Annual Flower Injury from Sublethal Rates of Dicamba, 2,4-D, and Premixed 2,4-D + Mecoprop + Dicamba

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Abstract. Greenhouse experiments were conducted to compare visible injury from sublethal rates of 2,4-D, dicamba, and a premixed product of 2,4-D + mecoprop + dicamba for eight annual flowers and to describe herbicide injury symptoms for these annual species. Herbicides were applied at rates 0.05×, 0.1×, and 0.2× of their highest labeled rate for turfgrass to simulate spray drift conditions. Visible injury varied between species, herbicide rate, and time after herbicide application. Alyssum (*Lobularia maritima* Desv.) showed the greatest initial injury and ageratum (*Ageratum houstonianum* Mill.) showed the greatest injury at 4 weeks after treatment. Symptom severity increased as herbicide rate increased, with the greatest injury from the premixed product, followed by 2,4-D, and then dicamba. The eight species varied in their degree of visible injury and flower production to dicamba, 2,4-D, and the premixed product. Reduced flowering was most obvious for prolific flowering species such as alyssum. Impatiens (*Impatiens wallerana* L.), salvia (*Salvia splendens* Sello), and snapdragon (*Antirrhinum majus* L.) produced more flowers in response to sublethal dicamba rates compared to the untreated plant. All rates of 2,4-D generally reduced flowering compared to untreated plants, except the lowest rate of 2,4-D for geranium (*Pelargonium xhortorum* Bailey) and snapdragon. Dahlia (*Dahlia hortensis* Cav.) sprayed with dicamba at the highest rate produced three times as many stems as plants untreated or those sprayed with 2,4-D. Overall order of species susceptibility to sublethal rates of dicamba, 2,4-D, or the premixed product from most susceptible to least susceptible was ageratum > alyssum > marigold (*Tagetes erecta* L.) > dahlia > geranium = salvia = snapdragon = impatiens. Differences in overall susceptibility to the plant growth regulator herbicides evaluated should provide useful information to horticulturalists designing annual flower beds and borders and lawn care applicators.

Herbicide spray drift is a concern for applicators, product manufacturers, and regulatory agencies. The spray drift task force was created in 1990 to develop a generic database in response to spray drift data requirements set forth by the Environmental Protection Agency (EPA, 1999). Representatives from 40 chemical companies developed a database from studies on the atomization, transport and deposition of sprays from aerial, ground, and orchard airblast applications, which were used to validate spray drift deposition models such as AgDRIFT (Teske et al., 1997). Hewitt (2000) reported that even though spray drift can be modeled based on tank-mix physical properties, atomizer type, and operation, air flow and other parameters, the effect of a given amount of active ingredient is product- and species-specific.

Marrs and Frost (1997) reported that most effects to nontarget plants downwind from MCPA and mecoprop, two plant growth regulator herbicides, were confined to an 8-m zone and that a few species showed increased performance at the 2- to 4-m downwind zone,

which they attributed to the hormonal effect on growth processes. They also suggested that an 8-m buffer zone should be implemented to adequately protect susceptible habitats from the most deleterious impacts on community processes. Similarly, Hatterman-Valenti et al. (1995a) suggested a 1.5-m buffer area for postemergence broadleaf herbicide applications to turfgrass to reduce nontarget plant injury. Unfortunately, maintaining a nonsprayed buffer area during postemergence broadleaf herbicide applications to turfgrass may not be practical, especially for small residential lawns heavily infested with broadleaf weeds.

Plant growth regulator herbicides such as 2,4-D and dicamba have been used extensively for broadleaf weed control in grass crops. Marth and Mitchell in 1944 reported on use of 2,4-D to control broadleaf weeds in turfgrass. As early as 1957, injury to garden plants from 2,4-D drift was reported (Dabbs and Forsberg, 1957). In 1963 injury symptoms to trees from 2,4-D spray drift was described (Phipps, 1963). However, information on injury symptoms to annual flowers from spray drift of 2,4-D and other plant growth regulator herbicides is limited. Hatterman-Valenti et al. (1995b) compared the susceptibility of several annual bedding plants to low concentrations of triclopyr and 2,4-D, and reported that petunia (*Petunia xhyb-*

rida Vilm.) was the most susceptible species tested and that petunia was more susceptible to triclopyr than 2,4-D. Salvia, periwinkle (*Catharanthus roseus* Don.), geranium, and impatiens were the least susceptible species tested with only salvia showing more than 20% visible injury to the highest triclopyr acid equivalent rate of 510 g·ha⁻¹. Unfortunately, the number of annual flower species evaluated in this study was small compared to the vast number of species commonly planted in residential flower beds.

Dicamba and 2,4-D are commonly used for broadleaf weed control in turfgrass, and numerous mixtures with both herbicides are commercially marketed. Premixed products are often used because more weed species are controlled than when the herbicides are applied individually. Gilreath et al. (2001b) reported that dicamba at 11.2 g·ha⁻¹ induced more foliar injury to pepper (*Capsicum annuum* L.) than 2,4-D and reduced vigor more as herbicide rate increased. The risk of injury to nontarget woody landscape plants within the sprayed turfgrass area is also greater with dicamba because it is more mobile than 2,4-D in many soils (Stople and Kuzila, 2002).

If the injury response to sublethal rates of each herbicide varied among annual flower species, lawn care operators could tailor their postemergence broadleaf weed control program to control the weeds present within a turfgrass while minimizing the risk of injury to nearby nontarget annual flowers. The objectives of this study were to compare visible injury from 2,4-D, dicamba, and a premixed product that includes both herbicides and mecoprop for several annual flowers and to describe herbicide injury symptoms for these annual species.

Materials and methods

Eight annual flower species: ageratum 'Blue Horizon', snapdragon 'Bells Mixture', dahlia 'Figaro Mix', impatiens 'Accent Sunrise Mix', alyssum 'Carpet of Snow', geranium 'Red Orbit', salvia 'Salsa Mix', and african marigold 'Inca II Yellow', were seeded into small flats containing a peat-based medium (Sunshine Mix no. 2, Sun Gro Horticulture, Bellevue, Wash.) under mist. Seedlings, one per pot, at the two to three true-leaf stage were transplanted into 500-cm³ plastic pots filled with the same medium. Plants were watered as needed and fertilized weekly with a 20–20–20 soluble fertilizer diluted to 200 ppm N. Greenhouse temperature was maintained at about 25/21 °C day/night, and natural lighting was supplemented with high-pressure sodium lights (250 μmol·m⁻²·s⁻¹) for a 15-h day length.

Plants were sprayed at the early flowering stage using a cabinet sprayer equipped with an 8001 even flat-fan nozzle (Spraying Systems Co., Wheaton, Ill.) delivering 94 L·ha⁻¹ at 210 k Pa. The herbicides were dicamba diglycolamine, 2,4-D dimethylamine, and a premixed product containing 2,4-D dimethylamine, mecoprop dimethylamine, and dicamba dimethylamine in a 11:6:1 ae ratio. Each herbicide was applied at 0.05, 0.10, and 0.2× of their highest labeled

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Table 1. Effect of species and portion of the herbicide labeled rate on plant injury 1, 2, and 4 WAT.^z

Species	Effect (%)								
	1 WAT			2 WAT			4 WAT		
	0.05 ^y	0.1	0.2	0.05	0.1	0.2	0.05	0.1	0.2
Ageratum	9 ^x	13	18	14	22	31	26	40	56
Alyssum	12	23	30	11	31	36	16	33	34
Dahlia	6	14	24	10	17	27	9	15	35
Geranium	2	5	7	2	9	14	4	9	16
Impatiens	6	12	15	2	6	7	4	8	6
Marigold	9	16	22	7	15	27	10	18	33
Salvia	6	13	14	6	15	16	5	12	12
Snapdragon	7	11	16	3	8	13	3	5	11
LSD (0.05)		11			6			7	

^zAbbreviation WAT = weeks after treatment.^yPortion of the highest labeled herbicide rate for use in turfgrass, which were dicamba acid equivalent at 560 g·ha⁻¹, 2,4-D acid equivalent at 1570 g·ha⁻¹, and the premixed 2,4-D:mecoprop:dicamba at 210:110:19 g·ha⁻¹.^xVisible injury was based on a percentage, where 0 = no injury and 100 = plant death.

rate for turfgrass; which were dicamba acid equivalent at 560 g·ha⁻¹, 2,4-D acid equivalent at 1570 g·ha⁻¹, and the premixed 2,4-D:mecoprop:dicamba at 210:110:19 g·ha⁻¹. Untreated plants were sprayed with water only.

Plants were returned to the greenhouse benches after the foliage was completely dry. Visible injury, the number of open inflorescences, and observed symptoms were recorded at 1, 2, and 4 week following the spray applications. Visible injury was based on a percentage where 0 = no injury and 100 = plant death. When inflorescences consisted of clusters of individual flowers, only the clusters were counted. During the last evaluation, the total number of inflorescences and number of secondary shoots were also recorded.

The factorial experiment was conducted as a randomized complete block with four replications and repeated in time. Data from the two trials were combined upon confirmation of homogeneity of variances. Data were analyzed using the GLM procedure of SAS (SAS Institute, Cary, N.C.) and means were separated by Fisher's protected least significant difference procedure ($p < 0.05$) where appropriate. Visible injury percentages were transformed to arcsine $\sqrt{x}$. The transformation did not affect results, so untransformed data are presented.

Results and Discussion

Foliar injury. Visible injury varied between species and herbicide rate, and time after spray application ($P < 0.005$). Visible injury 1 week after treatment (WAT) was greatest with alyssum and least with geranium, but generally increased with all species as the rate applied increased (Table 1). Increasing the rate applied by a factor of four more than doubled the visible injury for alyssum while the same rate increase resulted in only slight symptoms for geranium.

Injury continued to increase with time for most species and by 2 WAT, visual injury for all species except geranium, impatiens, salvia, and snapdragon was at least 20% for the highest herbicide rate (Table 1). Ageratum and alyssum showed the greatest injury, while impatiens was the least responsive with <10% injury for all herbicide rates. Increasing the rate applied by a factor of four more than tripled the visible injury for all species except salvia.

Injury 4 WAT continued to increase for ageratum, marigold, and dahlia (only the highest rate) and either remained the same or slightly decreased for the remaining species as the plants began to recover from the injury (Table 1). Ageratum was the most susceptible species to low rates of dicamba, 2,4-D, or the combination of 2,4-D + dicamba + mecoprop, while geranium, impatiens, salvia, and snapdragon were the least susceptible species.

There was a significant interaction between herbicide and rate for visible injury ($P \leq 0.05$). Visible injury increased linearly in response to increasing herbicide rates regardless of the herbicide (Fig. 1). However, symptom severity increased more with increasing rates for the premixed product, followed by 2,4-D, and then dicamba.

The eight annual flower species tested also varied in their response to herbicide and rate

over time ($P \leq 0.005$). Alyssum was more susceptible to dicamba and the premixed product compared to 2,4-D, while ageratum, marigold, salvia, and snapdragon were more susceptible to the premixed product than dicamba, and marigold was more susceptible to 2,4-D and the premixed product than dicamba (Table 2). Dahlia was more susceptible to dicamba than 2,4-D or the premixed product, while visible symptoms for geranium and impatiens were similar for all herbicide treatments.

Salvia was the only species that showed more visible injury from the premixed product compared to 2,4-D or dicamba (Table 2). This was attributed to the mecoprop in the premixed product and not a synergistic response since dicamba and 2,4-D had an additive to synergistic effect on several perennial weeds when mixed with glyphosate but not when they were mixed together (Flint and Barrett, 1989).

Fig. 1. Relationship between portion of the herbicide rate applied and percent injury for dicamba, 2,4-D and pre-mixed 2,4-D+mecoprop+dicamba averaged over the 4 week evaluation period. Injury was rated from 0 to 100 with 0 indicating no injury and 100 indicating dead plants. Linear regression equations for dicamba: $y = 4.5 + 58.57x$ ($r^2 = 0.98$), 2,4-D: $y = 14 + 97.14x$ ($r^2 = 0.97$), 2,4-D+mecoprop+dicamba: $y = 3.5 + 121.43x$ ($r^2 = 0.95$).^z Portion of the highest labeled herbicide rate for use in turfgrass, which were dicamba acid equivalent at 560 g·ha⁻¹, 2,4-D acid equivalent at 1570 g·ha⁻¹, and the premixed 2,4-D:mecoprop:dicamba at 210:110:19 g·ha⁻¹. Bar represents the standard error of the mean.

Table 2. Visual estimated effect of species and herbicide on plant injury averaged over the 4-week period.

Species	Effect (%)		
	Dicamba	2,4-D	2,4-D+Mec +Dic ^z
Ageratum	21 ^y	26	29
Alyssum	30	21	30
Dahlia	22	15	15
Geranium	7	9	5
Impatiens	6	7	9
Marigold	11	21	20
Salvia	7	10	17
Snapdragon	4	10	12
LSD 0.05		5	

^zAbbreviation 2,4-D+Mec+Dic = 2,4-D + Mecoprop + Dicamba.^yVisible injury was based on a percentage, where 0 = no injury and 100 = plant death.

Species variation in their susceptibility to dicamba and 2,4-D was expected. Hatterman-Valenti et al. (1995b) reported that petunia was more susceptible to triclopyr than 2,4-D. Similarly, Gilreath et al. (2001b) reported that dicamba induced more foliar injury to pepper than 2,4-D and reduced vigor more as herbicide rates increased. Unfortunately, they compared the same rates of dicamba and 2,4-D even though the labeled use rate for dicamba is much lower than 2,4-D for a specific crop or situation such as turfgrass.

Visual symptoms. Injury symptoms varied among species. Initial symptoms to ageratum occurred at the growing points where the small, recently formed leaves cupped downward and petioles flexed near the base. The premixed product caused the flower stems to elongate and curve making the flower head clusters appear loose and open compared to the tight clusters for the untreated plants and plants treated only with 2,4-D or dicamba. Some plants receiving 2,4-D had opposite leaves near the growing point that were fused together. With time callus formation appeared primarily on the flower stems near the heads. More callus formation occurred with 2,4-D and the premixed product than with dicamba. Often the central inflorescences, with callus formation just below the flower heads, would die without purple tubular flower development.

Injury symptoms to alyssum shortly after spraying consisted mainly of stem curvature, swelling at the nodal areas, and epinasty, i.e., downward bending of the leaves. Some flower buds that were developed at the time of spraying turned brown and never opened. The two highest rates caused flower stem elongation

where the plants lost the typical compact flower cluster appearance. Flower number per cluster was greatly reduced with the two highest herbicide rates. Stems turned a cream-color towards the growing point. Flower petals curled, which made the flower clusters appear more open and greatly reducing the solid white appearance observed in untreated plants and those receiving the lowest herbicide rate.

Symptoms on dahlia started within 24 h after herbicide application. Injury was most evident at the growing points where the petioles from the newly developed leaves turned downward and some spiraled. Dicamba caused more stem and petiole epinasty than 2,4-D. Dicamba at the highest rate often caused the growing point to appear swollen as if the emerging petioles and leaves had fused together. Extra secondary shoots began to develop on plants sprayed with dicamba. Affected leaflets generally curled upward and dicamba at the highest rate caused some leaf strapping. Dicamba also tended to cause the affected leaflet tips to elongate and form a sharp point.

Injury to geranium was subtle with minor leaf symptoms, including occasional upward curvature of the ends of the orbicular leaves. General growth suppression and delayed flowering were more evident with time. Herbicides at the two highest rates caused slight bending of the flower stems and reduced the number of flowers in an umbel. A few plants that received 2,4-D at the highest rate had an area on the flower stem that appeared to have split open.

Injury symptoms on impatiens were similar for all treatments with slight leaf puckering and newly formed leaves showed some upward curling. Slight growth and flowering

suppression was obvious when plants treated with the highest herbicide rate were placed next to untreated plants.

Marigold injury from dicamba was distinguishable from 2,4-D as dicamba caused tissue swelling at the petiole base (area of attachment to the stem) whereas 2,4-D caused a large amount of callus formation and root initiation along the stems. Dicamba also caused more epinasty of flower stems than 2,4-D. General leaf symptoms from all herbicides consisted of slight leaflet strapping with the toothed margins forming elongated points. Flower heads of plants treat with the highest herbicide rate had fewer ray flowers and the calyx split on many flower heads. Aborted flower buds were more prevalent with the highest herbicide rate than the two lowest rates.

Salvia leaves did not show herbicide injury. Some flower stem epinasty occurred after dicamba treatment but not with 2,4-D. All herbicide treatments appeared to affect the growing point of the flower raceme and the highest rate killed the apical tip. These plants had only a few whorls of flowers below the dead tip while untreated salvia or those receiving low herbicide rates had racemes that continued to elongate. Secondary flower shoots showed some injury even though the whorl of flowers was not killed. General growth suppression was more obvious with 2,4-D-treated than dicamba-treated plants.

Snapdragon leaves showed little visible injury following herbicide treatment. Only the 2,4-D-treated plants had leaves with slight curvature, which gave the leaves a wavy appearance. Some plants treated with the highest 2,4-D rate also showed some stem epinasty. General growth suppression and delayed flowering were observed with all herbicide-treated snapdragon except those receiving the lowest herbicide rate. However, these symptoms were only evident when plants were placed next to untreated plants.

All species showed some visible injury shortly after herbicide treatment. In general, similar visible symptoms were described by Hatterman-Valenti et al. (1995b), except that herbicide rates in their research were reduced to 1 and 2 g·ha⁻¹ and still caused at least 10% visible injury. Busey et al. (2003) also reported similar african marigold injury symptoms from 2,4-D isooctyl ester or MCPA isooctyl ester

Table 3. Effect of species and portion of the herbicide labeled rate on flower and flower cluster production 1, 2, and 4 WAT.^z

Species	Effect (no./plant)											
	1 WAT				2 WAT				4 WAT			
	Untreated	0.05 ^y	0.1	0.2	Untreated	0.05	0.1	0.2	Untreated	0.05	0.1	0.2
Ageratum	2 ^x	1	2	1	7	7	8	6	38	26	17	5
Alyssum	6	5	4	4	16	8	4	5	33	16	4	1
Dahlia	0	0	0	0	1	0	0	0	3	2	1	0
Geranium	1	1	1	1	1	1	1	1	2	2	2	1
Impatiens	1	1	1	1	7	4	7	5	30	30	29	23
Marigold	2	1	1	1	2	2	2	2	4	4	4	3
Salvia	9	9	8	8	11	10	9	8	7	10	11	10
Snapdragon	3	2	2	2	8	6	6	4	18	21	20	16
LSD (0.05)		1				3				2		

^zAbbreviation WAT = weeks after treatment.^yPortion of the highest labeled herbicide rate for use in turfgrass, which were dicamba acid equivalent at 560 g·ha⁻¹, 2,4-D acid equivalent at 1570 g·ha⁻¹, and the premixed 2,4-D:mecoprop:dicamba at 210:110:19 g·ha⁻¹.^xVisible injury was based on a percentage, where 0 = no injury and 100 = plant death.

Fig. 2. Influence of dicamba, 2,4-D, and 2,4-D + mecoprop + dicamba, herbicide rate, and plant species on flower production per plant.² Portion of the highest labeled herbicide rate for use in turfgrass, which were dicamba acid equivalent at 560 g·ha⁻¹, 2,4-D acid equivalent at 1570 g·ha⁻¹, and the premixed 2,4-D:mecoprop:dicamba at 210:110:19 g·ha⁻¹. Bar represents the standard error of the mean. LSD ($\alpha = 0.05$) for (A) = 2, (B) = 3, (C) = 2.

vapors and concluded that african marigold was one of the most susceptible landscape species tested.

Caution must be noted since this study only examined plant response to sublethal rates of 2,4-D, dicamba, or 2,4-D + mecoprop + dicamba applied to plants at the early flowering stage of development. No research has been reported on how annual flower species susceptibilities vary to plant growth regulator herbicides and the plant's stage of growth. Lee and Bewick (1947) reported that susceptibility of many annual broadleaf weeds to plant growth regulator herbicides decreased with age and that after fruiting, there was a period of minimum susceptibility. Therefore, it is likely that spray drift from these herbicides prior to the early flowering stage would cause more

injury even with those species showing relatively little susceptibility to plant growth regulator herbicides in the current study.

Number of flowers. The number of open flowers or flower clusters varied among species, herbicide rate, and time after treatment ($P < 0.01$). At 1 WAT, the number of open flowers/flower clusters for each species was similar compared with the untreated since all species were just beginning to flower (Table 3). The only exception was alyssum, which had fewer open flower clusters when the two highest herbicide rates were applied. By 2 WAT, reduced flowering was most obvious for the most prolific flowering species such as alyssum. Finally, at 4 WAT it was evident that sublethal herbicide rates greatly reduced flowering for ageratum and alyssum.

Low flower production by untreated dahlia, geranium, and marigold provided little opportunity to detect a flowering response to herbicide treatment (Table 3). The lowest two herbicide rates stimulated flowering of snapdragon. All herbicide rates appeared to stimulate salvia flowering, with the increase primarily from production of secondary flower shoots. Flowering of impatiens was reduced only by the highest herbicide rate.

The flowering response for plants sprayed with sublethal rates of 2,4-D + mecoprop + dicamba was similar to that observed for 2,4-D, except for impatiens (Fig. 2C). Flowering for all treated impatiens was similar and averaged 75% less than untreated plants even when the herbicide rate was increased four-fold.

The number of flower buds formed but not open at 4 WAT were counted to determine future flowering potential. Herbicide and herbicide rate significantly affected flower bud formation ($P < 0.05$). Untreated plants and those sprayed with 2,4-D + mecoprop + dicamba produced more flower buds than plants sprayed with dicamba or 2,4-D. Untreated plants averaged 14 flower buds and those plants sprayed with 2,4-D + mecoprop + dicamba initiated 13 flower buds, while plants treated with dicamba or 2,4-D initiated 11 and 10 flower buds, respectively. Likewise, untreated plants and those receiving the lowest herbicide rate produced more flower buds (14 and 12 flower buds/plant) than plants sprayed with the two highest herbicide rates (9 and 10 flower buds/plant).

Flower abscission has been observed in response to sublethal rates of plant growth regulator herbicides (Gilreath et al., 2001a, 2001b; Hatterman-Valenti et al., 1995b). The extent of delay in flowering due to flower abscission is dependent upon the herbicide rate and plant growth stage. Gilreath et al. (2001b) reported that pepper yield initially increased compared to untreated plants when treated with 2,4-D at 0.11 or 1.1 g·ha⁻¹ at the bloom stage, but higher 2,4-D rates reduced yield.

Bennet (1989) reported that 2,4-D at low concentrations promoted earlier flowering of tomato plants but 2,4-D concentrations caused delayed flowering and abnormal flower formation. Similarly, Marrs and Frost (1997) reported that performance of most broadleaf species increased with increasing distance downwind from a MCPA and mecoprop spray swath compared to those under the sprayer, but a few species showed increased performance compared to untreated plants in the 2- to 4-m downwind zone. They attributed the enhanced performance to a hormonal effect on growth processes or reduced interference from other plant community members.

Secondary shoots. Dahlia was the only species that altered its morphology in response to herbicide treatment, with many plants changing from tall, predominantly single-stemmed plants to much shorter, multi-stemmed plants ($P < 0.0001$). Secondary shoots were recorded as a stem when more than two internodes were visible. Dicamba appeared to be responsible for the altered appearance although one cannot eliminate mecoprop from contributing to this change since it was not evaluated separately (Fig. 3). Dahlia sprayed with the highest dicamba rate produced three times as many stems as the untreated plants. Stem number did not differ from the untreated plants for dahlia sprayed with 2,4-D.

Few researchers have reported secondary shoot initiation or increased branching of flower species in response to low rates of plant growth regulators. Hemphill and Montgomery (1981) reported that 2,4-D at 2.1 g·ha⁻¹ increased pep-

Fig. 3. Dahlia secondary shoot production per plant in response to herbicide and herbicide rate.^z Portion of the highest labeled herbicide rate for use in turfgrass, which were dicamba acid equivalent at 560 g·ha⁻¹, 2,4-D acid equivalent at 1570 g·ha⁻¹, and the premixed 2,4-D:mecoprop:dicamba at 210:110:19 g·ha⁻¹. Bar represents the standard error of the mean. LSD ($\alpha = 0.05$) = 2.

per branching and flowering, which resulted in increased yield compared to the untreated crop. However, pepper was the only species of the 15 tested that responded in this manner. Andersen et al. (2004) conducted a trial comparing soybean (*Glycine max* Merr.) injury from dicamba and 2,4-D applied at 1% to 20% of the labeled rate for maize (*Zea mays* L.) and reported more severe visual symptoms from dicamba-treated plants. Symptoms included apical bud death, which has been shown to remove the auxin source and allow lateral sprouting (Chatfield et al., 2000). In the current study, dahlia was the only species tested with tall, upright growth and little branching. Results suggest that dicamba caused the loss of apical dominance in dahlia and enabled lateral sprouting, which changed the overall plant architecture.

This study showed that mature annual flowers respond differently to the herbicides evaluated. Differences in overall susceptibility to the plant growth regulator herbicides evaluated should provide useful information to hor-

ticalists designing annual flower beds and borders and to lawn care applicators. Overall the order of species susceptibility to sublethal rates of dicamba, 2,4-D, and premixed 2,4-D + mecoprop + dicamba from most susceptible to least susceptible was ageratum > allysum > marigold > dahlia > geranium = salvia = snapdragon = impatiens. Further investigations should screen more annual and perennial species and evaluate herbicide susceptibility at several plant growth stages.

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