Effect of Three Desiccant-Type Herbicides on Fruiting Structures of *Colletotrichum truncatum* and *Phomopsis* spp. on Soybean Stems

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ABSTRACT

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Soybean (*Glycine max*) cultivars UFV_1 and UFV_2 grown at Florestal and Viçosa, Brazil, and cultivars Bonus and Wells grown at Urbana, IL, were sprayed at growth stages R5.5–6 (full pod) or R7 (physiologic maturity) with one of three desiccant-type, nonselective herbicides: glyphosate, paraquat, or sodium chlorate:sodium borate (50:50). The stems of all paraquat-sprayed plants had optimum development of fruiting structures of *Colletotrichum truncatum*, causal fungus of soybean anthracnose, and of *Phomopsis* spp., causal fungi of soybean pod and stem blight, stem canker, and seed decay as much as 3 wk earlier than unsprayed plants. Glyphosate-sprayed plants of Bonus and UFV_1 gave similar results. No differences were noted between plants unsprayed or sprayed with sodium chlorate:sodium borate. Parallel increases in the development of fruiting structures with time were recorded on stems of unsprayed and sprayed plants. Treatment, time of treatment, and location influenced the development of the fruiting structures of the test fungi.

Desiccant-type, nonselective herbicides are used as harvest aids of soybean (*Glycine max* (L.) Merr.) and other oilseed crops (20,24), common bean (*Phaseolus vulgaris* L.) (11), potatoes (*Solanum tuberosum* L.) (6,17,18), and other crops. Glyphosate or isopropylamine salt of *N*-(phosphonomethyl)glycine (Roundup, Monsanto Agricultural Products, St. Louis, MO 63166) and paraquat or 1, 1′-dimethyl-4-4′-bipyridinium dichloride (Chevron Chemical Co., Fresno, CA 93705) are herbicides with desiccant activity that are used for vegetation control prior to cultivation and for weed control in fields of limited cultivation and direct drilling (12,19). The two herbicides, when sprayed on cereal stubble, showed fungistatic effects on cereal pathogens (8,13).

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However, when diquat dibromide (chemical analogue of paraquat) was used in seed potatoes, more fruiting structures of *Phoma exigua* Desm. var. *foveata* (Foister) Boerema occurred on stems of sprayed plants than on unsprayed ones (6,17).

Laboratory and preliminary field studies indicated that paraquat applied to soybeans stimulates the production of the fruiting structures of *Colletotrichum truncatum* (Schw.) Andrus & Moore (anthracnose) and *Phomopsis* spp. (pod and stem blight, stem canker, and seed decay) several weeks earlier than on untreated plants (4,5,21). These fungi colonize and cause local, latent infections of immature soybean tissue with the production of fruiting structures occurring at maturity and senescence (15,16,23). Soybean debris from the current and previous season is a major source of inoculum for *C. truncatum, Diaporthe* spp., and *Phomopsis* spp. (2,9,16,23) and is particularly important in tropical regions where sequential cropping of soybeans is possible and where severe overwintering conditions do not occur.

Most studies on the effect of herbicides on plant disease report on greenhouse or laboratory exposure of pathogens to herbicides and neglect field aspects (1,14). In this study, we examined the effect of three desiccant-type, nonselective herbicides and of delayed harvest of soybean on the production of the fruiting structures of *C. truncatum* and *Phomopsis* spp. under field conditions in Brazil and Illinois. A portion of these studies was published in an abstract (4).

MATERIALS AND METHODS

Field sites were located at the Plant Pathology Research Center at the University of Illinois at Urbana-Champaign (UIUC) and at two field sites in Brazil (Universidade Federal de Viçosa Experimental Farm and Florestal Agricultural School), which are 300 km apart in the state of Minas Gerais. Cultivars Bonus and Wells soybeans of maturity groups IV and II, respectively, were planted on 30 May 1978 at Urbana; cultivars UFV_1 and UFV_2 of maturity groups IX and VIII, respectively, were planted on 1 November 1979 at Florestal and on 22 November 1979 at Viçosa. Seeding rates of 25 seeds per meter with row width of 60 cm for Viçosa and Florestal and of 75 cm for Urbana were used. Each plot was 3 × 4.6 m. All experiments consisted of two main treatments, sprayed and unsprayed, with five replicates per treatment and sampling times as subplots. Each subplot was arranged as a split plot in time in randomized complete blocks. Two treatments within each plot consisted of the untreated control and one of the following: 1) paraquat at 2.34 L/ha applied at R7 (physiologic maturity) stage (7), 2) same as (1) but applied at R5.5–6 (full-pod) stage, 3) sodium chlorate:sodium borate (50:50) at 3.4 kg/ha applied at R7 stage, or 4) glyphosate at 9.33 L/ha applied at R7 stage. Rates were based on suggested use by manufacturers. Desiccants usually are applied when plants are in R7 stage. The application at the R5.6–6 stage was 10 days earlier than suggested by the manufacturer. The herbicides were applied in late afternoon, using a knapsack sprayer.

Ten stems for each replicate, 8 cm long, were cut from the midregion of plants either unsprayed or sprayed and rated for the presence of acervuli of *C. truncatum* and pycnidia of *Phomopsis* spp. At the Brazilian sites, stems were harvested 9, 15, 20, and 36 days after herbicide application except where paraquat was applied at the R5.5–6 stage. In this case, stems were harvested 10 and 23 days after paraquat application. At Urbana, cultivars Wells and Bonus sprayed at the R7 stage with paraquat were harvested 5, 10, 15, 20, 32 days and 5, 10, 18, 36 days after application, respectively. Wells

plants sprayed with paraquat at the R5.5–6 stage were harvested 10 and 15 days after application, and Bonus plants sprayed with either glyphosate or sodium chlorate:sodium borate were harvested 10, 19, and 38 days after spraying.

A five-point rating system of the fruiting structures on soybean stems was used where 1 = 0%, 2 = 1–5%, 3 = 6–25%, 4 = 26–50%, and 5 = more than 50% of the soybean stem covered with acervuli of *C. truncatum* or pycnidia of *Phomopsis* spp. A disease severity index was calculated for each replicate by using the following formula: $DSI = (X_1Y_1 + X_2Y_2 + X_3Y_3 + X_4Y_4 + X_5Y_5)/N$, where DSI = disease severity index, X = rating number of fruiting structure, Y = number of plants with a specific rating number, and N = total number of plants in each replicate. Treatment indexes were analyzed using the Statistical Analysis System (SAS) of prepackaged programs at UIUC (3).

RESULTS

Acervuli of *C. truncatum* and pycnidia of *Phomopsis* spp. developed on paraquat-sprayed plants at least 3 wk earlier than on unsprayed plants at all locations and on all cultivars at both growth stages (Table 1). Stems of unsprayed plants at harvest maturity had less development of fungal fruiting structures than on paraquat-sprayed plants, unless harvest was considerably delayed.

Glyphosate-sprayed plants dried slower than those sprayed with paraquat at all three experimental sites. In Brazil, however, stems of sprayed plants were colonized by the two genera of fungi earlier and more at harvest maturity than were stems of unsprayed plants at harvest maturity (Table 1). Stems of sprayed and unsprayed plants had similar levels of increase of fungal fruiting structures of both genera of fungi when left in the field after harvest maturity in Brazil. In some cases, no statistically significant differences ($P = 0.05$) between desiccant-type herbicide and corresponding control were noted at Urbana because of high sample variability.

Plants sprayed with the sodium chlorate:sodium borate mixture did not differ significantly ($P = 0.05$) in number of fruiting structures from unsprayed plants at any location, and they had a slower rate of desiccation than did plants treated with the other two desiccant-type herbicides (Table 1).

Increases in fungal fruiting structures on stems with time was recorded in all treatments (including the control) except on Wells and UFV, plants sprayed with paraquat at the R5.5–6 growth stage at Urbana and Viçosa, respectively. In these two cases, the majority of the stems were so covered with fruiting structures after the first sampling period that no increase in fungal structures was detectable (Table 1). Treated and control stems had parallel

Table 1. Mean disease severity index[a] at sampling time for occurrence of fruiting structures of *Colletotrichum truncatum* and *Phomopsis* spp. on soybean stem pieces treated with one of three desiccant-type herbicides at two sites in Brazil (Florestal and Viçosa) and at Urbana, IL

Cultivar and site	Treatment[b]	Sampling time in days after application				Treatment means
		9	15	20	36	
UFV_1, Florestal-1	Control	13.6	14.4	22.0	33.0	20.8
	Paraquat	40.6*[c]	44.2*	48.0*	48.4	45.3*
FLSD[d]		8.47	5.57	8.95	NS[e]	4.78
UFV_2, Florestal-1	Control	20.4	26.0	40.4	46.6	33.4
	Paraquat	33.0*	34.4*	50.0*	49.8	41.8*
FLSD		11.02	4.53	7.58	NS	2.57
UFV_1, Florestal-1	Control	13.8	14.0	27.4	23.0	19.6
	Glyphosate	32.4*	37.2*	39.4*	49.4*	39.6*
FLSD		6.43	3.58	5.95	13.73	4.62
UFV_1, Florestal-1	Control	16.0	14.2	28.6	29.2	20.8
	SC:SB	13.6	12.6	30.4	35.2	23.0
FLSD		NS	NS	NS	NS	NS
UFV_1, Viçosa-1	Control	14.6	12.4	26.8	37.2	22.8
	Paraquat	46.0*	35.4*	35.8*	42.4	39.9*
FLSD		3.21	10.09	7.75	NS	3.13
UFV_2, Viçosa-1	Control	19.6	35.0	40.8	43.6	34.8
	Paraquat	48.0*	36.2*	46.4*	42.8	43.4*
FLSD		4.78	NS	5.38	NS	2.72
UFV_1, Viçosa-1	Control	22.0	13.0	21.6	28.2	21.2
	Glyphosate	43.8*	44.4*	40.8*	48.0*	44.2*
FLSD		13.84	21.66	12.08	7.57	4.61
UFV_1, Viçosa-1	Control	19.6	15.4	21.0	31.4	21.8
	SC:SB	18.8	21.2	25.8	33.0	24.7
FLSD		NS	NS	NS	NS	NS
		10	**23**			
UFV_1, Florestal-2	Control	12.4	14.6			13.5
	Paraquat	39.2*	44.8*			42.0*
FLSD		1.84	5.91			3.59
UFV_2, Florestal-2	Control	11.4	21.2			16.3
	Paraquat	40.6*	49.6*			45.1*
FLSD		19.64	6.89			12.9
UFV_1, Viçosa-2	Control	10.2	15.2			12.7
	Paraquat	49.8*	49.2*			49.5*
FLSD		0.68	8.24			4.18
UFV_2, Viçosa-2	Control	11.2	27.8			19.5
	Paraquat	49.0*	49.8*			49.4*
FLSD		1.62	9.85			4.57
		5	**10**	**15**	**20**	**32**	
Wells, Urbana-1	Control	18.6	29.4	28.8	38.2	42.0	31.4
	Paraquat	32.3	40.2*	46.4*	44.6	40.4	40.8*
FLSD		NS	7.82	13.62	NS	NS	5.15
Bonus, Urbana-1	Control	22.0	21.0	26.2	278	24.2	
	Paraquat	31.5	37.4	38.0	36.8	35.9	
FLSD		NS	NS	NS	NS	NS	
		10	**19**	**38**		
Bonus, Urbana-1	Control	19.2	22.0	25.6		22.3
	SC:SB	17.4	24.4	29.8		23.9
FLSD		NS	NS	NS		NS
Bonus, Urbana-1	Control	21.8	24.0	27.75		24.5
	Glyphosate	25.2	29.6	28.0		27.6
FLSD		NS	NS	NS		NS
		10	**15**			
Wells, Urbana-2	Control	17.4	16.5			17.0
	Paraquat	39.4*	47.5*			43.4*
FLSD		17.88	25.41			10.96

[a] Mean disease severity index (DSI) for stem colonization by *Phomopsis* spp. and *Colletotrichum truncatum* calculated for each replicate by using the following formula: $DSI = (X_1Y_1 + X_2Y_2 + X_3Y_3 + X_4Y_4 + X_5Y_5)/N$, where X = rating number of fruiting structure, Y = number of plants with specific rating number, and N = total number of plants in each replicate (based on five replicates of 10 stems each). Rating number of fruiting structure is based on five-point system where 1 = 0%, 2 = 1–5%, 3 = 6–25%, 4 = 26–50%, and 5 = more than 50% of soybean stem covered with acervuli of *C. truncatum* and pycnidia of *Phomopsis* spp.

[b] Application of paraquat, sodium chlorate:sodium borate (50:50) (SC:SB), or glyphosate at growth stage R7 (50% of leaves yellow, physiologic maturity) for Florestal-1, Viçosa-1; and Urbana-1; at R5.5–6 (pods containing full-sized, green soybeans at one of the four uppermost nodes) for Florestal-2, Viçosa-2, and Urbana-2.

[c] * = Significantly different from control at 5% level according to Fisher's least significant difference.

[d] Comparison between two treatment means by Fisher's least significant difference ($P = 0.05$).

[e] Not significantly different ($P = 0.05$).

levels of increase in fungal fruiting structures for all treatments and application times.

Treatment with paraquat and sampling time were important factors at Viçosa for both cultivar and application times but only when applied at growth stage R7 on UFV_2 at Florestal and on Wells at Urbana. Sampling time was also important for glyphosate at the two Brazilian sites but not for the sodium chlorate:sodium borate mixture at any location.

An analysis of variance of combined data from Florestal and Viçosa showed a significant ($P = 0.05$) effect on the occurrence of fruiting structures for cultivar and for application time with the use of paraquat. There was a significant ($P = 0.05$) interaction for location and location by treatment for cultivars UFV_1 at growth stages R7 and R5.5–6, respectively. Significant ($P = 0.05$) treatment effects were recorded for glyphosate but not for sodium chlorate: sodium borate, with a significant ($P = 0.05$) location effect for the former.

DISCUSSION

Our results showed that the same degree of development of the fruiting structures of *C. truncatum* and *Phomopsis* spp. occurred immediately after application of glyphosate and paraquat sprays as on untreated stems after a delayed harvest. A similar "senescence-induced" disease was reported with *Drechslera sorokiniana* (Sacc.) Subram. & Jain on *Poa pratensis* L. after application of four chlorophenoxy and one benzoic acid herbicides (10).

Soybean stem tissues are an important source of inoculum for *C. truncatum* and *Phomopsis* spp. (2,9,16,23). Soybean stem and pod tissues may be colonized early in the growing season by these fungi (15,16,23) without the production of symptoms or fruiting structures until late in the growing season. The rapid and early development of fungal fruiting structures on soybean tissue after paraquat application can result in higher levels of inoculum, leading to more stem, pod, and seed infections. In tropical regions like Brazil where severe overwintering conditions do not exist and sequential cropping of soybeans is possible, the early development of fungal fruiting structures after paraquat application could lead to higher disease levels in the next soybean crop. More careful management of soybean residues after paraquat application may be necessary to reduce inoculum levels.

Our results are similar to those in experiments where potato stems sprayed with diquat dibromide (chemical analogue of paraquat) developed more pycnidia of *Phoma exigua* var. *foveata* than did unsprayed stems (17) and to other experiments in which paraquat caused a transitory increase in sporulation of *Rhynchosporium secalis* (Oud.) J. J. Davis on volunteer plants among barley (*Hordeum vulgare* L.) stubble (22). In contrast, glyphosate and paraquat had a fungistatic effect on *Septoria nodorum* Berk. and *S. tritici* Rob. ex Desm. on cereal stubble (8,13). These differences in nontarget effects of similar herbicides on fungal pathogens indicate a need for careful study of each herbicide-host-pathogen system (1,14).

Our results suggest that glyphosate and paraquat application may have limited use on soybeans, particularly in tropical areas where sequential cropping may occur. The use of glyphosate can also result in soybean seed discoloration and reduced germination (24).

LITERATURE CITED

1. Altman, J., and Campbell, C. L. 1977. Effect of herbicides on plant diseases. Annu. Rev. Phytopathol. 15:361-385.
2. Athow, K. L., and Caldwell, R. M. 1954. A comparative study of Diaporthe stem canker and pod and stem blight of soybeans. Phytopathology 44:319-325.
3. Barr, A. J., Goodnight, J. H., and Sall, J. P. 1979. SAS Users Guide. SAS Institute, Raleigh, NC. 494 pp.
4. Cerkauskas, R. F., and Sinclair, J. B. 1979. Effect of three desiccants on soybean stem colonization by *Phomopsis sojae* and *Colletotrichum dematium* var. *truncata*. (Abstr.) Phytopathology 69:539.
5. Cerkauskas, R. F., and Sinclair, J. B. 1980. Use of paraquat to aid detection of fungi in soybean tissues. Phytopathology 70:1036-1038.
6. Copeland, R. B., and Logan, C. 1976. The effect of interval from haulm destruction to harvest on the gangrene potential of tubers in storage. Potato Res. 19:203-213.
7. Ferr, W. R., Caviness, C. E., Burmood, D. T., and Pennington, J. S. 1971. Stage of development descriptions for soybeans, *Glycine max* (L.) Merr. Crop Sci. 11:929-931.
8. Harris, D., and Grossbard, E. 1979. Effects of the herbicides Gramoxone W and Roundup on *Septoria nodorum*. Trans. Br. Mycol. Soc. 73:27-33.
9. Hildebrand, A. A. 1956. Observations on stem canker and pod and stem blight of soybeans in Ontario. Can. J. Bot. 34:477-499.
10. Hodges, C. F. 1980. Interaction of sequential leaf senescence of *Poa pratensis* and pathogenesis by *Drechslera sorokiniana* as influenced by postemergent herbicides. Phytopathology 70:628-630.
11. Hole, C. C., and Hardwick, R. C. 1978. Chemical aids to drying seeds of beans (*Phaseolus vulgaris*) before harvest. Ann. Appl. Biol. 88:421-427.
12. Jeater, R. S. L., and McIlvenny, H. C. 1965. Direct-drilling of cereals after use of paraquat. Weed Res. 5:311-318.
13. Jones, D. G., and Williams, J. R. 1971. Effect of paraquat on growth and sporulation of *Septoria nodorum* and *Septoria tritici*. Trans. Br. Mycol. Soc. 57:351-357.
14. Katan, J., and Eshel, Y. 1973. Interactions between herbicides and plant pathogens. Residue Rev. 45:145-177.
15. Kmetz, K., Ellett, C. W., and Schmitthenner, A. F. 1974. Isolation of seedborne *Diaporthe phaseolorum* and *Phomopsis* from immature soybean plants. Plant Dis. Rep. 58:978-982.
16. Kmetz, K., Ellett, C. W., and Schmitthenner, A. F. 1979. Soybean seed decay: Sources of inoculum and nature of infection. Phytopathology 69:798-801.
17. Logan, C., Copeland, R. B., and Little, G. 1976. The effects of various chemical and physical haulm treatments on the incidence of potato gangrene. Ann. Appl. Biol. 84:221-229.
18. Nelson, D. C., and Nylund, R. E. 1969. Effect of chemicals on vine kill, yield and quality of potatoes in the Red River Valley. Am. Potato J. 46:315-322.
19. Osborne, D. J. 1968. Defoliation and defoliants. Nature 219:564-567.
20. Sanderson, J. F. 1976. Pre-harvest desiccation of oilseed crops. Outlook Agric. 9:21-25.
21. Sinclair, J. B. 1982. Compendium of Soybean Diseases. 2nd ed. American Phytopathological Society, St. Paul, MN. 104 pp.
22. Stedman, O. J. 1982. The effect of three herbicides on the number of spores of *Rhynchosporium secalis* on barley stubble and volunteer plants. Ann. Appl. Biol. 100:271-279.
23. Tiffany, L. H. 1951. Delayed sporulation of *Colletotrichum* on soybean. Phytopathology 41:975-985.
24. Whigham, D. K., and Stoller, E. W. 1979. Soybean desiccation by paraquat, glyphosate and ametryn to accelerate harvest. Agron. J. 630-633.