

Soybean (*Glycine max*) Tolerance to 2,4-D Ester Applied Preplant¹

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Abstract. Field studies were conducted in 1991 and 1992 to determine potential soybean injury due to 2,4-D ester at 560, 1120, and 1680 g ai/ha applied 0, 7, and 14 d before planting (DBP). Delayed emergence and increased injury of soybean were observed as 2,4-D rate increased and interval between application and planting decreased. Delay in emergence ranged from 0 to 67% and 0 to 50% in 1991 and 1992, respectively. Injury at 15 days after planting (DAP) combined over years ranged from 0 to 61%. Minimal (0 to 8%) delay in emergence and minimal (0 to 5%) injury at 15, 30, 45, and 60 DAP occurred when 2,4-D at 560 or 1120 g/ha was applied 7 or 14 DBP. No significant yield reduction occurred due to 2,4-D rate, application timing, or their interaction. **Nomenclature:** 2,4-D (2,4-dichlorophenoxy)acetic acid, butoxyethyl ester formulation; soybean *Glycine max* (L.) Merr., 'Williams 82'.

Additional index words: Delayed emergence, no-tillage, injury, yield reduction.

INTRODUCTION

The percentage of soybean planted no-till (NT)³ is increasing dramatically with a 75% increase in NT acreage from 1991 to 1992 (2). The conservation compliance provisions of the 1985 Food and Security Act will probably continue to promote increases in NT acres of both corn (*Zea mays*) and soybean. Lower fuel, labor, and machinery costs are the major economic advantages of NT crop production (4) and a reduction in soil erosion and greater conservation of soil moisture are the major agronomic benefits of NT (11, 12, 25, 27).

Common NT herbicide programs consist of a PRE application of a nonselective herbicide tank-mixed with a residual grass and broadleaf herbicide. However, insufficient rainfall after the PRE application reduces potential weed control and a POST herbicide application may be required to achieve weed control (15).

Early preplant (EPP)³ herbicide applications may have several advantages over PRE applications in full-season NT soybean production. A single EPP application can provide excellent season-long weed control with low weed density (6, 8, 16, 24, 26). Rainfall probabilities are usually greater earlier in the growing season for herbicide mobilization to control subsequent weeds. Therefore, fields are generally weed-free at planting which facilitates planting. Controlling weeds

early may also conserve soil moisture under low moisture conditions.

The herbicide 2,4-D has been used extensively in EPP applications for weed control in NT corn and soybean production because it is economical and effectively controls certain weed species. Horseweed [*Conyza canadensis* (L.) Cronq.] can become a problem in full-season NT soybean production and tank-mixing 2,4-D with glyphosate [N-(phosphonomethyl)glycine] or paraquat (1,1'-dimethyl-4,4'-bipyridinium ion) has been shown to increase control with no antagonistic effects (5, 28). O'Sullivan and O'Donovan (20) reported that 2,4-D ester tank-mixed with paraquat may provide broader spectrum weed control compared with paraquat alone.

Until recently, the 2,4-D label for weed control in soybean production was ambiguous. Growers have applied 2,4-D EPP and PRE for control of existing weeds at application. However, 2,4-D may persist in soils from 1 to 4 wk depending on edaphic factors (1, 7, 9, 22, 23). Moyer et al. (19) reported that 2,4-D ester applied 15 and 0 days before planting (DBP)³ may be detrimental to the growth of canola (*Brassica napus* L.) and three legumes; alfalfa (*Medicago sativa* L.), lentil (*Lens culinaris* Medik), and peas (*Pisum sativum* L.), depending on rainfall after application. Current information on soybean tolerance to 2,4-D applied EPP or PRE is limited. Therefore, the objective of this study was to evaluate soybean tolerance to 2,4-D ester when applied at several rates 14, 7, and 0 DBP.

MATERIALS AND METHODS

Field studies were conducted in 1991 and 1992 at the Southern Illinois University research center at

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³Abbreviations: DAP, days after planting; DBP, days before planting; EPP, early preplant; NT, no-till.

Belleville, IL. The soil was a Rushville silt loam (a fine, montmorillonitic, mesic Typic Albaqualfs) with 1.8% organic matter, pH of 6.4, and cation exchange capacity of 9 meq/100 g in 1991. The soil was a Weir silt loam (a fine, montmorillonitic, mesic Typic Ochraqualfs) with 2.1% organic matter, pH of 6.6, and cation exchange capacity of 10 meq/100 g in 1992. Treatments consisted of the butoxyethyl ester formulation of 2,4-D at 560, 1120, and 1680 g/ha tank-mixed with paraquat and imazaquin {2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-3-quinolinecarboxylic acid} at 560 and 140 g/ha, respectively, applied 0, 7, and 14 DBP. The "no 2,4-D" treatment consisted of imazaquin at 140 g/ha plus paraquat at 560 g/ha applied PRE. The herbicides were applied with a hand-held CO₂ sprayer in a volume of 246 L/ha of water with 8004 flat fan nozzle tips⁴ at 276 kPa. Application dates corresponding to the 0, 7, and 14 DBP applications were Apr. 30, May 7, and May 14 in 1991, and Apr. 28, May 5, and May 13, 1992, respectively. The adjuvant X-77⁵ at 0.25% v/v was added to all paraquat treatments. No POST grass herbicide was needed for grass control in 1991. Quizalofop {(±)-2-[4-[(6-chloro-2-quinoxalinyloxy)phenoxy]propanoic acid} at 56 g/ha plus COC⁶ was applied POST on all plots except for the nontreated plots on June 25, 1992 for grass control.

Each plot consisted of four rows, 9 m long, with 76-cm row spacing. Williams 82 soybean were planted on May 14, 1991 and May 13, 1992. Delayed soybean emergence was evaluated visually at 10 days after planting (DAP)³ on a 0 to 100% scale (0 indicating no emergence and 100 indicating complete emergence). Soybean injury was evaluated visually at 15, 30, 45, and 60 DAP on a 0 to 100% scale (0 indicating no injury and 100 indicating complete soybean death). Soybean seed yield was obtained both years. The two center rows of each plot were machine-harvested and yield was adjusted to 13% moisture.

A randomized complete block design with three replicates was used. The data were subjected to factorial analysis of variance using year, application timing, and herbicide rate as factors. Delayed emergence

Table 1. Summary of rainfall during herbicide application and planting.

Week	Rainfall	
	1991	1992
	mm	
April 24–30	4	3
May 1–7	27	2
May 8–14 ^a	10	11
May 15–21	21	12
May 22–28	0	1
Total	62	29
April 24–May 28	114 ^b	

^aPlanting period both years.

^bNormal rainfall for corresponding period based on the 40 year average.

and injury ratings were analyzed as percentages and as transformed (arcsine of the square root) percentages. Because transformation did change the analysis the transformed means were separated with Fisher's Protected LSD Test at the 5% level. Backtransformed means are presented. Yield means were also separated with Fisher's Protected LSD Test at the 5% level.

RESULTS AND DISCUSSION

Generally, rainfall before and after planting was lower in 1992 than in 1991 (Table 1), which may be a reason why certain interactions occurred in 1991 and not in 1992. However, rainfall for Apr. 24 through May 28 was below the 40-year average both years. A year interaction precluded combining data over years with different variables at particular observation dates.

Soybean emergence. There was a significant rate by timing by year interaction in the combined analysis with percent delay in soybean emergence. Therefore, percent delay in emergence is presented for individual years (Table 2). In 1991, 2,4-D applied at 560 to 1680 g/ha 0 DBP caused a 50 to 67% delay in emergence (Table 2). Increasing the interval between 2,4-D application and planting from 0 to 7 DBP significantly increased emergence with all rates of 2,4-D compared with the nontreated control. There was no delay in emergence in 1991 when 2,4-D was applied at 14 DBP regardless of rate.

In 1992, emergence was delayed by 25 and 50% when 2,4-D was applied at 1120 and 1680 g/ha 0 DBP, respectively (Table 2). Increasing the interval between 2,4-D application and planting from 0 to 7 DBP increased emergence with the 1120 and 1680 g/ha rate of 2,4-D as in 1991. The delay in emergence was reduced from 25 to 2% and from 50 to 12% when 2,4-D was

⁴Spraying Systems Co., P.O. Box 7900, Wheaton, IL 60189.

⁵X-77 (a mixture of alkaryl-polyoxyethylene glycols, free fatty acids, and isopropanol). Valent U.S.A. Corp., 1333 N. California Blvd., Walnut Creek, CA 94596.

⁶Trade name Drexel crop oil concentrate containing 83% paraffinic mineral oil and 17% polyoxyethylene fatty acid ester, from Drexel Chemical Co., 2487 Pennsylvania Ave., Memphis, TN 38109.

Table 2. Effect of 2,4-D rate and application timing on soybean emergence in 1991 and 1992.

2,4-D rate g/ha	1991			1992		
	Application timing			Application timing		
	0 DBP ^a	7 DBP	14 DBP	0 DBP	7 DBP	14 DBP
	% ^b					
560	50 a	0 c	0 c	0 d	0 d	0 d
1120	58 a	8 c	0 c	25 b	2 d	0 d
1680	67 a	25 b	0 c	50 a	12 c	0 d
No 2,4-D ^c	0			0		

^aDBP = days before planting.^bPercent delayed emergence. Means within and between columns by year followed by the same letter are not significantly different at the 5% level of probability according to the LSD.^cNot included in analyses of delayed emergence in 1991 or 1992.

applied 0 and 7 DBP at 1120 and 1680 g/ha, respectively. There was no delay in emergence when 2,4-D was applied at 560 g/ha regardless of application timing in 1992. Delayed emergence with the 0 DBP application ranged from 0 to 50% and increased as the 2,4-D rate increased. There was no difference in emergence in 1992 when 2,4-D was applied at 14 DBP regardless of rate. Generally, the delayed emergence was lesser in 1992 than in 1991, probably due to less rainfall after application.

In 1991, 58 mm of rainfall was received from May 1 to May 21; whereas, in 1992, 25 mm of rainfall was received for the same period (Table 1). Other researchers also have attributed various injury levels due to herbicides between years to rainfall patterns (17, 19). At lower soil moisture levels, competition for adsorption sites is less intense and more of the herbicide becomes adsorbed to soil colloids (7). Therefore, more herbicide was likely available for plant uptake in 1991, causing a greater delay in emergence in 1991 than in 1992.

Soybean injury. Soybean injury consisted primarily of plant stunting. There was no rate by timing by year interaction in the combined analysis with injury at 15 and 60 DAP. Therefore, data were pooled over years for injury at 15 and 60 DAP (Table 3). Injury at 15 DAP increased from 20 to 61% as the 2,4-D rate at 0 DBP was increased. Injury at 15 DAP was less when applying 2,4-D at 7 or 14 DBP compared with 0 DBP with all rates. There was no difference in injury when 2,4-D was applied 14 DBP regardless of rate. Other researchers have reported no soybean injury when 2,4-D at 500 or 560 g/ha was applied 9 to 15 DBP (5, 18).

Injury at 60 DAP ranged from 0 to 12%, indicating that the plants were recovering from the severe injury observed at 15 DAP (Table 3). Soybean is quite resilient as suggested by other research (3, 10, 13, 14, 21). At 60 DAP, increasing the interval between 2,4-D application and planting, while decreasing the 2,4-D rate, resulted in less injury.

Table 3. Effect of 2,4-D rate and application timing on soybean injury, pooled over years.

2,4-D rate g/ha	15 DAP ^a			60 DAP		
	Application timing			Application timing		
	0 DBP ^b	7 DBP	14 DBP	0 DBP	7 DBP	14 DBP
	% ^c					
560	20 c	0 d	6 d	6 bc	0 d	3 bc
1120	40 b	5 d	3 d	8 ab	0 d	1 cd
1680	61 a	21 c	3 d	12 a	1 cd	1 cd
No 2,4-D ^d	0			0		

^aDAP = days after planting.^bDBP = days before planting.^cMeans within and between columns per observation date followed by the same letter are not significantly different at the 5% level of probability according to the LSD.^dNot included in analyses of soybean injury.

Table 4. Effect of 2,4-D rate and application timing on soybean injury in 1991 and 1992.

2,4-D rate g/ha	1991								1992					
	30 DAP ^a				45 DAP				30 DAP			45 DAP		
	Application timing ^b								Application timing					
	0 DBP ^c	7 DBP	14 DBP	Avg.	0 DBP	7 DBP	14 DBP	0 DBP	7 DBP	14 DBP	0 DBP	7 DBP	14 DBP	
	%													
560	35	0	7	14 b	18 ab	0 d	8 bc	0 c	0 c	0 c	0 b	0 b	0 b	
1120	45	3	3	17 b	27 a	2 d	2 d	12 b	0 c	0 c	2 b	0 b	0 b	
1680	60	22	3	28 a	28 a	5 cd	2 d	22 a	2 c	0 c	7 a	0 b	0 b	
No 2,4-D ^e	0				0			0			0			
Avg.	47 a	8 b	4 b											

^aDAP = days after planting.^bNo rate by timing interaction at 30 DAP in 1991.^cDBP = days before planting.^dMeans within and between columns per observation date followed by the same letter are not significantly different at the 5% level of probability according to the LSD.^eNot included in the analyses of soybean injury at 30 and 45 DAP.

A significant rate by timing by year interaction was present in the combined analysis for injury at 30 and 45 DAP. Therefore, injury data for individual years are presented for 30 and 45 DAP (Table 4). At 30 DAP in 1991, there was no significant rate by timing interaction. A significant rate and timing effect occurred with injury at 30 DAP. The greatest injury (28%) was observed when 2,4-D at the highest rate was applied. The most injury (47%) due to application timing was observed when 2,4-D was applied 0 DBP. At 45 DAP, in 1991, a significant rate by timing interaction occurred. Injury decreased significantly with all rates of 2,4-D by increasing the interval between 2,4-D application and planting from 0 to 7 DBP. Nevertheless, injury generally decreased from 30 to 45 DAP with all rates and application timings, indicating that soybean plants were recovering from earlier season injury.

In 1992, crop injury was not as severe as in 1991, probably due to less rainfall in 1992 as noted previ-

ously. A significant rate by date interaction occurred with injury at 30 and 45 DAP in 1992 (Table 4). At 30 DAP, injury was reduced significantly when 2,4-D at 1120 and 1680 g/ha was applied 7 or 14 DBP compared with 0 DBP. There was no difference in injury at both 30 and 45 DAP when 2,4-D was applied at 560 g/ha regardless of application timing. Soybean injury tended to decrease over time in 1992, similar to 1991.

Soybean yield. No significant rate by timing by year interaction was present in the combined analysis with grain yield, therefore, yield data were pooled over years (Table 5). Despite the severe injury observed earlier in the season, there was no difference in grain yield due to rate, application timing, or interactions between these factors. Other researchers have reported that injury from herbicides early in the season does not necessarily correlate well with yield reduction (3, 10, 14, 21).

There was no difference in grain yield when averaged over all 2,4-D rates and application timings compared with no 2,4-D in 1991, 1992, or combined over

Table 5. Effect of 2,4-D rate and application timing on soybean grain yield, pooled over years.

2,4-D rate g/ha	Application timing		
	0 DBP ^a	7 DBP	14 DBP
	kg/ha		
560	2120	2480	2060
1120	2240	2400	2220
1680	1900	2130	2390
No 2,4-D	2080		
LSD (0.05)	NS		

^aDBP = days before planting.

Table 6. Effect of 2,4-D on soybean grain yield.

Orthogonal comparisons ^a	Year		
	1991	1992	Combined
	kg/ha		
No 2,4-D	2760	1400	2080
vs 2,4-D	2660	1700	2220
	NS ^b	NS	NS

^aAveraged over all rates and application timings.^bNS = not significant ($P \geq 0.05$).

years (Table 6). By contrast, with other crops, research has indicated that 2,4-D ester applied at 550 g/ha 0 or 15 DBP may reduce the yield of canola, peas, lentil, and wheat (*Triticum aestivum* L.) (19).

The results from this study indicate that increasing the time interval between 2,4-D application and planting reduces potential for delayed soybean emergence and injury. Virtually no delay in emergence with little or no subsequent injury was caused by the application of 2,4-D ester at 560 or 1120 g/ha 7 or 14 DBP. Furthermore, 2,4-D may not limit soybean grain yield when applied 0, 7, or 14 DBP at rates up to 1680 g/ha on a low organic matter soil.

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