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Response of Bell Pepper and Broccoli to Simulated Drift Rates of 2,4-D and Dicamba

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Field experiments were conducted at Wooster, OH, in 2010 and 2011 to evaluate the effect of simulated drift rates of 2,4-D, dicamba, and 2,4-D plus glyphosate on processing broccoli and bell pepper. Treatments were made in July of each year when bell pepper and broccoli were at the 10- and eight-leaf stage, respectively, and included five 2,4-D rates (1/50, 1/100, 1/150, 1/200, and 1/400 of the recommended field rate of 840 g ae ha^{-1}), five dicamba rates (1/50, 1/100, 1/150, 1/200, and 1/400 of the recommended field rate of 560 g ae ha^{-1}), and three rates of 2,4-D plus glyphosate (1/100, 1/200, and 1/400 of the recommended field rates). Crop injury was recorded at 7 and 28 d after treatment (DAT). Broccoli and bell pepper responded differently to simulated drift rates each year with higher initial injury ratings observed in 2010, and more persistent symptoms in 2011. 2,4-D at the 1/50 rate reduced broccoli yield by approximately 50% in 2010. Simulated drift rates of 2,4-D did not cause broccoli yield reduction in 2011, nor did simulated drift rates of dicamba, or 2,4-D plus glyphosate reduce yield either year. Although simulated drift treatments did not reduce total yield of bell pepper, the timing of fruit maturity was affected. Yield at first harvest was reduced by high simulated drift rates of each herbicide and by the herbicide tank mix. These results indicate that broccoli and bell pepper are sensitive to very low doses of 2,4-D and dicamba that are typical of those encountered in drift events. The impact of actual drift on delayed maturity and total yield of these crops is likely to be costly for the farmer.

Nomenclature: Glyphosate; 2,4-D; dicamba; broccoli (*Brassica oleracea* L. var, *botrytis* L.); bell pepper (*Capsicum annuum* L.).
Keywords: Crop injury, herbicide drift, yield reduction.

En 2010 y 2011, se realizaron experimentos de campo en Wooster, Ohio, para evaluar el efecto de dosis de deriva simulada de 2,4-D, dicamba, y 2,4-D más glyphosate sobre el brócoli y el pimentón para procesamiento. Los tratamientos se realizaron en Julio de cada año cuando el pimentón y el brócoli estaban en el estado de 10 y 8 hojas, respectivamente, e incluyeron cinco dosis de 2,4-D (1/50, 1/100, 1/150, 1/200, y 1/400 de la dosis de campo recomendada de 840 g ae ha^{-1}), cinco dosis de dicamba (1/50, 1/100, 1/150, 1/200, y 1/400 de la dosis de campo recomendada de 560 g ae ha^{-1}), y de tres dosis de 2,4-D más glyphosate (1/100, 1/200, y 1/400 de las dosis de campo recomendadas). El daño al cultivo fue registrado a 7 y 28 d después del tratamiento (DAT). El brócoli y el pimentón respondieron en forma diferente a las dosis de deriva simulada en cada año con un daño inicial mayor observado en 2010, y síntomas más persistentes en 2011. A la dosis 1/50 el 2,4-D redujo el rendimiento del brócoli en aproximadamente 50% en 2010. Las dosis de deriva simulada de 2,4-D no causaron reducciones en el rendimiento del brócoli en 2011, ni lo hicieron las dosis de deriva simulada de dicamba, o de 2,4-D más glyphosate, en ninguno de los años. Aunque los tratamientos de deriva simulada no redujeron el rendimiento total del pimentón, esos sí afectaron el momento de maduración del fruto. Las dosis más altas de deriva simulada de cada herbicida y de la mezcla de herbicidas redujeron el rendimiento en la primera cosecha. Estos resultados indican que el brócoli y el pimentón son sensibles a dosis muy bajas de 2,4-D y dicamba que son típicas de dosis que se pueden encontrar en eventos de deriva. El impacto de deriva real en el retraso en la madurez y el rendimiento total de estos cultivos probablemente resultará costoso para el productor.

Spray drift has been defined as the movement of pesticide dust or droplets through the air beyond the intended area of application at the time of application, or soon after (US EPA 2014). Off-target movement of herbicides during application, which can be as high as 1/10 and 1/100 of the applied rate (Al-Khatib and Peterson 1999), can cause extensive injury to susceptible crops. The

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extent to which crops are damaged by herbicide spray drift depends on several factors, including prevailing environmental conditions, application height, driving speed of the sprayer, nozzle spacing, spray droplet size, and herbicide formulation (PISC Report 2002). Plants at different growth stages, and even different parts of a plant can respond differently to herbicide drift (Franzaring et al. 2000).

Deleterious effects of simulated spray drift on a variety of susceptible nontarget crops have been reported for many different herbicides (Al-Khatib et al. 2003; Egan et al. 2014; Felix et al. 2011; Flessner et al. 2012; Kruger et al. 2012). The Association of American Pesticide Control Officers (AAPCO) ranked 2,4-D first and dicamba third in herbicide active ingredients in confirmed drift occurrences that were reported for 2003 and 2004 (AAPCO 2005). These herbicides are widely used POST to control emerged broadleaf weeds selectively in grass crops [corn (*Zea mays* L.), sorghum (*Sorghum bicolor* L. subsp. *bicolor*)], fallow ground, pasture, and rangeland (Marple et al. 2007) and can also be used preplant prior to planting corn, cotton, or soybean, and in many other no-till systems (Everitt and Keeling 2007).

The earliest reports of nontarget damage from 2,4-D and dicamba were a few years after their initial commercialization in the 1940s and 1960s, respectively. By the 1950s, volatility and spray drift issues associated with 2,4-D applications were such that damage to cotton (*Gossypium hirsutum* L.), grape (*Vitis vinifera* L.), and tomato (*Solanum lycopersicum* L.) led to lawsuits (Akesson and Yates 1964). Drift incidences can be very serious and costly. As an example, in southwest Texas in 1983 and 1984, almost $20 million of cotton yield was lost due to physical drift of 2,4-D (Pimentel et al. 1992).

2,4-D and dicamba resistance genes have already been introduced in corn and soybean. Therefore, these herbicides are likely to become commonly used POST treatments for hard-to-control, or glyphosate-resistant broadleaf weeds such as Palmer amaranth (*Amaranthus palmeri* S. Wats.) and horseweed [*Conyza canadensis* (L.) Cronq.]. Vegetable farmers and processors across the United States are concerned that increased use of 2,4-D and dicamba to control weeds in agronomic crops will result in more incidents of crop loss due to drift (Kruger et al. 2011). Processing bell pepper and broccoli are important crops in the Midwest and eastern regions of the United States. In 2011, the two crops in Ohio accounted for over 3,200 ha of production and a combined value of over $40 million (NASS 2014). These crops, as well as other fruits and vegetables that are highly sensitive to 2,4-D and dicamba, are regularly planted in fields with close proximity to grain crops such as corn and soybean. In Ohio many farmers grow both grain and vegetables, rotating the crops through the same fields. The objective of this study was to evaluate the response of broccoli and bell pepper to simulated drift rates of 2,4-D, dicamba, and 2,4-D plus glyphosate.

Materials and Methods

Field studies were conducted at the Ohio Agricultural Research and Development Center (OARDC), Wooster, OH (40.78°N, 81.83°W), elevation 310 m, during the 2010 and 2011 growing seasons. 'Aristotle' bell pepper and 'Avenger' broccoli (Seminis Inc., 2700 Camino Del Sol, Oxnard, CA 93030) with 72- and 102-d maturities, respectively, were the varieties used for the experiments. Broccoli and pepper were direct-seeded in flats and grown in the greenhouse for 6 wk. Each field site was machine transplanted on June 21, 2010 and June 14, 2011. Plots consisted of three 7.5-m rows of pepper or broccoli planted on the flat 1.5 m apart. Herbicides were applied to the central row with a two-nozzle boom in a 0.9-m band centered over the central row. Guard rows were not sprayed. The experimental design was a randomized complete block with four replications. Prior to transplanting, *s*-metolachlor (Dual Magnum®, Syngenta Crop Protection, LLC, P.O. Box 18300, Greensboro, NC 27419) at 1.069 kg ai ha^{-1} was applied for preplant weed control. To evaluate the response of broccoli and pepper to simulated drift rates of herbicides, applications were made on July 13, 2010, and July 5, 2011, approximately 3 wk after transplanting, when bell pepper was at the 10-leaf stage and 10 cm tall and broccoli was at the eight-leaf stage and 13 cm tall. Herbicide treatments included a range of rates of 2,4-D dimethylamine salt (Weedar® 64, Nufarm Inc., 150 Harvester Dr., Burr Ridge, IL 60527), dicamba diglycolamine salt (Clarity®, BASF Corporation, 26 Davis Dr.,

Table 1. Injury and yield of broccoli treated with simulated drift rates of 2,4-D, dicamba, and 2,4-D tank mixed with glyphosate in 2010 and 2011 at Wooster, OH.

Treatment	Herbicide rate (proportion of field rate)	2010 Injury 7 DAT[b]	2010 Injury 28 DAT	2010 Yield $plot^{-1}$ 59 DAT	2011 Injury 7 DAT	2011 Injury 28 DAT	2011 Yield $plot^{-1}$ 71 DAT
	g ae ha^{-1}	%[a]		kg[a]	%[a]		kg[a]
2,4-D	16.8 (1/50)	23 a	0	1.6 b	9	19 a	7.2 bc
	8.4 (1/100)	16 ab	0	3.1 a	9	6 b	9.1 a
	5.6 (1/150)	8 bc	0	2.3 ab	5	6 b	7.0 bc
	4.2 (1/200)	0 c	0	3.5 a	8	4 b	8.9 ab
	2.1 (1/400)	3 c	0	1.6 b	5	3 b	6.5 c
Control		0	0	3.3 a	0	0	8.1 abc
$LSD_{(0.05)}$		2	NS	1.8	NS	12	1.9
Dicamba	11.2 (1/50)	3	0	2.1	9 a	10	6.6
	5.6 (1/100)	0	0	1.2	11 a	14	5.3
	3.7 (1/150)	0	0	1.0	5 b	5	7.4
	2.8 (1/200)	0	0	1.9	8 ab	6	9.9
	1.4 (1/400)	0	0	1.4	4 b	3	8.4
Control		3	0	3.3	0	0	8.1
$LSD_{(0.05)}$		NS	NS	NS	2	NS	NS
2,4-D + Glyphosate	8.4 + 8.4 (1/100)	8	0	2.7	11 a	6 a	7.0
	4.2 + 4.2 (1/200)	0	0	2.7	9 ab	8 a	9.5
	2.1 + 2.1 (1/400)	8	0	2.9	6 b	0 b	9.0
Control	-	0	0	3.3	0	0	8.1
$LSD_{(0.05)}$		NS	NS	NS	5	5	NS

[a] Means with the same letter (within a herbicide) are not significantly different according to Fisher's protected LSD test ($\alpha = 0.05$).
[b] Abbreviations: DAT, d after treatment; NS, Nonsignificant *F*-test at P = 0.05.

Research Triangle Park, NC 27709), and tank mixes of 2,4-D plus glyphosate dimethylamine salt (Durango® DMA®, Dow AgroSciences LLC, 9330 Zionsville Rd., Indianapolis, IN 46268) (Tables 1 and 2). These rate ranges are representative of those documented in actual drift events (Al-Khatib and Peterson 1999). Applications were made using a CO_2-pressurized backpack sprayer calibrated to deliver 140 L ha^{-1} at 276 kPa through 80015VS flat-fan spray nozzles (TeeJet Technologies, Wheaton, IL 60187). A nontreated control was included for comparison. Air temperatures at time of application were 25 and 19 C in 2010 and 2011, respectively. Wind speed at the time of application was below 5 km h^{-1} both years.

Symptoms of crop injury, including epinasty, leaf curl, stunting, chlorosis, and necrosis, were recorded 7 and 28 DAT and visually rated using a scale of 0 (no injury symptoms) to 100 (death of all plants) (Frans et al. 1986). Plant height (cm) from the soil line to the growing tip was measured at 7, 14, and 28 DAT. Broccoli was harvested on September 9, 2010 and September 14, 2011. Bell pepper was harvested four times between August and October of both years, based on the maturity of fruit in the control plots. Bell pepper fruit were graded according to the U.S. Department of Agriculture guidelines (USDA 2005).

Years and replications (nested within years or location), and all interactions containing either of these effects were considered random (Carmer et al. 1989). All other variables (application timing and herbicide drift rate) were considered fixed effects. The random effect of year and its interaction with herbicide treatments was significant for visual injury at 7 DAT and 28 DAT as well as plant height and yield. As a result, data for these parameters are reported by year. Differences in yield among years were likely due to weather conditions. Average minimum and maximum daily temperature as well the total precipitation were higher between July and September 2011 compared to the same period of time in 2010 (Anonymous 2014). Data for each herbicide were analyzed separately in order to test for different crop response across the range of simulated drift rates of each. Data from the same

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Table 2. Injury of bell pepper treated with simulated drift rates of 2,4-D, dicamba, and 2,4-D tank mixed with glyphosate in 2010 and 2011 at Wooster, OH.

Treatment	Herbicide rate (proportion of field rate)	Injury 2010 7 DAT[b]	Injury 2010 28 DAT	Injury 2011 7 DAT	Injury 2011 28 DAT
	g ae ha^{-1}	%[a]			
2,4-D	16.8 (1/50)	34 a	5 a	15	18 a
	8.4 (1/100)	30 ab	5 a	14	10 bc
	5.6 (1/150)	21 bc	5 a	13	13 ab
	4.2 (1/200)	33 ab	0 b	9	8 bc
	2.1 (1/400)	16 c	0 b	8	5 c
Control		0	0	0	0
$LSD_{(0.05)}$		12	1	NS	7
Dicamba	11.2 (1/50)	30	10 a	14	21
	5.6 (1/100)	24	8 b	13	14
	3.7 (1/150)	26	5 c	11	13
	2.8 (1/200)	29	0 d	11	10
	1.4 (1/400)	28	0 d	10	9
Control		0	0	0	0
$LSD_{(0.05)}$		NS	2	NS	NS
2,4-D + Glyphosate	8.4 + 8.4 (1/100)	26	0	16 a	11
	4.2 + 4.2 (1/200)	28	0	14 a	15
	2.1 + 2.1 (1/400)	19	0	6 b	5
Control		0	0	0	0
$LSD_{(0.05)}$		NS	NS	5	NS

[a] Means with the same letter (within a herbicide) are not significantly different according to Fisher's protected LSD test ($\alpha = 0.05$).
[b] Abbreviations: DAT: d after treatment; NS, Nonsignificant *F*-test at P = 0.05.

control plots were used in each statistical analysis. Analyses were conducted using PROC GLM in SAS 9.2 (SAS Institute, Inc., SAS Campus Dr., Cary, NC 27513). Data were subjected to ANOVA and means were separated with the use of Fisher's protected LSD test at the 5% level of probability.

Results and Discussion

Broccoli. Initial symptoms of 2,4-D injury at 7 DAT were more pronounced in 2010 (average of 20% at the two highest rates) than they were in 2011 (Table 1). However, the crop recovered quickly in 2010, and by 28 DAT foliar symptoms were not observed. In 2011 injury at the highest rate of 2,4-D was 9% 7 DAT and 19% at 28 DAT. Persistent symptoms of injury (< 10%) detected in plots treated with more dilute concentrations of 2,4-D in 2011 did not differ amongst rates. Broccoli height was not affected by any of the simulated herbicide drift rates (data not shown). The 1/50 rate of 2,4-D depressed broccoli yield by approximately 50% in 2010. A similar reduction in yield was noted when broccoli was treated with a 1/400 (2.1 g ae ha^{-1}) rate of 2,4-D; however, significant foliar injury was not observed, and we suspect the yield result to be anomalous. Broccoli yield in plots treated with simulated drift rates of 2,4-D did not differ from that of the control in 2011 (Table 1).

Broccoli responded less dramatically to dicamba than to 2,4-D (Table 1). Considering that weeds in the Brassicaceae are generally less susceptible to dicamba than 2,4-D, this outcome is not surprising (Everman and Jordan 2013). Injury was not detected in 2010. In 2011 slight injury (< 11%) was observed 7 DAT regardless of dicamba rate. By 28 DAT, a rate effect was apparent with the 1/50 rate causing more injury than the more dilute concentrations. Simulated drift rates of dicamba did not affect broccoli yield.

The tank mix of 2,4-D plus glyphosate caused slight injury that was distinct from the control at 7 DAT and 28 DAT in 2011; however, observed effects were not distinct from the control at any rating interval in 2010. Effects of the 2,4-D plus

Table 3. The effect of simulated drift rates of 2,4-D, dicamba and 2,4-D tank-mixed with glyphosate in 2010 and 2011 on bell pepper yield at Wooster, OH.

Treatment	Herbicide rate (proportion of field rate)	Yield per plot at DAT [a]									
		2010					2011				
		39	56	66	78	Total	42	51	57	66	Total
	g ae ha^{-1}	kg[b]									
2,4-D	16.8 (1/50)	0.4 b	1.2 b	2.3	3.9	7.7	0.7 b	1.0 b	1.0 ab	3.0 b	5.7
	8.4 (1/100)	1.1 ab	1.4 ab	1.6	4.5	8.6	1.9 a	1.0 b	0.2 bc	1.6 c	4.7
	5.6 (1/150)	1.8 a	0.9 b	1.3	5.0	8.9	2.3 a	0.1 c	0.1 bc	1.3 cd	3.7
	4.2 (1/200)	1.7 a	0.9 b	1.6	4.3	8.4	2.0 a	0.1 c	0.6 bc	0.8 d	3.5
	2.1 (1/400)	0.9 ab	0.9 b	2.0	3.7	7.5	2.6 a	0.2 bc	0 c	0.8 d	3.6
Control		1.7 a	1.9 a	1.6	3.9	8.7	1.7 a	0.5 bc	0.4 bc	1.5 cd	4.0
$LSD_{(0.05)}$		1.0	0.6	NS	NS	NS	1.0	0.8	1.0	0.8	NS
Dicamba	11.2 (1/50)	0.3 b	1.1 b	2.6 a	4.1 b	8.0 a	0.0 c	0.9 a	1.0 a	2.2 a	5.8
	5.6 (1/100)	0.5 b	1.0 bc	2.3 ab	5.2 a	9.0 a	1.7 b	0.5 ab	0.4 b	1.6 abc	4.3
	3.7 (1/150)	0.3 b	0.9 bc	1.7 bc	4.9 ab	7.8 a	1.8 b	0.2 b	0.3 b	1.3 bc	3.3
	2.8 (1/200)	0.7 b	0.6 c	1.4 c	4.9 ab	7.6 a	1.5 b	0.1 b	0.2 b	1.8 ab	4.9
	1.4 (1/400)	0.5 b	0.7 c	2.0 abc	2.6 c	5.8 b	2.7 a	0.8 a	0.1 b	0.9 c	3.4
Control		1.7 a	1.9 a	1.6 c	3.9 b	8.7 a	1.7 ab	0.5 ab	0.4 b	1.5 abc	4.0
$LSD_{(0.05)}$		1.5	0.5	0.7	1.0	1.4	0.7	0.5	0.4	0.8	NS
2,4-D + Glyphosate	8.4 + 8.4 (1/100)	0.3 b	1.6 ab	1.1	5.0 a	8.0	1.6 b	0.6	0.7	2.0	4.9 ab
	4.2 + 4.2 (1/200)	1.9 a	1.3 bc	1.9	3.9 ab	8.6	2.0 b	0.3	0.6	0.9	3.7 c
	2.1 + 2.1 (1/400)	2.2 a	1.1 c	2.0	2.8 b	7.7	2.9 a	0.9	0.4	1.7	5.8 a
Control		1.7 a	1.9 a	1.6	3.9 ab	8.7	1.7 b	0.5	0.4	1.5	4.0 bc
$LSD_{(0.05)}$		0.8	0.5	NS	1.2	NS	740	NS	NS	NS	1.0

[a] Abbreviations: DAT: d after treatment; NS, Nonsignificant *F*-test at P = 0.05.

[b] Means with the same letter (within a herbicide) are not significantly different according to Fisher's protected LSD test ($\alpha = 0.05$).

glyphosate mix on broccoli yield were not detected (Table 1).

Bell Pepper. In 2010, simulated drift rates of 2,4-D (1/50 to 1/400) caused relatively severe injury symptoms that ranged from 16% to 34% 7 DAT (Table 2). However, bell pepper had largely recovered from obvious effects on foliage by 28 DAT with only a trace of injury (5%) observed at the three highest rates. Plants treated with the lowest rates (1/200 and 1/400) were indistinguishable from plants in nontreated control plots. The impact of simulated drift rates of 2,4-D on foliage was less intense in 2011 (average response of 12%) compared to 2010, but the crop did not recover over the 28 d assessment period with mean injury values for each rate of 2,4-D largely unchanged from the earlier assessment. Bell pepper plant height was not affected by 2,4-D, dicamba, or the 2,4-D plus glyphosate tank mix.

Simulated drift rates of 2,4-D affected bell pepper yield in subtle and unexpected ways (Table 3). Although total yield of marketable fruit was unaffected, early yield was reduced when the herbicide was applied at 1/50 (16.8 g ha^{-1}). In 2010, yield at 39 and 56 DAT was reduced by 77 and 36%, respectively, with the 1/50 rate. A similar effect was noted at 56 DAT with all but the 1/200 rate (4.2 g ha^{-1}). In 2011, first yield, 42 DAT, was reduced by 59% when the herbicide was applied at 1/50.

The injury response of bell pepper 7 DAT to simulated drift rate treatments of dicamba averaged 27% in 2010 and 12% in 2011 (Table 2). Injury occurred even at the lowest rate of 1.4 g ha^{-1} (1/400). Reminiscent of the yearly trends noted with 2,4-D, symptoms of crop injury caused by dicamba were lower 28 DAT in 2010 but not in 2011. A clear rate effect was apparent in the 2010 data with injury declining in a stepwise manner as the rate of dicamba decreased from 1/50 to 1/400. In 2011, injury ratings averaged 12% 7 DAT and 13% 28 DAT. Dicamba reduced total bell pepper yield when applied at 1/400 in 2010 (Table 3). This effect was primarily related to the final harvest (78 DAT) which was approximately 50% lower than

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that recorded in other dicamba-treated plots; however, it is not clear whether this was due to the dicamba treatment or an unknown factor. Similar to 2,4-D, dicamba affected bell pepper maturity. All rates of dicamba reduced yield in 2010 at the first harvest (39 DAT) by an average of 74%. Likewise, at second harvest (56 DAT), yield was reduced across the range of simulated drift rates. Yield at first harvest (42 DAT) in 2011 was reduced by the 1/50 rate (11.2 g ha^{-1}).

Bell pepper injury ratings with the tank mix of 2,4-D plus glyphosate averaged 24% 7 DAT in 2010, but symptoms were not observed at 28 DAT (Table 2). In 2011, injury 7 DAT was 15% with the 1/100 (8.4 + 8.4 g ha^{-1}) and 1/200 (4.2 + 4.2 g ha^{-1}) rates and 6% with the 1/400 rate. Injury persisted through 28 DAT, averaging 10% across the rate range. The 1/400 (2.1 + 2.1 g ha^{-1}) rate of glyphosate plus 2,4-D increased total yield in 2011. Conversely, no effect on total yield was observed in 2010 (Table 3). The highest rate of the tank mix (1/100 + 1/100) reduced pepper yield at first harvest (39 DAT) by 81%. However, the 1/400 rate increased yield at first harvest (42 DAT) in 2011 by 73%. This increase in early yield is reflected in the higher total yield achieved with this rate of simulated drift that year.

Foliar responses of broadleaf plants to drift of 2,4-D, dicamba, and 2,4-D tank-mixed with glyphosate have been described by a number of authors (Al-Khatib et al. 1993; Egan et al. 2014; Flessner et al. 2012; Kruger et al. 2012). Their descriptions corresponded well to the symptoms observed in our experiments. In this research, we documented the response of broccoli and bell pepper resulting from applications of sublethal doses that took place soon after transplanting. Injury symptoms resulting from simulated drift rates of each herbicide or tank mix tended to decline and become less obvious with time over the 4-wk period of observation in 2010. In contrast injury symptom expression persisted throughout the 4-wk observation period in 2011. Regardless of the herbicide or tank mix examined, impacts of simulated drift rates on yield were greater in 2010, a year when yield of both crops in control plots was much higher. We speculate that greater herbicide effects on yield in 2010 might be related to the more severe impact that each herbicide had on broccoli and bell pepper at 7 DAT. Impacts on final yield and on earliness are both likely to have great significance to the farmer. Bell pepper maturity at the earliest harvest date was adversely impacted at high simulated drift rates, regardless of the herbicide being evaluated. Delay in bell pepper harvest by 10 d can reduce the price paid to the farmer by 30% or more (S Polter, personal communication).

Adoption of new herbicide-resistant crops is inevitable and will lead to increased use in 2,4-D and dicamba throughout much of the Midwest. Because 2,4-D and dicamba are both more toxic to many broadleaf plants than the predominantly used glyphosate, the incidence of crop damage from herbicide drift in susceptible vegetable crops is likely to increase (Peterson and Hulting 2004). Impacts on yield of bell pepper and broccoli as a result of 2,4-D or dicamba drift are likely to be subtle, requiring careful measurement, and can be expected to vary depending on the year. Although not a focus of this research, drift might prevent the farmer from selling the crop if maximum residue limits are exceeded or tolerances are not established. For the organic producer, drift could create obstacles to marketing, and might challenge certification of impacted fields. It is important that grain growers and commercial herbicide applicators be aware that many vegetable and fruit crops, often planted in adjacent fields, are both highly sensitive to 2,4-D and dicamba, and are of very high cash value. New herbicide formulation technologies, coupled with application methods that reduce production of very low-diameter spray droplets, will reduce the potential for 2,4-D and dicamba off-target movement (Anonymous 2011). However, avoiding applications during temperature inversions and periods of high wind are essential to prevent drift from occurring.

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