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Effects of Time of Application of Glyphosate in the Control of Johnsongrass

Marlin Moody
Western Kentucky University

Moody,

Marlin D.

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EFFECTS OF TIME OF APPLICATION OF GLYPHOSATE IN THE CONTROL OF JOHNSONGRASS

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EFFECTS OF TIME OF APPLICATION OF

GLYPHOSATE IN THE CONTROL OF JOHNSONGRASS

Recommended Dec 1, 1976
(Date)

James P. Worthington
Director of Thesis

F. D. Brown

W. C. Norman

Approved 12-6-76
(Date)

Elmer Gray
Dean of the Graduate College

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Directed by: J. P. Worthington, W. C. Normand, and L. D. Brown

Department of Agriculture Western Kentucky University

Investigations were conducted to determine the effects of the herbicide glyphosate and its time of application on the control of johnsongrass.

Johnsongrass plots were divided into areas designated undisturbed, spring plowed, and clipped. These areas were compared to determine differences in control of johnsongrass when using glyphosate with different management procedures. Glyphosate was applied at weekly intervals and treatment effects were statistically analyzed. There were three replications of each treatment.

It appears from the results that:

1. Glyphosate kills approximately 100% of the johnsongrass topgrowth regardless of the application date.

2. Height of the johnsongrass plant at the time of glyphosate application had little influence on the ability of the herbicide to kill the rhizomes.

3. Rhizomes from plants that had received an application of glyphosate produced a significantly lower number of plants than did rhizomes from untreated plants.

4. The management procedures (spring plowed, clipped, undisturbed) had no effect on the ability of glyphosate to kill the rhizomes.

5. As glyphosate applications were applied later in the growing season, johnsongrass control increased.

6. In 1975 glyphosate utilized with spring plowing produced better total johnsongrass control than either clipped or undisturbed plots which had utilized glyphosate. In 1976 there was no significant difference in the control given by the three methods.

INTRODUCTION

The need for johnsongrass (Sorghum halapense L.) control has been definitely established in Kentucky and throughout the southern regions of the United States. Johnsongrass is classified among the world's ten worst weeds (24) and costs American farmers millions of dollars annually (57). Soybean yield losses due to competition with johnsongrass have been estimated as high as 50 percent (46).

Johnsongrass has long been utilized as a forage and in some areas is still used quite extensively. This situation is due primarily to the difficulty of control rather than the preference of the farmer. Although it is thought that johnsongrass was introduced primarily to be used as a forage there is evidence that cites johnsongrass seed being introduced into the country due to its use as a packing material by merchants (39). Names such as meanie grass and bankruptcy grass indicate that johnsongrass has been a problem to farmers in the past (39).

Kentucky lies between southern regions of the United States where farmers sometimes utilize johnsongrass as a forage and northern regions where many johnsongrass rhizomes may be killed by freezing temperatures. Therefore johnsongrass may be a greater weed problem in Kentucky than in some other states.

Various cultural and mechanical control procedures have been attempted to reduce the problem of johnsongrass, and most of these methods have proved to be highly unsuccessful. It is generally conceded that some type of chemical control method should be utilized with these cultural methods to obtain more satisfactory johnsongrass control.

The following study was conducted to obtain more information concerning the proper use of the herbicide glyphosate [(N-phosphonomethyl) glycine] for control of the perennial weed johnsongrass.

REVIEW OF LITERATURE

History of Johnsongrass

Johnsongrass [Sorghum halapense (L.) Pers.] was first introduced into the United States around 1830 and is native to the Mediterranean area (7,39). In a search conducted by McWhorter (39), no evidence was found that documented the presence of agricultural workers from the United States in the Mediterranean region before 1840. Documentation of the initial introduction was difficult due to the use of over 40 different common names supposedly for this same weed. Eight different Latin names for johnsongrass were in use during the nineteenth century. Around 1840 Colonel William Johnson carried this grass to the black clay soils of Alabama (7) and this is thought to be the origin of the name "johnsongrass." A letter written in 1874 from Herbert Post of Selma, Alabama to George Vasey, a USDA employee in Washington, D.C. is given credit as being responsible for the term "johnsongrass" becoming the only commonly accepted name for the new grass. Johnsongrass had spread to almost every state by the late 1800's and many reports were already being made as to the severity of this grass as a weed. The tenacity of the spread of this weed led to the first federal appropriation specifically for weed control in 1900, and also to the first report compiled for johnsongrass control, prepared by C.R. Ball in 1902 (39).

Johnsongrass spread rapidly across the country by various means. To a great degree it was carried by farmers to new areas because it was such a vigorous forage plant (39). Other methods of distribution were not so obvious. Thousands of square miles became infested due to the seed being carried by flood waters, railroad cars, and in contaminated grain or baled hay. In the late 1800's Texas farmers became so disgruntled with the pesky weed that laws were passed governing the use of johnsongrass and penalties were imposed on farmers knowingly selling or giving away farm produce contaminated with either seed or rhizomes. Railroad owners were even fined for allowing johnsongrass to go to seed upon their rights of way (39).

Growth Habit of Johnsongrass

Johnsongrass is difficult to control because it reproduces vegetatively by rhizomes and also by seed (26,29,38,40,41). It has been found that johnsongrass plants produce rhizomes within four weeks after emergence (1,34,52) and up to 33.6 metric tons of rhizomes can be produced per hectare (31,40,53). Although some rhizome growth does occur early, most rhizome production occurs after flowering (29,34,53). Shoot growth predominates early in the growing season but after blooming rhizome growth increases rapidly and shoot growth decreases considerably (34,53). Flowering and rhizome production occur in greatest quantity late in the growing season and under conditions of warm temperature (35 C) and a photoperiod of approximately 12 hours (12,33). It was found that both flowering and rhizome production of johnsongrass can be delayed by a brief interruption of the night period. The use of flares has been suggested to provide the light if this method was utilized. If environmental alterations could block seed and rhizome production of johnsongrass the plant would cease to survive due to lack of reproductive potential (12). McWhorter and Jordan (48) found that root and rhizome growth and development increased with increasing light intensity. With the production of up to 5000 nodes (1,34) per individual plant in a growing season there is a tremendous potential for annual spread of the weed.

Various cultural methods such as flooding (42), tillage (9,46), and clipping (27) have been used to some extent in an attempt to control johnsongrass produced by spreading rhizomes. The difficulty in obtaining control by these methods is thought by some researchers to be due to large quantities of stored carbohydrates present in the rhizomes (26,35, 45). Smith and associates (59) stated that carbohydrate levels in storage organs of plants indicate the periods of storage versus usage and are useful in evaluating the potential of plants for regrowth and production after utilizing control procedures.

Johnsongrass exhibits apical dominance similar to that found in many other perennial weeds (5,30). Apical dominance is the suppression of lateral bud development due to auxin production in the apical meristem (32). Clipping results in the re-establishment of shoots arising from underground storage organs. In johnsongrass the regrowth is due to development of crown buds and lateral buds present on rhizomes (5). Hull (30) could find no evidence directly linking bud dormancy with erratic germination of rhizome buds. Studies by Taylorson and McWhorter (66) indicate that seed dormancy is genetically controlled by maternal tissues. McWhorter (43) found that more plants come from shorter rhizome sections at depths to 7.6 cm but more plants come from longer rhizome sections at depths greater than 7.6 cm. Percentage germination of rhizome buds was greater for shorter rhizome sections.

Temperature has been shown to have a definite influence on the growth of johnsongrass plants (12,25,30,48). Bud sprouting was absent at 10 C, slow at 20 C, and maximum at 28 C. Seed germination required about a 10 C higher temperature for sprouting than did rhizomes (26,30). Rhizome production and total fresh weight were both higher at 33 C than at either 20 or 25 C (12). Temperatures of 50 to 60 C killed rhizome buds in 1 to 3 days. Rhizomes could not survive temperatures of -3 to -5 C more than a few hours (25,30,43). McWhorter and Jordan (43) found that both maximum leaf growth and development and maximum root and rhizome development occured at 32 C.

It has been found that different johnsongrass ecotypes react differently to certain environmental conditions (11,37,40,67). Several investigators have found that johnsongrass hybridizes with other Sorghum species (14,19). Different germination characteristics were noted between various ecotypes (66).

Hamilton (20) and Hamilton and Tucker (21) demonstrated that different ecotypes varied in their response to foliarly-applied herbicides. This may explain to some extent the variability of johnsongrass control throughout the United States.

Herbicides Used in the Control of Johnsongrass

Soil incorporated herbicides

McWhorter (44) found that incorporation of trifluralin [α,α,α-trifluoro-2,6-dinitro-N,N-dipropyl-p-toluidine] or nitrilin [4-(methylsulfonyl)-2,6-dinitro-N,N-dipropylaniline] at rates of 1.12 to 2.24 kg/ha for two successive years effectively controlled johnsongrass from rhizomes and greatly increased soybean yields. Standifer and Thomas (64) found that trifluralin had only a slight inhibitory effect on rhizomatous johnsongrass. In a study by Burt (10) trifluralin was more toxic to johnsongrass rhizomes than nitrilin. EPTC [S-ethyl dipropylthiocarbamate] gave better control than vernolate [S-propyl dipropylthiocarbamate], butylate [S-ethyl diisobutylthiocarbamate], and pebulate [S-propyl butylethylthiocarbamate]. Roeth (58) found that EPTC and butylate gave up to 93 percent control of rhizomatous johnsongrass. When using soil incorporated herbicides, such as EPTC or butylate, for johnsongrass control rather than foliar applied herbicides, corn can be planted at the optimum date and one herbicide application is eliminated. The main disadvantage is that johnsongrass control is often not adequate until the second year.

There are many variables which can affect the performance of soil incorporated herbicides. Some of these are: soil texture, organic matter content, tillage operations, date of application, and johnsongrass density (58).

Foliar applied herbicides

In a study by Hamilton (20) it was found that monosodium methanearsonate (MSMA) and disodium methanearsonate (DSMA) were more effective than dalapon [2,2-dichloropropionic acid] in controlling established johnsongrass. McWhorter (37) found that dalapon controlled regrowth of johnsongrass better than DSMA. There was no indication of translocation of DSMA to rhizomes. DSMA gave better control of johnsongrass in dry weather than did dalapon. Split applications of DSMA and dalapon satisfactorily controlled both seedling and rhizome johnsongrass on drainage ditchbanks in sugarcane (50). Sodium chlorate gave adequate rhizome control but rapid reinfestation by seedling johnsongrass occurred. Millhollon (51) found that MSMA controlled johnsongrass better than dalapon. The results cited indicate that no specific foliar applied herbicide for the control of johnsongrass is universally accepted as being the best control method. It has been found that tillage (9,45) and mowing (9) of johnsongrass in late summer helps to increase the effectiveness of follow-up herbicide treatments. In this study the follow-up herbicides were sodium trichloroacetate and sodium chlorate. Hull (29) concluded that the effectiveness of phloem-mobile herbicides may be enhanced by partial depletion of the carbohydrates of rhizomes prior to herbicide application.

Hauser and Thompson (22) found that dalapon translocation was not critically affected by low soil moisture, reduced sunlight, or the use of additional wetting agents. Hull (29) found that clipping did not increase herbicide translocation. Funderburk and Davis (18) found that root treated plants had a more reduced growth than did shoot treated plants. The explanation given was that the roots have no cutin barrier to prevent entry of the herbicide whereas the shoots do have a cutin barrier. They also thought that the translocation that occurs when herbicide enters through the roots would be through the xylem and not the phloem as with shoot entry. Dalapon was less toxic to johnsongrass when applied to younger shoots (18). Parochetti (55) obtained best johnsongrass control with dalapon and trifluralin when compared with several other herbicides. Cultivation five weeks after soybean planting greatly increased the herbicide effectiveness of both dalapon and trifluralin on the johnsongrass. McWhorter (36) found that the herbicidal activity of dalapon can be greatly increased by including a surfactant in the spray solution.

In the 1975 weed control recommendations, dalapon was the only herbicide recommended by the University of Kentucky College of Agriculture (23) for johnsongrass control on cropland.

Glyphosate

Glyphosate is a nonselective postemergence herbicide which was introduced in 1971 and since that time has been found to exhibit herbicidal activity on a diverse group of herbaceous perennial weeds (3). Zandstra et al. (69) found that glyphosate showed great potential for use in the control of purple nutsedge (*Cyperus rotundus* L.), the worst weed in the world (24). Williams and Foley (68) found that glyphosate significantly reduced the carbohydrate content of bracken [*Pteridium aquilinum* (L.) Kuhn] rhizomes and suggested significant herbicide translocation. Glyphosate has given good control in quackgrass (*Agropyron repens*) (6,56, 60), yellow nutsedge (*Cyperus esculentus* L.) (65), hemp dogbane (*Apocynum cannabinum* L.) (4), leafy spurge (*Euphorbia esula* L.), canada thistle [*Cirsium arvense* (L.) Scop.], and field bindweed (*Convolvus arvensis* L.) (49).

Dowland and Tweedy (17) found that glyphosate gave excellent control of johnsongrass and control was better when herbicide applications were made to more mature plants (31 cm). Roeth (57) found that glyphosate was more effective when applied on July 5 rather than June 13 and a 1.12 kg/ha rate was as effective as 2.24 kg/ha. Glyphosate applied at a 2.24 kg/ha rate on July 5 lowered rhizome yield 77 percent.

Hull (29,30) and Oyer et al. (52) stated that the use of a phloem-mobile herbicide is likely to be the most rational approach to rhizomatous weed control. Glyphosate is definitely thought to be a phloem-mobile herbicide (56,62). Sprankle et al. (62) using ^{14}C-glyphosate on quackgrass found that absorption occurred most rapidly within four hours after treatment and continued to increase but not significantly until 48 hours after treatment. Translocation also occurred rapidly and the amount of ^{14}C increased significantly over each time period (4, 8, 24 and 48 hrs) with 66.7 percent of the labeled ^{14}C being present in untreated areas of the plant at 48 hours after application. The rate of translocation would have a great effect on the amount of time that should elapse before tillage operations should be performed after herbicide application. It was also noted that apparently translocation into rhizomes occurred at a more rapid rate in 1- to 2-leaf stage plants than in 3- to 4-leaf stage plants. Brockman and coworkers (8) found that applications of glyphosate on quackgrass were more effective at the 4- to 6-leaf stage than at the 2- to 3-leaf stage. Plowing 1 to 8 days after application increased control and gave season-long control. Cultivation performed 4 to 21 days after application of glyphosate to johnsongrass had no effect on early herbicide performance. However, to obtain optimum results when evaluated at 45 and 99 days a 14 to 21 day interval between spraying and cultivation was required (2). Application of 0.56 kg/ha gave approximately 80 percent control of johnsongrass regardless of growth stage (52). Glyphosate at 1.68 and 3.36 kg/ha gave excellent control of rhizome johnsongrass when applied to plants before seedbed preparation and was superior to dalapon (16).

Sprankle and coworkers (61) found that very minute quantities of ^{14}C-glyphosate were absorbed by corn and soybeans after soil application of glyphosate. Their investigations also indicated that the low degree of absorption was due to adsorption to soil particles. Normal application rates of glyphosate are 1.12 kg/ha to 2.24 kg/ha. Dry weights of plants grown on clay loam soils were not reduced when 56.0 kg/ha of glyphosate were applied. This study also indicated that wheat (<u>Triticum aestivum</u> L.) could readily absorb glyphosate from a nutrient solution; thus, it was concluded that absence of glyphosate absorption from the soil was not due to failure of plants to absorb glyphosate by way of the roots. Absorption of glyphosate by wheat plants was much greater when high levels of phosphate were present in the soil indicating a competition between glyphosate and phosphate for binding sites (63). Glyphosate mobility was very limited and was affected by soil type, pH, and phosphate level. Up to 45 percent of labeled ^{14}C-glyphosate was degraded to $^{14}CO_2$ in 28 days in sandy clay loam soil. The possibility of microbial degradation was discounted when it was found that autoclaving the soil did not prevent glyphosate inactivation. The conclusion was that the pattern of degradation consisted of co-metabolism by the microbial populations following initial inactivation of glyphosate bonding in the soil. Clay loam soils adsorbed more glyphosate than did sandy loam soils. Glyphosate mobility in the soil decreased at low pH.

Parochetti et al. (55) found that glyphosate can give excellent control of rhizome johnsongrass. It was found to be much more effective than dalapon. There were no significant differences in foliage control between rates of 0.56 to 2.24 kg/ha of glyphosate; however, lower rates failed to give response as quickly as higher rates. It was found that plowing 4 to 21 days after applications of glyphosate had no significant effect on control of rhizomes. Glyphosate was more effective on johnsongrass control when applied in the boot to full seed head stage than when applied at a 45 to 60 cm height. Plowing within 0.5 hour following herbicide application reduced control. The conclusion of Parochetti and coworkers was that optimum time to treat johnsongrass with glyphosate would be in mid-summer when plants are in boot to full head stage.

Campbell et al. stated that starch grain production was reduced with increased dosage of glyphosate and suggested that glyphosate may interfere with the Hill reaction. Their electron microscopy studies also indicated that glyphosate enhances the leaf senescence process. During leaf senescence chlorophyll levels decrease and most of the protein in the leaf is located in the chloroplasts. Leaves cannot continue to survive after much protein loss due to chloroplast damage. Plastoglobulin accumulation was noted in the disrupting chloroplasts. Although not uncommon in normal leaves, the plastoglobulin content was increased in the senescent leaves. It is thought that the plastoglobuli represent the accumulation of lipid components released on the breakdown of the thylakoids and other insoluble lipid compounds.

MATERIALS AND METHODS

Description of the Experimental Area

An area thoroughly infested with johnsongrass was selected on the Western Kentucky University Farm in Bowling Green Kentucky. The soil type was Pembroke silty clay loam. The experiment began in 1975 and was repeated in 1976 on a similar location at the university farm.

Experimental Design

A split-plot design with three replications was used. The main plots consisted of the management procedures (spring plowed, clipped, undisturbed) and the subplots were the dates of herbicide application. Main plots each contained 8 subplots. The subplots were 2.44 m wide by 29.25 m long in 1975 and 2.44 m wide by 10.66 m long in 1976. The method of statistical analysis used to report the results of this thesis are essentially those outlined for analysis of variance in Cochran and Cox (15).

Land Preparation and Application of Treatments

Spring plowed plots were mold-board plowed on April 25 in 1975 and on April 15 in 1976. In both years a light disking of these areas was performed about one week after plowing to level the plots. The clipped areas were mowed with a rotary cutter on May 30, 1975 and June 7, 1976. The undisturbed areas had no special attention and were allowed to grow naturally. An application of 4.48 kg/ha of alachlor [2-chloro-2',6'-diethyl-_N_-(methoxymethyl)acetanilide] and 1.12 kg/ha of atrazine [2-

chloro-4-(ethylamino)-6-(isopropylamino)-s-triazine] was made during the first week of June each year. These herbicides were used to provide control for some annual grasses and broadleaves.

Weekly applications of glyphosate [N-(phosphonomethyl)glycine] to the subplots began on May 30, 1975 and continued through July 17, 1975. In 1976 the weekly applications were begun one week later on June 7 through July 26. The delay for beginning the applications in 1976 was due to the growth stage not being as advanced in 1976. Treatments were initiated when the plants in the undisturbed plots reached approximately 45 cm. This is the recommended height stated by the experimental label of glyphosate. The canopy height of the johnsongrass was recorded on each spray date. The rate of glyphosate used was 3 kg/ha applied in 187.00 liter/ha of water. All herbicides used in this study were applied with a CO_2 hand-held sprayer.

Two weeks after spraying, three plants from each subplot were dug and all rhizomes attached to each plant were collected. Number of nodes, evidence of branching, number of plants attached to the rhizome, evidence of rhizome rotting, and depth of rhizome were recorded. The rhizomes were placed in greenhouse flats which contained potting soil and were watered as needed. After a five week waiting period to allow germination of rhizome buds, the rhizomes were dug and the number of plants produced was recorded.

On August 25, 1975 a visual rating for total johnsongrass control was made on each subplot. In 1976 this rating was made on September 6.

RESULTS AND DISCUSSION

It was noted that in practically every observation made two weeks after glyphosate application approximately 100 percent of the topgrowth of the johnsongrass was killed. Few exceptions to these observations were noted; but one such instance was observed on July 10, 1975 when the results of the June 26 application were observed. The rainfall data for 1975 (Table 1) indicates that the johnsongrass could well have been under drought stress at the time the application of glyphosate was made. It was noted on June 26 that leaf curling of the johnsongrass was present and the dark green color of vigorously growing johnsongrass was not present. More importantly, even though topgrowth was not killed as quickly (topgrowth did proceed to be killed as in other treatments), no plants were produced from the rhizomes taken from the plants of the June 26 application date.

There had been some indication by early workers using glyphosate that plant height of johnsongrass at the time of herbicide application directly influenced the ability of glyphosate to be translocated throughout the rhizomes and therefore influenced the rhizome killing potential of glyphosate. Tables 2 and 3 show the height of the johnsongrass canopy at the time of glyphosate application, and tables 4 and 5 show that the height of the johnsongrass at the time of herbicide application had little influence on the ability of glyphosate to kill the rhizomes. Table 4 shows that in 1975 more plants were produced in the plots receiving the June 6 application than any other plots receiving herbicide. Plants

Table 1. Rainfall at the Western Kentucky University farm for 1975 and 1976.

Date	1975	1976
	(cm)	(cm)
April 1-15	3.10	0.46
April 16-30	8.21	1.50
May 1-15	2.49	5.92
May 16-31	3.51	9.12
June 1-15	4.47	5.16
June 16-30	0.97	7.03
July 1-15	0.03	5.69
July 16-31	0.03	9.85
August 1-15	6.45	1.35
August 15-31	4.65	2.77

Table 2. Average height of johnsongrass canopy at time of glyphosate application in 1975.

Date of application	Undisturbed	Clipped	Spring plowed
	(cm)	(cm)	(cm)
May 30	63.5	--	--
June 6	96.5	25.4	43.2
June 13	114.3	27.9	55.9
June 18	121.9	30.5	63.5
June 26	137.2	40.6	101.6
July 3	165.1	50.8	165.1
July 10	165.1	60.1	177.8
July 17	170.2*	76.2	182.9
July 24	--	83.8*	188.0*

* Check

Table 3. Average height of johnsongrass canopy at time of glyphosate application in 1976.

Date of application	Undisturbed	Clipped	Spring plowed
	(cm)	(cm)	(cm)
June 7	50.8	--	28.0
June 14	68.6	28.0	33.0
June 21	71.1	33.0	43.2
June 28	81.3	40.6	68.6
July 5	91.4	61.0	96.6
July 12	114.3	91.4	122.0
July 19	155.0	106.7	182.3
July 26	182.9*	116.8	203.3*
August 2	--	127.0*	--

* Check

Table 4. Effect of time of application of glyphosate on regrowth of johnsongrass from rhizomes in 1975.

	Undisturbed		Clipped		Spring plowed	
Date of application	No. of nodes[a]	No. of plants produced[b]	No. of nodes[a]	No. of plants produced[b]	No. of nodes[a]	No. of plants produced[b]
May 30	159	0	--	--	--	--
June 6	98	0	160	12	118	2
June 13	132	0	68	0	65	0
June 18	107	0	105	0	108	0
June 26	116	0	98	0	94	0
July 3	82	0	104	0	156	0
July 10	146	0	85	0	151	0
July 17	152	25*	129	0	220	1
July 24	--	--	166	31*	226	37*

* Check

[a]Sum of nodes on rhizomes harvested from three plants in each replication.

[b]Sum of plants produced five weeks after planting harvested rhizomes.

Table 5. Effect of time of application of glyphosate on regrowth of johnsongrass from rhizomes in 1976.

	Undisturbed		Clipped		Spring plowed	
Date of application	No. of nodes[a]	No. of plants produced[b]	No. of nodes[a]	No. of plants produced[b]	No. of nodes[a]	No. of plants produced[b]
June 7	173	4	--	--	77	0
June 14	70	0	145	0	91	0
June 21	89	0	100	0	149	0
June 28	109	0	125	0	80	0
July 5	121	0	123	0	102	0
July 12	126	0	106	0	131	0
July 19	77	0	111	0	90	0
July 26	124	15*	169	0	129	27*
August 2	--	--	140	10*	--	--

* Check

[a]Sum of nodes on rhizomes harvested from three plants in each replication.

[b]Sum of plants produced five weeks after planting harvested rhizomes.

in this plot area were the shortest plants treated in the entire year. The lower degree of control could be attributed to plants not being tall enough for optimum translocation, however, it is also possible that the reason for decreased control was due to inadequate leaf surface area being present to receive herbicide to be translocated into the plant. The June 6 application had been preceded one week by a clipping of the johnsongrass which removed the major portion of leaf tissue present. It was noted on the June 6, 1975 application that glyphosate was essentially being applied to stem material with very few leaves present. Moisture stress on the johnsongrass at this time compounded the effect of leaf removal. Slow growth was evident in the clipped area in both 1975 and 1976 (Tables 2 and 3). Table 2 shows that on the June 6 application the plant height was 25.4 cm and regrowth from rhizomes did occur. However, one week later plant height had increased only 2.50 cm and no plants were produced from the rhizomes. This indicates that better control was realized through apparent increased leaf surface area and not through increased plant height. Another interesting point indicated by Tables 2 and 3 is that in both years the johnsongrass in the undisturbed areas was taller at early application dates than the johnsongrass in the spring plowed plots. This can be attributed to the interruption of the growth of the spring plowed johnsongrass by plowing. The undisturbed johnsongrass continued its normal growth. Later in the growing season the johnsongrass in the spring plowed plots was taller than that in the undisturbed plots. Parochetti (54) stated that spring plowing may reduce stand density of the johnsongrass. Spring plowing may have also been responsible for the presence of fewer annual grasses and broadleaves. Reduced competition between johnsongrass plants should result in more vigorous growth of the plants present and provide more nutrients and moisture to each individual plant.

In both 1975 and 1976 rhizomes from plants that had received an application of glyphosate produced a highly significant lower amount of plants than did rhizomes from untreated plants (Appendix A, Tables 1 and 2). These results indicate that glyphosate can definitely be a factor in the reduction of plants arising from rhizomes. The information in Table 6 also points out that any regrowth present at a later date probably results either from seeds or from rhizomes that had not emerged at the time of glyphosate application.

In 1975 the check plots of the undisturbed, clipped, and spring plowed produced 16.4%, 18.7%, and 16.4% respectively of the number of possible plants that could have developed from the number of nodes present (Table 4). This is a total of 17.2% of possible plants produced in the check plots. The rhizomes from plants that did receive an application of glyphosate produced 0% plants in the undisturbed areas, 1.7% plants in the clipped areas, and 0.32% of possible plants produced in the spring plowed areas. Glyphosate only allowed a total of 15 plants to be produced from the 2501 nodes present on the rhizomes that had been dug. This gives a value of only 0.60% of possible plants produced from rhizomes attached to plants receiving an application of glyphosate in 1975. Table 5 shows that the results from 1976 were strikingly similar. Check plots of undisturbed, clipped, and spring plowed produced 12.1%, 7.1%, and 20.9% respectively of the number of possible plants that could have developed from the number of nodes present. This is a total of 12.3% of possible plants produced in the check plots. Only 0.45% plants were produced from rhizomes dug in the undisturbed areas which had received glyphosate

Table 6. Average regrowth from johnsongrass rhizomes as affected by time of application of glyphosate.[a] (Number of plants produced/number of rhizome nodes).

Time of application[b]	Regrowth	
	1975	1976
	(%)	(%)
1st week	2.02 a	0.41 a
2nd week	0.00 a	0.00 a
3rd week	0.00 a	0.00 a
4th week	0.00 a	0.00 a
5th week	0.00 a	0.00 a
6th week	0.00 a	0.00 a
7th week	0.00 a	0.00 a
Check	17.24 b	15.19 b

[a]Means within columns followed by the same letter are not significantly different at the 0.01 level, as determined by Duncan's multiple range test.

[b]Date of application varies depending upon management procedure and year.

and 0% plants were produced from both the clipped and spring plowed areas. In 1976 even fewer plants were produced in treated areas than in 1975. Only four plants were produced from a total of 2401 nodes. The percent of possible plants produced is only 0.17%. In the two year study rhizomes dug from treated plots had a total of 4902 nodes. A total of only 19 plants were produced from these nodes which gives a grand total of 0.39% of the possible plants being produced. Table 4 shows that of the 15 plants produced all but one came from plots sprayed on the first application date. Including both years, only a total of one plant was produced from all plots after the first week of application, and this plant came on the last application date in the spring plowed area in 1976 (Table 4). A possible explanation is that at some point in the growing season it may be that control of rhizomes by glyphosate decreases due to plant maturity limiting the action of glyphosate.

In both 1975 and 1976 the analysis of variance (Appendix A, Tables 1 and 2) shows that there is no significant difference between the three management procedures with regard to ability for glyphosate to kill rhizomes. This information points out that the rhizomes dug from glyphosate treated plants were killed equally as well regardless of the management procedure used.

There was a highly significant difference between the amount of regrowth produced from applications during different weeks (Appendix A, Tables 1 and 2). This is because the last weekly application was a check, and the difference between the regrowth in treated and untreated areas shows in the analysis of variance as differences between weeks. The separation of means shows that there are no significant differences between regrowth from weeks 1 through 7 but that the eighth week (check) is significantly different from all other weeks. This was true for both years.

Total johnsongrass control steadily improved as applications of glyphosate were applied later in the growing season (Table 7). In 1975 spring plowed plots produced a highly significant greater total control of johnsongrass than did clipped or undisturbed plots (Table 7). There were no significant differences between total control in clipped and undisturbed plots. In 1976 there were no significant differences between the three management procedures in relation to total johnsongrass control (Table 7). After the 1975 results were computed but prior to the work in 1976, it was thought that spring plowing might increase the efficiency of glyphosate. A possible explanation for the increased control in the spring plowed plots was that by plowing in April the soil was loosened, permitting more air to flow through the soil. Thus, soil temperatures increased more rapidly. With increased soil temperatures the rhizomes could germinate faster and produce plants more quickly and especially aid control in the early application dates. It was discussed previously that the glyphosate killed practically all rhizomes attached to plants receiving herbicide; therefore, the objective is to encourage germination of as many plants as possible from rhizomes as early as possible. Interrelated with the soil-warming possibility and spring plowing is the effect on soil moisture. In the spring plowed plots soil moisture content will decrease more rapidly than in the clipped or undisturbed plots. Rainfall data (Table 1) shows that there was more rainfall immediately after plowing in 1976 than in 1975. Plowing was performed on April 25 in 1975 and on April 15 in 1976. Wet soil warms more slowly than dry soil; and this would explain why that in 1975 the soil warmed more quickly, produced more plants earlier, and thus glyphosate gave bet-

Table 7. Effect of time of application of glyphosate and management procedure on total johnsongrass control.[a,b]

Time of application[c]	Management procedure					
	Undisturbed		Clipped		Spring plowed	
	1975	1976	1975	1976	1975	1976
1st week	0.0	64.0	30.0	21.6	90.6	46.7
2nd week	20.0	49.3	21.6	30.0	94.3	51.7
3rd week	40.0	88.0	31.6	66.6	96.3	84.0
4th week	76.0	97.0	91.6	87.7	96.3	93.3
5th week	88.3	96.3	94.6	92.7	99.0	97.3
6th week	91.6	99.7	96.0	99.0	99.0	99.0
7th week	94.6	99.3	96.3	99.7	99.0	100.0
Mean[b] 1975	58.7 a		65.9 a		96.3 b	
1976		84.8 a		71.0 a		81.7 a

[a]Control based on scale of 0 - 100% with 0% control in check. Ratings were made on August 25, 1975 and September 6, 1976.

[b]Means in same line followed by same letter are not significantly different at the 0.01 level, as determined by Duncan's multiple range test.

[c]Date of application varies depending upon management procedure and year.

ter control because more plants had emerged to receive herbicide. Table 7 shows that early control in 1975 was much better than in 1976 in the spring plowed plots. It appears that the increased rainfall immediately following spring plowing in 1976 prevented the soil from warming as rapidly as it had in 1975. Soil temperature records indicate warmer soil temperatures prior to early applications in 1975 than in 1976.[1] Control was lower in 1976 on early treatments in spring plowed applications and therefore the total control given for the spring plowed treatments was lower in 1976 than in 1975.

Table 8 shows that as glyphosate applications were made later in the growing season total johnsongrass control improved. The ratings that were made to obtain the values shown in Table 7 express the percent johnsongrass found in the plots compared to the check which is assumed to have 0% control. Late applications not only kill johnsongrass from rhizomes but also kill seedling johnsongrass that has emerged after the seedling control herbicides have become ineffective. Appendix A, Tables 3 and 4 indicate that the means in Table 8 do have differences which are highly significant.

From the information supplied in the two years' data presented it appears that to obtain optimum johnsongrass control from the use of glyphosate at this location applications should not be made before the first week in July. Improved control from the use of glyphosate might be obtained by making applications in late July. The weeks by management interaction was significant in 1975 but not in 1976 (Appendix A, Tables 3 and 4). The significance found in 1975 is due to the spring plowed

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[1]Personal communication. James M Koepper, Statistical Reporting Service, USDA, Louisville, Ky. 40201.

Table 8. Effect of time of application of glyphosate on total johnsongrass control in 1975 and 1976.[a]

Time of application[b]	1975	1976
	(%)	(%)
1st week	40.22 a	44.11 a
2nd week	45.33 ab	43.66 a
3rd week	55.78 b	79.55 b
4th week	88.67 c	92.67 bc
5th week	97.00 c	95.49 bc
6th week	95.33 c	98.89 c
7th week	96.67 c	99.67 c

[a]Means within columns followed by the same letter are not significantly different at the 0.01 level, as determined by Duncan's multiple range test.

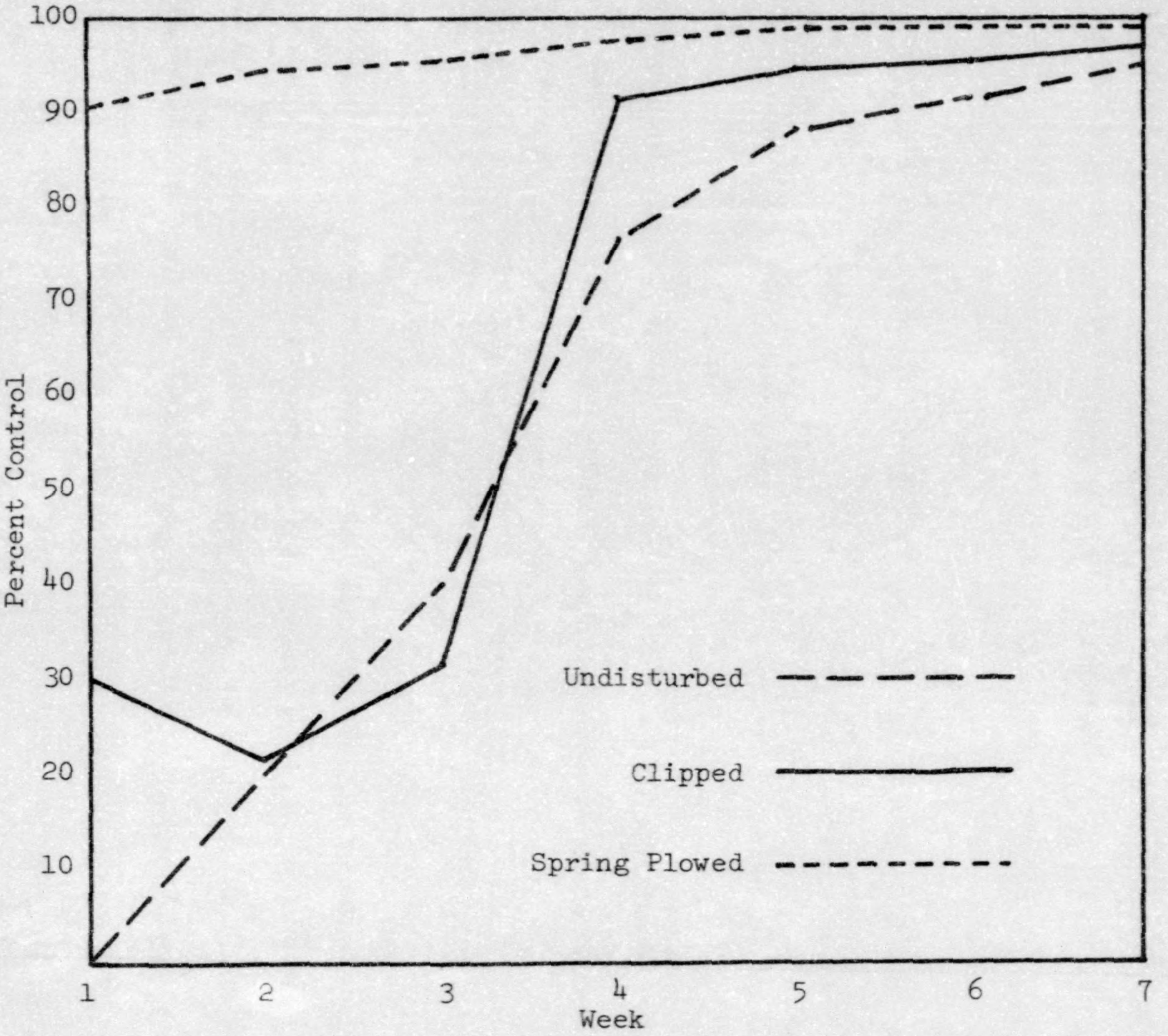
[b]Date of application varies depending upon management procedure and year.

plots producing better control at early application dates than either clipped or undisturbed plots (Figure 1). As the applications were made later in the season the degree of control given by the three methods became very close.

Many questions about the proper use of the herbicide glyphosate for the control of johnsongrass remain unanswered. According to the results reported herein it seems unlikely that corn for grain production could be successfully utilized in a program with glyphosate because the optimum date for planting corn is earlier than the recommended application date of glyphosate. A possibility of using glyphosate for johnsongrass control does exist when planting corn for silage. A system more likely to be used in southern Kentucky would be the planting of soybeans after glyphosate application. Farmers must decide whether their major objective in using glyphosate is to eradicate johnsongrass rhizomes or only to reduce competition enough for a crop to be successfully produced.

Reflecting upon this study it appears that improvement could be made in scientific procedure to possibly gain more information about johnsongrass control. One possibility is to examine untreated rhizomes on each date that treated rhizomes are examined. The untreated rhizomes could produce different numbers of plants if dug and replanted at different times within the growing season. Other possibilities include weekly applications of glyphosate to johnsongrass present in wheat stubble and also increasing the number of applications so that applications are made later in the growing season to the more mature plants. This would indicate whether maturity of the plants influences the effectiveness of glyphosate for killing rhizomes. Another possibility would be to make visual ratings of total johnsongrass control at specific intervals of time after each

Figure 1. Percent of johnsongrass control as affected by time of application and management procedure in 1975.



Percent Control
100
90
80
70
60
50
40
30
20
10
Undisturbed
Clipped
Spring Plowed
1
2
3
4
5
6
7
Week

herbicide application. An example would be to rate the plots approximately five weeks after each glyphosate application. This procedure would differ from the present study in that only one rating was made approximately seven weeks after the last application.

SUMMARY AND CONCLUSIONS

Investigations were conducted at the Western Kentucky University farm at Bowling Green, Kentucky, to determine the effects of the herbicide application on johnsongrass. Statistical analysis was used to determine treatment differences resulting from weekly applications of glyphosate when applied to areas which had been either undisturbed, spring plowed, or clipped. Further investigations concerning these factors and related areas could be useful in determining the most efficient use of the herbicide glyphosate.

Under the conditions of the investigations it appears that:

1. Glyphosate kills approximately 100% of the johnsongrass topgrowth regardless of the application date.

2. Height of the johnsongrass plant at the time of glyphosate application had little influence on the ability of the herbicide to kill the rhizomes.

3. Rhizomes from plants that had received an application of glyphosate produced a significantly lower number of plants than did rhizomes from untreated plants.

4. The management procedures (spring plowed, clipped, undisturbed) had no effect on the ability of glyphosate to kill the rhizomes.

5. As glyphosate applications were applied later in the growing season, johnsongrass control increased.

6. In 1975 glyphosate utilized with spring plowing produced better total johnsongrass control than either clipped or undisturbed plots which had utilized glyphosate. In 1976 there was no significant difference in the control given by the three methods.

APPENDIX A

Table 1. Analysis of variance of percent regrowth as affected by time of application of glyphosate in 1975.

Source	df	SS	MS	F
Total	71	376.79		
Replications	2	47.37	23.69	0.52
Management	2	38.55	19.28	0.43
Error (a)	4	180.40	45.10	
Weeks	7	2295.53	327.93	13.71**
Weeks x management	14	198.11	14.15	0.59
Error (b)	42	1004.82	23.92	

** Significant at the 1 percent level.

Table 2. Analysis of variance of percent regrowth as affected by time of application of glyphosate in 1976.

Source	df	SS	MS	F
Total	71	2562.81		
Replications	2	2.75	1.38	0.12
Management	2	47.04	23.52	2.08
Error (a)	4	45.16	11.29	
Weeks	7	1804.59	257.80	31.40**
Weeks x management	14	1891.80	156.90	19.11**
Error (b)	42	345.01	8.21	

** Significant at the 1 percent level.

Table 3. Analysis of variance on effect of time of application and management procedures on total johnsongrass control in 1975.

Source	df	SS	MS	F
Total	71	73386.86		
Replications	2	446.96	223.48	1.27
Management	2	16856.00	8428.00	47.97**
Error (a)	4	702.76	175.69	
Weeks	6	34903.75	5817.29	47.81**
Weeks x management	12	15001.78	1250.15	10.27**
Error (b)	45	5745.61	121.68	

** Significant at the 1 percent level.

Table 4. Analysis of variance on effect of time of application and management procedures on total johnsongrass control in 1976.

Source	df	SS	MS	F
Total	71	48721.71		
Replications	2	1550.09	775.05	1.53
Management	2	2155.81	1077.91	2.13
Error (a)	4	2022.67	505.67	
Weeks	6	33711.49	5618.58	36.48**
Weeks x management	12	2351.74	195.98	1.27
Error (b)	45	6929.91	154.00	

** Significant at the 1 percent level.

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