Glyphosate Translocation and Quackgrass Rhizome Bud Kill[1]

J. S. CLAUS and R. BEHRENS[2]

Abstract. The effect of quackgrass [*Agropyron repens* (L.) Beauv.] rhizome length and foliage height on glyphosate [N-(phosphonomethyl)glycine] translocation was determined on the basis of bud kill and ^{14}C-accumulation in quackgrass rhizomes. Foliar glyphosate treatments of 0.28 kg/ha resulted in significantly reduced quackgrass rhizome bud survival, and rates of 0.56, 0.84, and 1.12 kg/ha gave nearly complete bud kill. Rhizome buds on glyphosate-treated quackgrass plants with 20 to 90 nodes had a higher survival rate than rhizome buds on plants with 10 nodes. Quackgrass bud kill was greatest when glyphosate was applied to taller foliage. When all rhizome buds were not killed, those closest to the mother shoot survived glyphosate treatments. The ^{14}C accumulation following applications of ^{14}C-glyphosate was greatest in nodes near the rhizome tip and least in nodes near the mother shoot. This suggests that greater bud kill near the rhizome tip was due to larger accumulation of glyphosate in this part of the rhizome.

INTRODUCTION

Quackgrass, a perennial, is one of the most troublesome weeds in North America. Rhizomes first develop when the plants are 2 to 3 months old. They are the main means of propagation once quackgrass becomes established (6, 8). A shoot from a single rhizome bud without competition is capable of producing 90 m of rhizomes per year (6). Rhizome buds in addition to top growth must be killed to control quackgrass. Glyphosate is a foliarly applied herbicide, highly toxic to quackgrass (1, 2, 3, 4, 5, 7). It is readily translocated acropetally and basipetally in quackgrass (10). The following experiments were conducted to determine the effect of quackgrass rhizome length and foliage height on rhizome bud kill by glyphosate. Translocation of glyphosate throughout quackgrass rhizome systems was also examined.

MATERIALS and METHODS

Effect of rhizome length on bud kill with glyphosate. Two experiments were conducted to study the effect of rhizome length on the pattern of glyphosate translocation and rhizome bud kill. Five quackgrass rhizome nodes per pot positioned with buds upright at a depth of one cm in potting soil contained in an opaque, 15 cm diameter, plastic pot were kept moist in a greenhouse at 22 to 24 C. Fluorescent lamps provided approximately 15 klux of supplemental radiation for a 15-hr day. Each pot was fertilized with N, P and K at 10-day intervals. Pots were rotated every 10 days to reduce position effects on the greenhouse benches. Plants were thinned to four per pot after 1 month. In the first experiment quackgrass plants were grown for 10, 11 and 12 weeks. They were approximetely 10, 20 and 30 rhizome nodes in length respectively. In a similar second experiment plants were grown for 12, 14 and 16 weeks. These plants had rhizome lengths of approximately 30, 60, and 90 nodes per plant respectively.

Quackgrass plants differing in rhizome node number were sprayed with glyphosate at 0, 0.28, 0.56, 0.84, or 1.12 kg/ha using a volume of 209 L/ha. Each group of plants was sprayed when the rhizome node number approximated the desired number. The plants were replaced on the greenhouse benches for 3 days after spraying. Then the plants in each pot were washed free of soil and two plants with approximately the desired number of rhizome nodes were segmented into individual nodes which were planted, as described above, in consecutive order in flats of potting soil. A map was drawn of the rhizome system of each plant indicating the location of individual nodes. Preliminary studies indicated that viable rhizome buds capable of producing shoots did so within 1 month of planting. Therefore, viable buds were determined from counts made 1 month after planting. Ten replications each consisting of two plants per pot, were used and the experiments were analyzed as completely randomized factorial designs.

Effect of foliage height on rhizome bud kill with glyphosate. Quackgrass plants were grown as described above for 10 weeks until the rhizomes of each plant contained approximately 10 nodes. The shoots of one group of plants were clipped 2.5 cm above the soil 10 days prior to glyphosate treatment, shoots of a second group were clipped 5 days prior to treatment, while those of a third group were not clipped. Shoot heights of the unclipped, early-clipped and late-clipped plants were 45, 25, and 13 cm when treated. Three days after treatment, the rhizome systems of the plants in each pot were washed free of soil, and two plants with rhizome systems of a suitable size were segmented into individual nodes which were planted in flats. Maps of the rhizome systems were prepared as described above. Viable buds were determined from counts made after 1 month. Ten replications, each consisting of two plants per pot, were used and the experiment was analyzed as a completely randomized factorial design.

Accumulation of ^{14}C in rhizomes following foliar treatment of quackgrass with ^{14}C-glyphosate. In two experiments quackgrass plants were grown under the same conditions described above until they had approximately 30 rhizome nodes. The isopropylamine salt of ^{14}C-glyphosate (spec. act. 1.51 mCi/mM) combined with 0.5% by weight of a surfactant (MON-0818–a nonionic polyethoxylated tallow amine) in water solution containing approximately 150,000 dpm of ^{14}C per

[1] Received for publication December 16, 1974. A portion of the M.S. dissertation of the senior author, Univ. of Minnesota, St. Paul.

[2] Former Res. Asst. and Prof., Dep. of Agron. and Plant Genetics, Univ. of Minnesota, St. Paul, MN 55108. Present address of J.S. Claus is Dow Chem. Co., 2800 Mitchell Dr., Walnut Creek, CA 94598.

microliter was applied to the second youngest leaf of each plant in ten 0.1 – μl drops. The plants were placed in the greenhouse for 3 days under the same conditions used in the previous experiments. In one experiment the quackgrass rhizomes of three plants were washed free of soil, pressed flat, and dried in a forced draft oven at 38 C for 3 days. A second experiment with two plants was identical excepting the plants were segmented into shoots and individual rhizomes prior to drying. To determine ^{14}C concentrations, single-node rhizome segments were assayed. A wet combustion method was used to convert the rhizome tissue to CO_2. The node and adjacent 5-mm rhizome segment was placed in a 50 ml beaker containing the digestion solution, 10 ml of concentrated H_2SO_4 layered under 5 ml of 0.05 m $Na_2Cr_2O_7 \cdot 2H_2O$. The 50-ml beaker containing the plant sample, the digestion solution, and an empty scintillation vial were placed in a 475-ml glass jar. The jar was sealed and the digestion solution was swirled to mix the H_2SO_4 and $Na_2Cr_2O_7 \cdot 2H_2O$. Heat produced by the reactants was adequate to bring about rapid, complete digestion of the rhizome segment[3]. After the digestion mixture cooled, 1 ml of methyl cellosolve-ethanolamine (3:2, v/v), a CO_2-trapping solution, was injected with a needle and syringe into the scintillation vial through a rubber septum in the jar lid. After 2 hr for CO_2 absorption, the jar was opened and 17 ml of a scintillation mixture (8.8 g of a 98% PPO-2% POPOP mixture plus 1 L of toluene plus 0.75 L of methyl cellosolve) was added to the scintillation vial. The ^{14}C was then assayed using a scintillation spectrometer. The level of ^{14}C (dpm/per rhizome segment) was superimposed on the rhizome maps to illustrate patterns of ^{14}C accumulation. Statistical differences in ^{14}C-distribution within rhizomes were determined by analysis of variance of ^{14}C accumulation in each of the three basal rhizome node segments (those closest to the treated shoot) and each of the three tip rhizome node segments (those farthest from the treated shoot) of treated rhizomes that had from 6 to 12 nodes. A total of 10 rhizomes was used in the statistical analysis. By including only three basal and three tip node segments in the analysis of variance, the number of segments used were equal for each rhizome position analyzed. Since results did not differ whether or not plants were segmented prior to drying, the data from the two experiments were combined in the statistical analysis.

RESULTS and DISCUSSION

Effect of rhizome length on bud kill with glyphosate. The proportion of quackgrass rhizome buds from untreated plants that produced shoots after rhizome dissection ranged from 60% to 84% (Table 1). There was no apparent relationship between rhizome size and the number of buds that produced shoots. All glyphosate applications significantly reduced rhizome bud viability. Plants with smaller rhizome systems, about 10 nodes per plant, had significantly higher mortality. This is best illustrated in Table 1 at the 0.28 kg/ha rate of glyphosate. Higher glyphosate application rates killed nearly all of the rhizome buds regardless of the rhizome size.

Within rhizomes from untreated plants smaller percentages of the buds close to the mother shoot and near the tip developed shoots (Table 2). Bud survival following glyphosate treatment was greatest for buds close to the mother shoot.

Table 1. Effect of foliar applications of glyphosate on percent of shoots developing from quackgrass rhizomes that differ in length (10 to 90 nodes). Nodes were dissected 3 days after treatment and shoots counted 30 days after dissection.

Glyphosate rate (kg/ha)	Approximate number of rhizome nodes per plant[a]					
	Experiment I			Experiment II		
	10 (%)	20 (%)	30 (%)	30 (%)	60 (%)	90 (%)
0	64	70	79	60	81	84
0.28	7	31	34	38	20	25
0.56	2	7	4	4	2	6
0.84	1	1	0	0	0	2
1.12	0	3	0	0	0	1

[a]Bayes LSD (0.05) for individual means: Expt. I = 10 and Expt. II = 7.

Table 2. Effect of foliar applications of glyphosate on percent[a] of buds developing shoots by location within quackgrass rhizomes 15 nodes in length. Nodes were dissected 3 days after treatment and shoots were counted 30 days after dissection.

Rhizome segment[b]	Glyphosate (kg/ha)		
	0 (%)	0.28 (%)	0.56 (%)
1	75	75	0
2	92	83	17
3	100	91	8
4	100	64	8
5	100	91	17
6	100	55	8
7	100	30	8
8	100	55	0
9	100	50	0
10	100	33	0
11	100	25	0
12	100	8	0
13	83	8	0
14	75	0	0
15	25	0	0

[a]Means of 12 rhizomes.
[b]Segment number 1 is closest to mother shoot. Branch rhizomes discarded.

[3] The effectiveness of the wet combustion method was compared to that of a modified Schöniger oxygen combustion method (9) and was found to be equally effective for recovery of ^{14}C from rhizomes of ^{14}C-glyphosate treated quackgrass. However, in studies with other ^{14}C-labeled compounds, some were found that were not completely oxidized to $^{14}CO_2$ by the wet combustion method. Therefore, wet combustion should not be used without first determining its effectiveness in digesting the specific tissues and ^{14}C-labeled compounds that are being assayed.

This was apparent at both the 0.28 and 0.56 kg/ha rates of glyphosate. Possible explanations are that buds near the mother shoot may be more tolerant of glyphosate or that glyphosate accumulation may be less in the buds close to the treated shoot.

Effect of foliage height on rhizome bud kill with glyphosate. The percentage of shoots produced by rhizome buds from untreated plants with varied foliage height was significantly different, ranging from 40% to 80% (Table 3). Intermediate foliage height (25 cm) resulted in the greatest percentage of shoots from rhizome buds.

Table 3. Effect of foliar applications of glyphosate on percentage of shoots developing from rhizome buds of quackgrass plants that differ in foliage height (13, 25 and 45 cm). Nodes were dissected 3 days after treatment and shoots counted 30 days after dissection.

Glyphosate rate (kg/ha)	Foliage height when sprayed (cm)[a] 45 (%)	25 (%)	13 (%)
0	52	80	40
0.28	0	8	38
0.56	3	1	22
0.84	0	3	9
1.12	0	0	11

[a]Bayes LSD (0.05) for individual means = 11.

Glyphosate treatments applied to taller quackgrass foliage, 25 to 45 cm height, caused the greatest bud mortality. There was no significant difference in bud kill if the treated foliage was 25 or 45 cm tall. A 0.84-kg/ha-rate of glyphosate was required on 13-cm foliage to give a level of bud mortality similar to that obtained with 0.28 kg/ha of glyphosate applied to 25 or 45 cm foliage. Efforts are now under way to determine whether the lower bud mortality in plants with shorter top growth is due to reduced spray retention per unit plant weight or to reduced glyphosate translocation.

Accumulation of ^{14}C in rhizomes following foliar treatment of quackgrass with ^{14}C-glyphosate. All rhizome node segments contained measurable amounts of ^{14}C 3 days after the plants were treated with ^{14}C-glyphosate. Figure 1 is a diagram of the rhizome system of a single plant illustrating ^{14}C distribution in the nodes. The distribution pattern was similar in all of the plants treated with ^{14}C-glyphosate. The ^{14}C-activity ranged from slightly over background to more than 4,000 dpm. There was a definite pattern of lowest ^{14}C accumulation in node segments nearest the mother shoot and greatest accumulation near the rhizome tip (Figure 2). If these findings are considered along with bud viability pattern illustrated in Table 2, it seems probable that the greater survival of buds closest to the mother shoot was due to a reduced glyphosate accumulation in that area. Further studies to isolate, identify and quantitate ^{14}C-glyphosate in the rhizome buds would be required to fully substantiate this assumption.

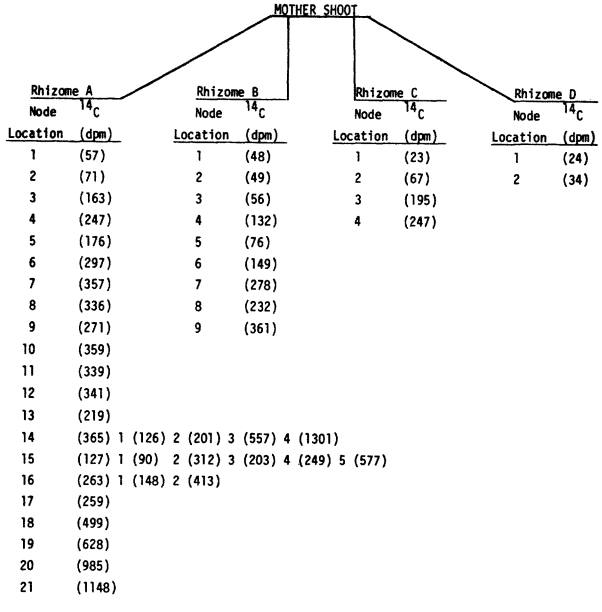

Figure 1. Typical distribution pattern of ^{14}C (dpm) in a quackgrass rhizome system 3 days after a foliar application of ^{14}C-glyphosate. Secondary rhizomes have developed from Bud no. 14–16 in Rhizome A.

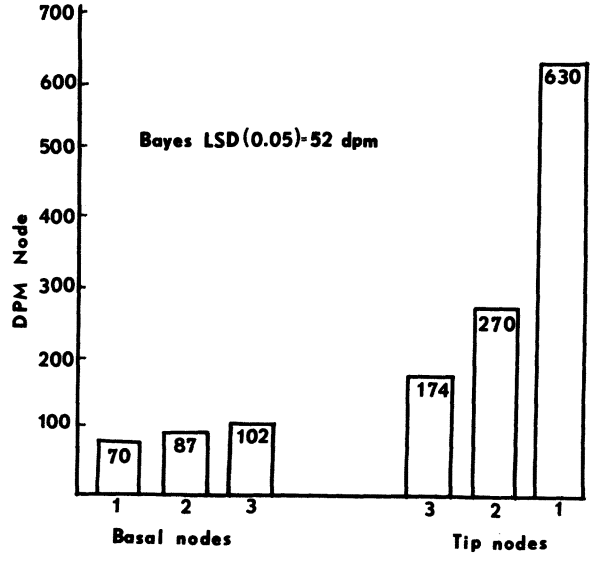

Figure 2. Distribution of ^{14}C (dpm) in the basal and tip rhizome nodes 3 days after foliar application of ^{14}C-glyphosate (means of 10 rhizomes).

ACKNOWLEDGMENT

The authors are grateful to the Monsanto Company for furnishing the radioactive glyphosate, commercial glyphosate, and MON-0818 used in this study.

LITERATURE CITED

1. Arnold, W.E. and B. O'Neal. 1972. Quackgrass and Canada thistle control with MON-2139 (glyphosate). Res. Rept. N. Cent. Weed Contr. Conf. 29:26–27.
2. Baird, D.D., S.C. Phatak, R.P. Upchurch, and G.F. Begeman. 1973. Glyphosate activity on quackgrass as influenced by mowing and rhizome density. Proc. Northeast. Weed Contr. Conf. 27:16–20.
3. Baird, D.D., R.P. Upchurch, W.B. Homesley, and J.E. Franz. 1971. Introduction of a new broad spectrum postemergence herbicide class with utility for herbacious perennial weed control. Proc. N. Cent. Weed Contr. Conf. 26:64–68.
4. Behrens, R. and M. Elakkad. 1972. Quackgrass control with glyphosate. Abstr., Proc. N. Cent. Weed Contr. Conf. 27:54.
5. Brockman, F.E., W.B. Duke, and J.F. Hunt. 1973. Agronomic factors influencing the effectiveness of glyphosate for quackgrass control. Proc. Northeast. Weed Contr. Conf. 27:21–29.
6. Hay, J.R. 1962. Biology of quackgrass and some thoughts on its control. Down Earth. 18:14–16.
7. Jaworski, E.G. 1973. Mode of action of n-phosphonomethylglycine: inhibition of aromatic amino acid biosynthesis. J. Agr. Food Chem. 20:1195–1212.
8. Kephart, L.W. 1931. Quackgrass. U.S.D.A. Farmers' Bulletin No. 1307. pp. 1–43.
9. Oliverio, V.T., C. Denham, and J.D. Davidson. 1962. Oxygen flask combustion in determination of C^{14} and H^{3} in biological materials. Anal. Biochem. 4:188–189.
10. Sprankle, Paul, Donald Penner, and W.F. Meggitt. 1973. The movement of glyphosate and bentazon in corn, soybean and several weed species. Abstr. Weed Sci. Soc. Amer. pp. 75.

Journal of the Weed Science Society of America

NEWS NOTES

The Terminology Committee has approved for use in publications of the Weed Science Society of America the common name oxyfluorfen for the herbicide 2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl)benzene which has been formulated by Rohm & Haas Company under code number RH-2915.