily determined by the strength of source-to-sink partitioning (Cobb and Reade, 2010). In perennial weeds, underground storage structures may become a strong sink for surplus photosynthate produced in mature leaves (Coble et al., 1970), which is believed to enhance the efficacy of herbicide applications by increasing basipetal movement of weak-acid herbicides to underground storage organs (Tworkoski, 1992). Oppositely, during anthesis, the production of flowers and seeds is likely a major sink for photosynthate; therefore, basipetal movement of auxinic herbicides may be limited, resulting in reduced control.

Turf managers need information on herbicide performance in the spring, and our literature search revealed no reports in the refereed literature concerning the influence of spring application timing on dandelion control with postemergence broadleaf herbicides currently used on turfgrass. Furthermore, because these herbicides typically contain multiple active ingredients that may be additive, synergistic, or antagonistic, each combination herbicide itself should be tested rather than testing its individual components. Therefore, the objective of our study was to determine the effect of spring application timing on dandelion control with seven commercially available postemergence broadleaf herbicides.

Materials and Methods

Site characteristics and experimental design. Field studies were conducted in 2010 and 2011 on adjacent sites at the Rocky Ford Turfgrass Research Center in Manhattan, KS. The soil at both sites was a Chase Silt Loam (fine, smectitic, mesic, Aquertic Argiudoll) with a pH of 6.9. Soil tests indicated adequate levels of phosphorus and potassium. The 1.2 × 1.8-m plots were mown at 7.6 cm. The 2010 site contained turf-type tall fescue (*Festuca arundinacea* Schreb. Syn Schedonorous arundinaceus Schreb.) with an existing dandelion stand and was irrigated as needed to prevent drought stress; typically this meant one to two irrigations weekly at 80% to 100% evapotranspiration (ET) replacement. The 2011 site was chosen to provide a more rigorous test of treatments; it had been previously seeded to crested wheatgrass (*Agropyron cristatum* L.) and had an existing dandelion infestation. However, the crested wheatgrass density was poor and dandelions were much larger compared with the 2010 site. The 2011 site was irrigated only when visual wilt symptoms were observed; typically this meant irrigation every 10 to 14 d at 60% to 70% ET replacement. Dimension 2EW [dithiopyr, S,S′-dimethyl 2-(difluoromethyl)-4-(2-methylpropyl)-6-(trifluoromethyl)-3,5-pyridinecarbothioate; Dow AgroSciences, Indianapolis, IN] was applied at 0.195 kg a.i./ha on 24 May 2010 and 18 May 2011 to control large crabgrass [*Digitaria sanguinalis* (L.) Scop.]. A two-factor, randomized complete block design with three replicates was used to evaluate seven herbicides (Factor A) at three application timings (Factor B). Each block contained six untreated control plots to better account for normal variation in weed incidence within blocks.

Treatments and application. All herbicides were commercially available formulations applied at their lowest label rate recommended for dandelion control. The seven herbicides were 4 Speed XT, Confront, Cool-Power, Escalade 2, Speedzone, Surge, and Trimec Classic (chemical names and other herbicide information are available in Table 1). The spring application timings coincided with dandelion pre-bloom, peak-bloom, and post-bloom anthesis stages. Plots were considered to be at the pre-bloom stage when dandelions, after emerging from winter dormancy, were green and actively growing, but less than 10% of dandelions had a blossom present; plots were considered to be at peak-bloom when there were one or more fully

Table 1. Herbicide descriptions and rates for the herbicides used in application timing studies.[z]

Trade name	Common name	Chemical name	Formulation	kg a.i./ha
4 Speed XT	Pyraflufen ethyl	2-chloro-5-difluoromethoxy-1-methyl-1H-pyrazol-3-yl)-4-fluorophenoxyacetate		0.0023
	2,4-D	(2,4-dichlorophenoxy)acetic acid	Isooctyl ester	0.9550
	Triclopyr	[(3,5,6-trichloro-2-pyridinyl)oxy]acetic acid	Butoxyethyl ester	0.1201
	Dicamba	3,6-dichloro-2-methoxybenzoic acid	Acid	0.1201
Confront	Triclopyr	[(3,5,6-trichloro-2-pyridinyl)oxy]acetic acid	Triethylamine salt	0.4724
	Clopyralid	3,6-dichloro-2-pyridinecarboxylic acid	Triethylamine salt	0.1574
Cool Power	MCPA	(4-chloro-2-methylphenoxy)acetic acid	Isooctyl ester	1.041
	Triclopyr	[(3,5,6-trichloro-2-pyridinyl)oxy]acetic acid	Butoxyethyl ester	0.1036
	Dicamba	3,6-dichloro-2-methoxybenzoic acid	Acid	0.1036
Escalade 2	2,4-D	(2,4-dichlorophenoxy)acetic acid	Dimethylamine salt	0.9169
	Fluroxypr	[(4-amino-3,5-dichloro-6-fluoro-2-pyridinyl)oxy]acetic acid	1-methylheptyl ester	0.1144
	Dicamba	3,6-dichloro-2-methoxybenzoic acid	Acid	0.1144
Speedzone	Carfentrazone	X,2-dichloro-5-[4-(difluromethyl)-4,5-dihydro-3-methyl-5-oxo-1H-1,2,4-triazol-1-yl]-4-fluorobenzenepropanic acid		0.0209
	2,4-D	(2,4-dichlorophenoxy)acetic acid	2-ethylhexyl ester	0.6426
	Mecoprop	(±)-2-(4-chloro-2-methylphenoxy)propanoic acid	Acid	0.2014
	Dicamba	3,6-dichloro-2-methoxybenzoic acid	Acid	0.0586
Surge	Sulfentrazone	N-[2,4-dichloro-5-[4-(difluoromethyl)-4,5-dihydro-3-methyl-5-oxo-1H-1,2,4-triazol-1-yl]phenyl]methanesulfonamide		0.0274
	2,4-D	(2,4-dichlorophenoxy)acetic acid	Dimethylamine salt	0.6406
	Mecoprop	(±)-2-(4-chloro-2-methylphenoxy)propanoic acid	Dimethylamine salt	0.2288
	Dicamba	3,6-dichloro-2-methoxybenzoic acid	Dimethylamine salt	0.1007
Trimec Classic	2,4-D	(2,4-dichlorophenoxy)acetic acid	Dimethylamine salt	0.9047
	Mecoprop	(±)-2-(4-chloro-2-methylphenoxy)propanoic acid	Dimethylamine salt	0.2425
	Dicamba	3,6-dichloro-2-methoxybenzoic acid	Dimethylamine salt	0.0958

[z] All herbicides were applied at their lowest label rate for dandelion control.

open, unwithered blossoms on at least 70% of the dandelion plants in the plot area; and plots were considered to be at the post-bloom stage when, after peak-bloom, blossoms had completely withered and less than 10% of dandelion plants had an unwithered blossom present. In 2010, treatments were applied on 4 Apr. (pre-bloom), 20 Apr. (peak-bloom), and 27 May (post-bloom). In 2011, the treatments were applied on 8 Apr. (pre-bloom), 18 Apr. (peak-bloom), and 31 May (post-bloom). Herbicides were applied with a two-nozzle (TeeJet XR8002VS; Spray Systems Co., Wheaton, IL), CO$_2$-pressurized backpack sprayer operating at 207 kPa to deliver a spray volume of 342 L·ha^{-1}.

Measurements. Treatment efficacy was determined using a 1.0 × 1.6-m rating grid sectioned into 160 individual 10 × 10-cm squares. The grid was placed over each treated plot, a count was registered for each square containing an alive dandelion, and the counts were recorded. Mortality was visually estimated; dandelions exhibiting greater than 90% necrotic tissue were considered "dead," and dandelions with less injury were considered to be alive. Percent control was calculated by comparing the counts of alive dandelions in treated plots with the mean count of the six untreated plots in the same replication, e.g., [(mean count of untreated plots – count of treated plot)/(mean count of untreated plots)]*100. In 2010, percent control data were determined at 30 DAT and end of season (15 Nov. 2010). In 2011, percent control data were determined at 30 DAT, 60 DAT, and end of season (12 Nov. 2011).

To improve homogeneity of residual variances, all percent control data were arcsine-transformed before subjected to analysis of variance. Means were separated using Fisher's protected least significant difference ($P \le 0.05$) range test using the MIXED procedure of Statistical Analysis System (Version 9.2; SAS Institute Inc., Cary, NC). Treatment means were back transformed for presentation. A three-factor factorial analysis (year × herbicide × timing) was conducted to determine if data from 2010 and 2011 could be combined. The year × timing interaction was significant; therefore, data for each year are presented separately.

Results and Discussion

2010. Spring herbicide application dates coincided with dandelion anthesis stages (pre-bloom, peak-bloom, post-bloom), providing turf managers a phenological indicator to aid in determining the appropriate time to treat. Application timing had a significant effect on dandelion control at 30 DAT in 2010; best overall control was achieved with post-bloom applications (Tables 2 and 3). The range of control among all herbicides at 30 DAT was 80% to 94% when applied pre-bloom, 66% to 96% when applied at peak-bloom, and 98% to 100% when applied post-bloom (Table 3). Based on 2010 results, peak-bloom applications should be avoided with some herbicides (discussed below).

Table 2. Two-way analysis of variance for the effect of herbicide and spring application timing on percent dandelion control in 2010 and 2011.

	2010		2011		
	30 DAT^z	End of season^y	30 DAT	60 DAT	End of season
Source	Probability of > F				
Herbicide	0.06	0.16	<0.0001	<0.0001	0.62
Timing	<0.0001	0.11	<0.0001	<0.0001	0.01
Herbicide × timing	0.04	0.49	0.002	0.01	0.50

[z] DAT = days after treatment.

[y] End of season ratings were recorded on 15 Nov. and 12 Nov. in 2010 and 2011, respectively.

Table 3. Percent dandelion control at 30 d after treatment in 2010 when postemergence broadleaf herbicides were applied at three different spring application timings coinciding with dandelion anthesis stages (pre-, peak-, post-bloom).^{z}

	Pre	Peak	Post
Herbicide^y	Dandelion control (%)^x		
4 Speed XT	93 a	96 a	99
Speedzone	94 a	95 a	100
Surge	88 ab	92 ab	99
Escalade 2	89 ab	89 abc	100
Confront	82 b	81 bcd	98
Trimec Classic	81 b	76 cd	100
Cool Power	80 b	66 d	100
Timing means^w	88 B	85 B	99 A

[z] Pre-bloom: 4 Apr.; Peak-bloom: 20 Apr.; Post-bloom: 27 May.

[y] Herbicides are ranked over spring peak-bloom timing.

[x] Means followed by the same lowercase letter in a column are not statistically different ($P \le 0.05$) by Fisher's least significant difference. Means in columns without letters are not significantly different.

[w] Means followed by the same uppercase letter in a row are not statistically different ($P \le 0.05$) by Fisher's least significant difference for each rating date.

There were no differences among herbicides at the post-bloom timing; all herbicides provided 98% or greater control 30 DAT. At the pre- and peak-bloom timings, 4 Speed XT and Speedzone provided 93% or greater control at 30 DAT, which was significantly greater than Confront, Trimec Classic, and Cool Power. Both Speedzone and 4 Speed XT contain a PPO inhibitor, whereas Confront, Trimec Classic, and Cool Power do not. At 30 DAT, the PPO inhibitors may have caused additional necrosis, making mortality easier to determine compared with products containing only auxinic herbicides. Cool Power, in particular, gave poor control 30 DAT (66%) when applied peak-bloom, which was worse than all herbicides except Confront and Trimec Classic (Table 3).

When dandelion control was evaluated at the end of the growing season in 2010, there were no differences among herbicides at any application timing; all herbicides provided 89% or greater control (data not shown). Because some herbicides gave as low as 66% control at 30 DAT, those herbicides apparently needed additional time to cause complete dandelion mortality. Air and soil temperatures are typically cooler in the early spring; therefore, turf managers should allow additional time to determine ultimate dandelion control for products that do not contain a PPO inhibitor. This was most apparent with Confront, Trimec Classic, and Cool Power in our study.

2011. In an effort to provide a more rigorous test of all treatments, the study was repeated on a site that had lower turf density, larger dandelions, and received less irrigation. Consequently, the level of dandelion control in 2011 was more variable among herbicides, shorter-lived, and application timing effects were more pronounced (Tables 2 and 4). Because dandelions were significantly larger in 2011 compared with 2010, the level of control at 30 DAT was lower; most plants had severe necrosis at 30 DAT, but a significant percentage of leaf material was still green. Consequently, a 60 DAT rating was added because we felt a better determination of weed control could be made.

At 60 DAT, dandelion control was highly influenced by herbicide timing with peak-bloom application resulting in poorer control (Table 4). Among herbicides, control ranged from 58% to 98% when applied pre-bloom, 16% to 72% when applied at peak-bloom, and 35% to 97% when applied post-bloom (Table 4). At the pre-bloom timing, all herbicides except Cool Power and Confront provided 87% or greater control; and Cool Power and Confront, which were the only herbicides lacking 2,4-D, gave 60% or less control.

Overall control was drastically reduced at 60 DAT for the peak-bloom timing; all herbicides provided 72% or less dandelion control, and most gave less than 40%. Speedzone gave the best peak-bloom control (72%), which was superior to all other herbicides except 4 Speed XT (63%). After peak-bloom, overall control increased at the post-bloom timing, and was comparable to overall control at the pre-bloom timing. Herbicides 4 Speed XT and Trimec Classic gave 96% or greater control at 60 DAT when applied post-bloom, which was superior to all other herbicides except Speedzone.

Data recorded at 30 and 60 DAT show that under heavy dandelion pressure, peak-bloom application is less effective than pre- or post-bloom application. Inference on herbicide translocation without the use of radio-labeled material is difficult; however, the movement of weak acids in plants is strongly influenced by the strength of source to sink partitioning (Cobb and Reade, 2010). During peak-bloom, flowers and seeds are likely a major sink and may limit the amount of free acid reaching the active meristematic tissues,

Table 4. Percent dandelion control at 30 and 60 d after treatment (DAT) and at the end of the growing season in 2011 when postemergence broadleaf herbicides were applied at three different spring application timings coinciding with dandelion anthesis stages (pre-, peak-, post-bloom).[z]

	30 DAT			60 DAT			End of season[y]		
	Pre	Peak	Post	Pre	Peak	Post	Pre	Peak	Post
Herbicide[x]	Dandelion control (%)[w]								
4 Speed XT	97 a	80 ab	99 ab	98 a	63 ab	97 a	51	20	54
Escalade 2	97 a	67 bc	94 bc	93 ab	23 c	72 b	42	32	31
Trimec Classic	95 ab	42 cd	100 a	92 ab	32 bc	96 a	43	31	68
Speedzone	94 ab	91 a	95 bc	89 b	72 a	89 ab	47	34	52
Surge	96 ab	51 cd	90 cd	87 b	16 c	74 b	47	32	48
Confront	86 bc	43 cd	73 e	60 c	27 c	35 c	45	29	16
Cool Power	80 c	30 d	82 de	58 c	16 c	68 bc	54	14	26
Timing means[v]	92 A	57 B	91 A	82 A	36 B	76 A	47 A	26 B	42 A

[z] Pre-bloom: 8 Apr.; Peak-bloom: 18 Apr.; Post-bloom: 31 May.

[y] End of growing season data were recorded on 12 Nov. 2010.

[x] Herbicides are ranked over spring peak-bloom timing.

[w] Means followed by the same lowercase letter in a column are not statistically different ($P \leq 0.05$) by Fisher's least significant difference. Means in columns without letters are not significantly different.

[v] Means followed by the same uppercase letter in a row are not statistically different ($P \leq 0.05$) by Fisher's least significant difference within each rating date (means for 30 DAT data are not comparable to means for 60 DAT and end-of-season data).

resulting in reduced control. Generally, Speedzone and 4 Speed XT gave the best control at 60 DAT across application timings. Speedzone and 4 Speed XT were the only herbicides that contained both a PPO inhibitor and ester formulations of synthetic auxins, which are more soluble in the plant cuticle than amine forms, resulting in increased absorption (Nice et al., 2004). Because other less effective herbicides contained either a PPO inhibitor (e.g., Surge) or an ester formulation of a synthetic auxin (e.g., Cool Power), but not both, the combination found in Speedzone and 4 Speed XT appears to be particularly effective. Future research specifically investigating possible synergism between PPO inhibitors and other herbicides would be valuable.

When control was evaluated at the end of the season, there were no differences among herbicides, but unlike 2010, overall control was drastically reduced (Table 4). However, the effect of application timing was still evident at the end of the growing season rating (Table 2); although overall control was poor (47% and 42% at pre- and post-bloom, respectively), mean control resulting from peak-bloom application was significantly lower (26%).

With regard to the shorter-lived control observed in 2011, other researchers have recorded good dandelion control several weeks after treatment but noticed regrowth from the taproot (Mann, 1981; Watschke and Borger, 1999). In 2011, careful observation of our plots revealed that reductions in control were the result of dandelion regrowth from the mature rosette rather than newly germinating dandelions.

Several factors were likely responsible for the reduced long-term control in 2011 compared with 2010: smaller plants are generally easier to control than larger plants; smaller plants are typically younger and their cuticle is less developed, allowing for increased absorption of herbicidal compounds (Peterson et al., 2010). Derr and Serensits (2006) hypothesized that increased weed control in their first trial compared with the second was likely the result of younger plants at the time of application and increased competition from tall fescue. The importance of a competitive turfgrass stand is critical for long-term weed control (Alumai et al., 2009; Calhoun et al., 2005; Johnson and Bowyer, 1982). The lower turfgrass density in 2011 may have allowed injured dandelions to have greater exposure to sunlight to produce new photosynthate. Compared with 2011 dandelions, those that re-emerged in 2010 may have relied more on carbohydrate reserves from the taproot because the competition from turfgrass likely reduced the amount of photosynthate produced in the new leaves. Ultimately, plants that re-emerged in 2010 may have depleted their carbohydrate reserves when attempting to reinitiate growth, which resulted in better long-term control compared with 2011.

Despite the poor long-term control in 2011, it should be re-emphasized that excellent control was achieved at 60 DAT with several herbicide/timing combinations, and such control is of great practical value to turfgrass managers.

In summary, when at least moderate turfgrass competition is present and dandelions are relatively small (similar to 2010), this study showed that excellent long-term dandelion control can be achieved with spring application of postemergence broadleaf herbicides. Under such conditions, all herbicides in our study provided effective long-term control, regardless of spring application timing. However, faster dandelion mortality (e.g., within 30 DAT) may be achieved by using products containing a PPO inhibitor or applying other herbicides post-bloom.

Under more rigorous conditions, including greater weed pressure (similar to 2011), season-long control with available herbicides may be difficult to achieve. We used the lowest labeled rates for dandelion control for all products in this study; higher rates and/or repeat applications may provide better long-term control. However, even at the rates used here, excellent control for at least 60 DAT is achievable with careful selection of herbicide and application timing. Under such conditions, herbicides should be applied pre- or post-bloom. If circumstances force peak-bloom application, products combining PPO inhibitors with ester formulations of 2,4-D (e.g., Speedzone and 4 Speed XT) should be used, although control may be less than optimal. Ester formulations of 2,4-D can potentially volatilize when applied to turfgrass, so applicators should be aware of sensitive plants nearby (Raudenbush and Keeley, 2014). When applied pre-bloom under heavy dandelion pressure, all herbicides in our study, except Cool Power and Confront, gave greater than 86% control 60 DAT. When applied post-bloom, 4 Speed XT and Trimec Classic gave 96% or greater control, and Speedzone provided equivalent control at 89%. Cool Power and Confront, which were the only herbicides in our research that lacked 2,4-D, were the least effective herbicides in 2011 and are not recommended for spring applications when dandelion pressure is high.

Literature Cited

Alumai, A., S. Salminen, D. Richmond, J. Cardina, and P. Grewal. 2009. Comparative evaluation of aesthetic, biological, and management programs. Urban Ecosyst. 12:127–144.

Ashigh, J. and J.C. Hall. 2010. Bases for interactions between saflufenacil and glyphosate in plants. J. Agr. Food Chem. 58:7335–7343.

Branham, B. 1990. Post-emergence weed control in cool-season turfgrasses. Landscape Mgt. 29:36–40.

Breeden, G. and J. McElroy. 2006. Carfentrazone antagonizes foramsulfuron control of white clover (*Trifolium repens*). Annual Meeting Abstracts [CD-ROM]. ASA/CSSA/SSSA, Madison, WI.

Calhoun, R., G. Rinehart, A. Hathaway, and D. Buhler. 2005. Maximizing cultural practices to minimize weed pressure and extend herbicide treatment interval in a cool-season turfgrass mixture. Intl. Turfgrass Soc. Res. J. 10:1184–1188.

Christians, N. 2007. Broadleaf weed control with Dismiss (sulfentrazone), 2007. Iowa State Univ., Hort. Res. Station, ISRF07-36.

Cobb, A.H. and J.P.H. Reade. 2010. Herbicides and plant physiology. 2nd Ed. Wiley & Sons, Hoboken, NJ.

Coble, H.D., F.W. Slife, and H.S. Butler. 1970. Absorption, metabolism, and translocation of 2,4-D by honeyvine milkweed. Weed Sci. 18:653–656.

Derr, J. and T. Serensits. 2006. Effect of application temperature on winter broadleaf weed control. Proc. Northeastern Weed Sci. Soc. 60: 103–104.

Gardner, D. 2009. New options for golf course weed control. Golf Course Mgt. 77:119–124.

Gray, E., E.M. McGehee, and D.F. Carlisle. 1973. Seasonal variation in flowering of common dandelion. Weed Sci. 21:230–232.

Haley, J.E., D.J. Wehner, and T.W. Fermanian. 1995. Postemergence broadleaf weed control. Illinois Turfgrass Res. Rpt. p. 55–57.

Johnson, B.J. and T.H. Bowyer. 1982. Management of herbicide and fertility levels on weeds and kentucky bluegrass turf. Agron. J. 74:845–850.

Loughner, D.L. and S.P. Nolting. 2010. Influence of foliar moisture on postemergent granule herbicide control of white clover and dandelion in cool-season turf. Online. Appl. Turfgrass Sci. Nov. 2010. <https://www.agronomy.org/publications/ats/pdfs/7/1/2010-0713-01-RS>.

Mann, H. 1981. Common dandelion (*Taraxacum officinale*) control with 2,4-D and mechanical treatments. Weed Sci. 29:704–708.

McCarty, L., J. Everest, D. Hall, T. Murphy, and F. Yelverton. 2001. Color atlas of turfgrass weeds. Ann Arbor Press, Chelsea, MI.

Nice, G., B. Johnson, and T. Bauman. 2004. Amine or ester, which is better? Purdue Ext.Weed Sci., WS-31-W.

Olson, B. and A. Hall. 1988. Postemergence broadleaf weed control in turf with non-phenoxy herbicide combinations. Proc. Northeastern Weed Sci. Soc. 24:185–186.

Peterson, D., C. Thompson, D. Shoup, and B. Olson. 2010. Herbicide mode of action. Kansas State Univ. Agr. Expt. Sta. and Coop. Ext. Serv., C-715.

Raudenbush, Z. and S.J. Keeley. 2014. Volatility of broadleaf herbicides when applied to turfgrass. Online. Appl. Turfgrass Sci. Aug. 2014. <https://www.agronomy.org/publications/ats/pdfs/11/1/ATS-2013-0030-RS>.

Reicher, Z. and D. Weisnenberger. 2007. Herbicide selection and application timing in the fall affects control of ground ivy. Online. Appl. Turfgrass Sci. Dec. 2010. <https://www.agronomy.org/publications/ats/pdfs/4/1/2007-0831-01-RS>.

Schleicher, L.C. 1997. Influence of postdormancy development on herbicide scheduling for control of dandelion in turf. Ph.D. diss., Purdue Univ., West Lafayette, IN (Diss. Abstr. 9819029).

Senseman, S.A. 2007. Herbicide handbook. 9th Ed. Weed Sci. Soc. of Amer., Lawrence, KS.

Sterling, T.M. 1994. Mechanisms of herbicide absorption across plant membranes and accumulation in plant cells. Weed Sci. 42: 263–276.

Sterling, T.M. and J.C. Hall. 1997. Mechanism of action of natural auxins and the auxinic herbicides, p. 111–141. In: Roe, R.M., J.D. Burton, and R.J. Kuhr (eds.). Herbicide activity: Toxicology, biochemistry and molecular biology. IOS Press, Burke, VA.

Tworkoski, T. 1992. Developmental and environmental effects of assimilate partitioning in Canada thistle (*Circium arvense*). Weed Sci. 40:79–85.

Uva, R., J. Neal, and J. DiTomaso. 1997. Weeds of the Northeast. Cornell Univ. Press, Ithaca, NY.

Watschke, T. and J. Borger. 1999. Post-emergence control of broadleaf weeds. Annu. Res. Rpt. [Penn State]. p. 87–89.

Wilson, R. and A. Michiels. 2003. Fall herbicide treatments affect carbohydrate content in roots of Canada thistle (*Cirsium arvense*) and dandelion (*Taraxacum officinale*). Weed Sci. 51:299–304.

Zhang, J., A.S. Hamill, and S.E. Weaver. 1995. Antagonism and synergism between herbicides: Trends from previous studies. Weed Technol. 9:86–90.