4-1982

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Research Report 73, April 1982

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The research reported in this publication was supported in part by Federal funds made available through the provisions of the Hatch Act.

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Received for publication March 17, 1982.

THE EFFECT OF GLYPHOSATE/GROWTH REGULATOR COMBINATIONS ON BLACKBERRY CONTROL.

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ABSTRACT

Blackberry plants (Rubus allegheniensis Porter) from a wild clone were treated with growth regulators at known rates for growth inhibition in combination with a glyphosate application at 1.26 kg ae/ha. Results of these experiments indicated that application of ABA at 300 ppm w/v applied 24 hours after a glyphosate treatment, ABA at 300 ppm w/v applied in the spray solution, or ethephon applied at 500 or 1,000 ppm w/v applied in the spray solution had no beneficial effect on glyphosate activity. The use of MH at 1,000 ppm applied in the spray solution reduced the effectiveness of glyphosate. The use of SADH at 2,000 ppm w/v in the spray solution or applied 9 days before a glyphosate treatment generally reduced the number of adventitious buds per crown and increased herbicidal activity. The use of SADH at 5,000 ppm w/v applied in the spray solution or applied 9 days before a glyphosate treatment in most cases was not as effective as the 2,000 ppm w/v

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treatment. A second experiment indicated that glyphosate/SADH treatments at either the 2,000 or 5,000 ppm w/v concentrations resulted in 100% crown mortality 105 days after treatment; whereas, plants treated with glyphosate alone only had 33% crown mortality.

INTRODUCTION

Mid season applications of glyphosate to blackberry plants have been reported to result in poor control of the blackberry population, and increasing the rate of application during this treatment time only increases the rate of knockdown (6). Reasons for poor control at this time include poor translocation of glyphosate to the crown (9), translocation of glyphosate to the developing primocane (9), and low amounts of leaf area which exist at this time (6).

Other plant species--quackgrass, Canada thistle and purple nutsedge, to name a few, also show similar specific treatment time requirements and regrowth potentials (3, 4, 5, 10).

Since growth regulators are known to have modifying effects on plant processes, including translocation, these experiments were undertaken to see if increased glyphosate activity could result from combination with growth regulators.

MATERIALS AND METHODS

Experiment 1. Preliminary Glyphosate/Growth Regulator Studies.

These experiments were conducted in a greenhouse at the Agronomy Research Farm in the winter and spring seasons of 1979 and 1980 to investigate the effect of growth retardants on glyphosate activity. Plants used during the 1979 spring season were collected as needed from a wild clone of blackberries which existed on the farm. The plants used in the 1980 growing season were collected from a wild clone on

November 16, 1979 and stored in a cold storage at 1.5°C until they were to be used. All plants were planted in 13.75 cm plastic pots and then clipped to achieve a uniform cane height of 45 cm. Plants were subjected to normal care and fertilization practices that would be expected for most greenhouse plants.

Growth regulator treatment groups used for this preliminary screening are listed below with their appropriate treatments:

1) SADH[2/] at 2000 ppm w/v, SADH at 5000 ppm w/v, glyphosate at 1.26 kg ae/ha plus SADH at 2000 ppm w/v, glyphosate at 1.26 kg ae/ha plus SADH at 5000 ppm w/v, glyphosate at 1.26 kg ae/ha, and untreated control.
2) SADH at 2000 ppm w/v, SADH at 5000 ppm w/v, glyphosate at 1.26 kg ae/ha applied 9 days after a SADH treatment at 2000 ppm w/v, glyphosate at 1.26 kg ae/ha applied 9 days after a SADH treatment at 5000 ppm w/v, glyphosate at 1.26 kg ae/ha, and untreated control.
3) Ethephon[3/] at 5000 ppm w/v, ethephon at 1000 ppm w/v glyphosate at 1.26 kg ae/ha plus ethephon at 500 ppm w/v, glyphosate at 1.26 kg ae/ha plus ethephon at 1000 ppm w/v, glyphosate at 1.26 kg ae/ha, and untreated control.
4) ABA[4/] at 300 ppm w/v, ABA at 300 ppm w/v plus glyphosate at 1.26 kg ae/ha, glyphosate at 1.26 kg ae/ha, and untreated control.

2/ Applied as B-9, Uniroyal, Naugatuck, CT. This formulation contains 85% succinic acid 2,2 dimethyl hydrazide (SADH).

3/ Applied as Ethrel, Union Carbide, Agricultural Products Co., Inc. This formulation contains 21.6% Ethephon [(2-Chloroethyl)Phosphonic Acid].

4/ Sigma Chemical Company, applied as sodium salt of the parent acid of abscissic acid.

5) ABA at 300 ppm w/v, ABA at 300 ppm w/v applied 24 hours after a glyphosate treatment at 1.26 kg ae/ha, glyphosate at 1.26 kg ae/ha, and untreated control.

6) Maleic Hydrazide (MH)[5/] at 1000 ppm w/v, MH at 1000 ppm w/v plus glyphosate at 1.26 kg ae/ha, glyphosate at 1.26 kg ae/ha, and untreated control.

Treatments of groups 1, 2, and 3 were made on May 2, 1979. Experimental design chosen for these experiments was a completely randomized design. Treatments of groups 4, 5, and 6 were made on March 16, 1980. Experimental design chosen for these experiments was a completely randomized block. Three replicates were used in all experiments.

All treatments were applied using a mechanical pot sprayer with a 6502 Spraying Systems nozzle at a pressure of 2.8 kg/cm^2. Plants were sprayed by using a double pass in order to assure a uniform spray distribution. This gave a volume equivalent to 467 L/ha. All treatments were initiated after the plants had set fruit and the basal leaves of the primocane were fully expanded. In all cases, plants were ready for treatment four to five weeks after being placed in the greenhouse. Once the plants were treated they were not watered for 36 hours after treatment.

Four weeks after treatment, injury ratings were taken, the plants harvested, the number of adventitious buds per plant, and dry weights of the top growth and crown were determined. All data were statistically analyzed and the means separated using Duncan's multiple range test at a 5% probability level.

5/ Uniroyal Chemical, Naugatuck, CT. Applied as MH-30 Formulation. This formulation contains 30% 1,2-Dihydropyridazine-3,6-Dione.

Experiment 2. Glyphosate/SADH Experiment.

This experiment was done to better understand and define the results obtained in Experiment 1. Since there was no difference between the treatments where glyphosate was applied with SADH or 9 days after SADH, all treatments were made as a combined spray. Plants for this experiment were blackberries collected from a wild clone on November 16, 1979, clipped to give a uniform cane height of 45 cm and stored in moist sphagnum moss in cold storage at 1.5°C until they were to be used. A completely randomized block design with three replicates was used for this experiment. Plants were started on March 21, 1980 and were treated on April 28, 1980. All treatments were made in a manner consistent with those in Experiment 1.

Injury ratings were taken 1, 2, 3, and 4 weeks after treatment. The tops were harvested on May 23, 1980 and the dry weight was determined. At this point the plants were watered daily to keep the soil moist. On June 20, 1980 the number of adventitious buds per crown was determined by washing the soil away from the crown and main roots by using a high pressure stream of water and counting the number of buds present. Soil was then replaced around the crown and roots and watered in. On August 11, 1980 the plants were harvested, the number of adventitious buds determined, and regrowth of the tops in terms of dry weight was recorded. All data were statistically analyzed with the means being separated by Duncan's multiple range test at a 5% probability level.

RESULTS AND DISCUSSION

Experiment 1. Preliminary Glyphosate/Growth Regulator Studies.

Of all the growth regulator/glyphosate combinations tried, SADH showed promise because this combination resulted in high-

er injury levels and caused a reduction in the number of adventitious buds that developed on the crown (Table 1). The application of glyphosate at 1.26 kg ae/ha to blackberries 9 days after an SADH treatment at 2000 ppm w/v produced significantly more injury than applications of glyphosate alone. Treatment with glyphosate 9 days after an SADH treatment at 5000 ppm also produced more injury than the glyphosate treatment alone but produced less injury than the glyphosate treatment 9 days after SADH treatment at 2000 ppm w/v. Plants which had been treated with glyphosate after an SADH treatment exhibited greater amounts of foliar damage and more death of the florocane and developing primocane. Treatment under these conditions also resulted in significant glyphosate X SADH interaction in terms of visual injury ratings but

Table 1. The effect of SADH on the herbicidal activity of glyphosate on blackberries when applied 9 days before glyphosate treatment.

Glyphosate kg ae/ha	SADH ppm	Injury Ratings 1/	Adventitious Buds per Crown	Dry Weight of Tops Grams
0.00	0	0.0d	3.3b	3.2
	2000	0.0d	3.7b	5.2
	5000	0.0d	4.3b	5.0
1.26	0	1.7c	16.7a	4.3
	2000	3.3a	9.7ab	3.1
	5000	2.2b	4.3b	3.3
				NS

1/ Injury Rating is on a 0 to 10 basis with 0 equal to no injury and 10 equal to total kill. Injury Rating taken May 30, 1979.

2/ Values not followed by the same letter in the same column are significantly different at the 5% level by the Duncan's multiple range test.

interactions in terms of dry weight of the tops or adventitious buds were not significant. Under no circumstances did SADH alone produce any symptoms of injury.

The use of glyphosate by itself at 1.26 kg ae/ha often failed to produce severe injury. Plants treated in this manner often produced an excessive number of adventitious buds which may or may not produce new plants. Field observations of plants which had been sprayed with glyphosate but were not killed revealed that over a period of time recovery of the buds is possible. Also recovery of the buds along the rhizome was noted to occur. Control plants often produce a few adventitious buds which later develop into a new plant. The use of SADH at 5000 ppm w/v 9 days before a glyphosate treatment reduced adventitious budding to a level which was comparable to the control and SADH alone treatments. The SADH treatment at 2000 ppm 9 days before a glyphosate treatment also reduced adventitious bud development somewhat but not to the extent noted in the 5000 ppm w/v treatment. The use of SADH alone at 2000 or 5000 ppm w/v did not have any effect on adventitious bud development of the plants. Also, no differences in the dry weight of the top growth was noted to occur in any of the treatment conditions.

Treatment of plants with SADH and glyphosate at the same time produced similar results as those obtained when glyphosate was applied 9 days after an SADH treatment (Table 2). Application of both materials at the same time resulted in similar injury ratings, number of adventitious buds per crown and glyphosate X SADH interaction in terms of injury ratings with one exception. Treatment with glyphosate and SADH at 5000 ppm w/v resulted in no reduction in adventitious bud development when compared to the glyphosate treatment alone. In this experiment, differences were noted in the dry weight of the top growth. However, these differences do little to explain the effects on

Table 2. The effect of SADH on the herbicidal activity of glyphosate on blackberries when applied together in the spray solution.

Glyphosate kg ae/ha	SADH ppm	Injury Rating[1/]	Adventitious Buds per Crown	Dry Weight of Tops Grams
0.00	0	0.0d	3.5c	3.2b
	2000	0.0d	3.7c	5.2a
	5000	0.0d	4.3c	5.0a
1.26	0	1.7c	16.7a	4.3a
	2000	4.0a	7.0bc	2.2b
	5000	2.8b	14.7ab	3.2b

1/ Rating is on a 0 to 10 basis with 0 equal to no injury and 10 equal to total kill. Injury Rating taken May 30, 1979.

2/ Values not followed by the same letter in the same column are significantly different at the 5% level by Duncan's multiple range test.

herbicidal activity. The control, glyphosate plus SADH at 2000 ppm w/v and glyphosate plus SADH at 5000 ppm w/v produced the lowest amounts of top growth. The SADH treatment at 2000 ppm w/v, SADH at 5000 ppm w/v, and glyphosate alone had higher amounts of top growth. One would expect the control treatment to have the highest, the SADH treatments to be intermediate, and the glyphosate treatment with or without SADH to have the lowest amounts of dry weight of the plant tops. Since the dry weight of the tops, particularly the control, does not follow the expected trend, the cause of these differences could be the result of poor uniformity of the plant material.

The use of ABA in conjunction with a glyphosate treatment applied in the spray solution (Table 3) or 24 hours after a glyphosate treatment (Table 4) did not increase glyphosate injury or result in a decrease in adventitious budding. Plants in these treatment groups had a high degree of glyphosate injury and the use of ABA did not seem to increase

Table 3. The effect of ABA on the herbicidal activity of glyphosate on blackberries when applied together in the spray solution.

Glyphosate kg ae/ha	ABA ppm	Injury Ratings[1]	Adventitious Buds per Crown
0	0	0b[2]	0.3b[2]
	300	0b	1.7ab
1.5	0	9a	5.0ab
	300	9a	30.7a

[1] Injury Rating is on a 0 to 10 basis with 0 equal to no injury and 10 equal to total kill. Injury Rating taken April 11, 1980.

[2] Values not followed by the same letter in the same column are significantly different at the 5% level by the Duncan's multiple range test.

Table 4. The effect of ABA on the herbicidal activity of glyphosate on blackberries when applied 24 hours after a glyphosate treatment.

Glyphosate kg ae/ha	ABA ppm	Injury Ratings[1]	Adventitious Buds per Crown
0	0	0b[2]	0.3
	300	0b	1.7
1.5	0	9a	11.8
	300	10a	32.0
			NS

[1] Injury rating is on a 0 to 10 basis with 0 equal to no injury and 10 equal to total kill. Injury Rating taken April 11, 1980.

[2] Values not followed by the same letter are significantly different at the 5% level by Duncan's multiple range test.

glyphosate activity. The only difference noted between these two treatment groups was in the number of adventitious buds per crown. Plants which received glyphosate at 1.26 kg ae/ha and ABA in the spray solution (Table 3) had higher levels of adventitious budding than the control treatment. While this

treatment had more adventitious buds than glyphosate alone this difference was not significant. Adventitious budding in the ABA treatments applied 24 hours after a glyphosate treatment were not significant (Table 4). Since greater injury or a decrease in the number of adventitious buds per crown are the criteria that would indicate a beneficial use, the use of glyphosate in conjunction with ABA is not warranted.

Application of ethephon in conjunction with glyphosate did not have any beneficial effects on glyphosate activity in terms of greater injury, adventitious buds per crown or reductions in dry weight of the tops (Table 5). Plants treated with ethephon alone at 1000 ppm w/v produced significant amounts of epinasty and foliar damage. Since ethephon produces such an effect it is likely that glyphosate uptake and/or translocation could be reduced by such a treatment. While treatment of blackberry plants with ethephon at 500 ppm w/v alone failed to produce visible injury symptoms, a treatment of glyphosate at 1.26 kg ae/ha and ethephon at 500 ppm

Table 5. Effect of ethephon on the herbicidal activity of glyphosate on blackberries when applied together in the spray solution.

Glyphosate kg ae/ha	Ethephon ppm	Injury Rating[1]	Adventitious Buds per Crown	Dry Weight of Tops Grams
0	0	0c[2]	3.3c[2]	9.7b[2]
	500	0c	2.7c	12.8a
	1000	1.7a	11.0ab	8.4b
1.5	0	1.7a	16.7a	12.9a
	500	0.8b	7.7ab	12.8a
	1000	2.0a	17.0a	8.4b

[1] Injury Rating is on a 0 to 10 basis with 0 equal to no injury and 10 equal to total kill. Injury Rating taken May 30, 1979.

[2] Values not followed by the same letter in the same column are significantly different at the 5% level by the Duncan's multiple range test.

Table 6. Effect of MH on the herbicidal activity of glyphosate on blackberries when applied together in the spray solution.

Glyphosate kg ae/ha	MH ppm	Injury Rating[1]	Adventitious Buds per Crown	Dry Weight of Tops Grams
0.0	0	0.0c[2]	2.7[2]	22.1a[2]
	1000	0.0c	8.7	8.3c
1.5	0	6.3a	2.3	19.2ab
	1000	3.3b	2.0	11.0bc
		NS		

[1] Injury Rating is on a 0 to 10 basis with 0 equal to no injury and 10 equal to total kill. Injury Rating taken April 11, 1980.

[2] Values not followed by the same letter in the same column are significantly different at the 5% level by the Duncan's multiple range test.

w/v resulted in increased injury. However, the injury resulting from this treatment was significantly less than that from treatment with glyphosate alone at 1.26 kg ae/ha.

The use of MH in conjunction with glyphosate also failed to produce any desirable benefits (Table 6). The use of MH at 1000 ppm w/v failed to produce significant increases in injury or reductions in adventitious buds per crown or dry weight of the tops. The use of MH in conjunction with glyphosate resulted in less visible injury then glyphosate alone.

In conclusion, the use of SADH at 2000 ppm w/v in the spray solution or applied 9 days after a glyphosate application resulted in greater injury symptoms, more death of canes, and reduced numbers of adventitious buds per crown.

The use of MH, ethephon, or ABA generally resulted in less injury and often had no effect on the degree of adventitious budding of blackberry. As a result, the use of these materials in combination with glyphosate seems to offer no improvement in control of blackberry.

Experiment 2. Glyphosate/SADH Experiment

The results of this experiment confirm the general observations noted in Experiment 1. The use of glyphosate with SADH at 2000 ppm w/v produced significantly higher levels of injury one week after treatment (Table 7). Four weeks after application this combination showed slightly higher levels of injury than glyphosate alone and significantly more injury than the glyphosate/SADH at 5000 ppm w/v. The higher level of injury noted in the glyphosate/SADH at 2000 ppm w/v treatment was characterized by greater amounts of foliar injury and death to the florocane and primocane. On the fourth week after treatment significant glyphosate X SADH interaction was noted to occur. Again, as in Experiment 1, no evidence of injury in any of the control or SADH at 2000 or 5000 ppm w/v treatments were noted to occur.

Significant reduction in dry weight of tops of blackberries treated with glyphosate/SADH 2000 ppm w/v as compared to untreated plants was observed (Table 7). This data confirms the visual injury ratings.

Results in terms of the number of adventitious buds per crown 4 weeks after treatment were similar in some respects, but differences between Experiment 1 and 2 exist. Plants in this experiment had lower levels of budding and differences between the various treatments were not as distinct (Table 8). Treatment with SADH at 2000 ppm resulted in 5.0 adventitious buds per crown; whereas the glyphosate alone and glyphosate/SADH at 5000 ppm treatment each resulted in 3.0 adventitious buds per crown. Differences between these treatments were not significant. Treatment with SADH alone resulted in 1.3 adventitious buds per crown and this was not significantly different from the control treatment which had 0.7 adventitious buds per crown or the glyphosate/SADH treatment which

Table 7. The effect of SADH on the herbicidal activity of glyphosate on blackberries.

Glyphosate kg ae/ha	SADH ppm	Observation Date 5-2	5-9	5-16	5-23	Dry Weight of Tops grams[2]
		Injury Rating[1]				
0.00	0	0.0b[3]	0.0b[3]	0.0c[3]	0.0d[3]	12.3a[3]
	2000	0.0b	0.0b	0.0c	0.0d	12.1ab
	5000	0.0b	0.0b	0.0c	0.0d	9.7ab
1.26	0	0.7b	3.0a	5.7ab	7.0b	5.2ab
	2000	2.0a	3.7a	7.0a	8.3a	4.8b
	5000	0.7b	1.3ab	2.0bc	3.0c	5.0ab

[1] Injury Rating is on a 0 to 10 basis with 0 equal to no injury and 10 equal to total kill.

[2] Harvest date May 23, 1980.

[3] Values not followed by the same letter in the same column are significantly different at the 5% level by the Duncan's multiple range test.

Table 8. The effect of SADH on the herbicidal activity of glyphosate on blackberries in terms of adventitious buds per crown and the dry weight of the regrowth of plant tops.

Glyphosate kg ae/ha	SADH ppm	Observation Date 6-20 Adventitious Buds per Crown	8-11	8-11 Top Regrowth Dry Weight grams[1]
0.00	0	0.7b[2]	0.7	1.5bc[2]
	2000	5.0a	2.3	5.4a
	5000	1.3b	1.3	3.5b
1.26	0	3.0ab	4.3	0.0c
	2000	0.0b	0.0	0.0c
	5000	3.0ab	0.0	0.0c
		NS		

[1] Mean of 3 replications.

[2] Values not followed by the same letter in the same column are significantly different at the 5% level by the Duncan's multiple range test.

had no recoverable buds. The only significant difference at this time was noted between the SADH treatment at 2000 ppm and the glyphosate/SADH at 2000 ppm treatment. The results of this experiment suggest that a glyphosate treatment can increase the number of adventitious buds per crown and further study of this effect may be necessary.

Observations on August 11, 1980 (Table 9) were made to evaluate the status of the adventitious buds and to determine the potential for regrowth. Results in terms of adventitious buds were not significant on this date due to variability in the treatments. Death of all the crowns in the glyphosate/SADH combinations was noted at this time. Despite the presence of apparently viable adventitious buds, no regrowth was observed with any glyphosate treatment by the August 11 rating. Significant regrowth had occured where SADH alone was applied.

Significant crown mortality and glyphosate X SADH interaction were noted by the addition of SADH at 2000 or 5000 ppm w/v to the spray solution (Table 9). While the use of glyphosate with SADH at 5000 ppm w/v produced less injury and similar amounts of adventitious budding as the glyphosate

Table 9. The effect of SADH and glyphosate on the percent mortality of blackberry crowns 105 days after treatment.

Rate kg ae/ha	SADH ppm	Crown Mortality %[1/]
0.00	0	33b
	2000	0b
	5000	0b
1.26	0	33b
	2000	100a
	5000	100a

1/ Values not followed by the same letter are significantly different at the 5% level by the Duncan's multiple range test.

treatment alone, the fact that crown survival was adversely affected is particularly interesting.

Sub-lethal rates of glyphosate have been reported to increase tillering in quackgrass, sorghum and wheat by several researchers (1, 2). Simply stated, tillering is caused by the development of adventitious buds at the base of the plant. These greenhouse experiments would indicate that Rubus spp. are capable of reacting in a similar manner. The data also shows that plants at the physiological equivalent of mid-season stages of development are not killed by a glyphosate application at 1.26 kg ae/ha. Field observations would also confirm this.

Monselise and Luckwill (7) noted that an SADH treatment immediately resulted in a reduction of the translocation of ^{14}C-labeled assimilates to the shoot tips and favored the movement of these assimilates to the root tips. Since glyphosate is known to be phloem mobile and moves in the plant in a similar manner as assimilates (8), SADH most likely influences the movement of glyphosate in the treated plants. Because this effect is immediate, one would not expect any difference between a glyphosate treatment with SADH or some time after a SADH treatment. The modification of glyphosate translocation in the plant should result in changes in injury, adventitious bud development, and crown mortality. Since more glyphosate is moved to the roots and crowns of the plant, lower levels of adventitious bud development and greater crown mortality should occur.

The differences between the 2000 and 5000 ppm w/v treatments can be explained by the extent of glyphosate movement that occurs. A SADH treatment at 2000 ppm w/v has lower amounts of growth modification and most likely doesn't affect glyphosate translocation to the extent that a 5000 ppm w/v

treatment does. Treatment with SADH at 2000 ppm w/v spreads the glyphosate better throughout the plant and increases the amounts of glyphosate moved into the crown and roots of the plant. This results in lower levels of bud development due to higher levels of injury and crown mortality

The use of SADH at 5000 ppm w/v reduces plant growth to a greater extent and this may also result in a greater influence on translocation. Since injury in this treatment is less than the injury in the SADH at 2000 ppm w/v glyphosate or glyphosate alone treatments, it would appear that glyphosate is moved to the roots in greater amounts. It is also possible that high levels of SADH interfere with glyphosate activity. However, crown mortality was similar to the glyphosate/SADH at 2000 ppm w/v treatment.

Treatment with glyphosate alone results in high amounts of the applied glyphosate being moved into the root tips and shoot tips of the developing primocane. As a result of this, small amounts of glyphosate reach the crown and bases of the roots. This results in a low level of crown mortality and associated high levels of adventitious bud development and ultimately poor control.

On the basis of this data it would appear that SADH results in greater amounts of glyphosate movement into the crown and roots which results in higher crown mortality. Differences between the 2000 ppm w/v and the 5000 ppm w/v treatment in terms of adventitious bud development can be explained by the extent of glyphosate movement into the crown and root regions. Since injury and crown death are largely responsible for weed control, the SADH at 2000 ppm w/v glyphosate treatment would be preferable to the SADH at 5000 ppm w/v glyphosate treatment.

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