JOHNSONGRASS CONTROL IN FOUR AGRONOMIC CROPS WITH GLYPHOSATE APPLIED WITH A RECIRCULATING SPRAYER

By

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JOHNSONGRASS CONTROL IN FOUR AGRONOMIC
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A RECIRCULATING SPRAYER

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CHAPTER I

INTRODUCTION

Continual pressure from environmentalists to develop herbicides and methods of application that will not be harmful to the environment has resulted in many new ideas on herbicides and methods of application. Many of these consist of manually treating individual weeds, for example the herbicide glove or spot treatment. This is an acceptable practice for localized weed infestations; however applying herbicides to individual weeds by hand on a broad scale basis is impractical on today's large farms (6).

One method being evaluated for selective herbicide placement is the recirculating sprayer (RCS) developed in the mid-1960's at the Delta Branch of the Mississippi Agricultural and Forestry Experiment Station. Because of several factors at that time the idea of recirculating a pesticide material was not accepted and this concept appeared headed for only a footnote in agronomic literature. Today many growers and scientists praise the RCS for its economics, simplicity of equipment, and its efficiency in eliminating tall escape weeds from row crops.

This system is ecologically acceptable, for example, when applying a 1.68 kg/ha broadcast equivalent rate, approximately .112 kg/ha would remain in the field (25). The amount of herbicide applied per hectare with a RCS is dependent on the number of weeds per hectare growing above the crop canopy. Approximately 80% of the total herbicide solution can be reused with weed populations of approximately 2,470 plants per hectare and 50% can be reused with populations of 24,700 plants per hectare. Thus, the RCS combines efficiency and economy (42).

The RCS uses solid stream type nozzles that are directed horizontally above and across the crop rows (Figure 1). Horizontal positioned jet-stream nozzles produce a minimum of liquid turbulence. Under these conditions, liquid emerges from a circular orifice as a cylindrical filament, thus reducing the amount of drift usually accompanied with conventional fan nozzle equipped boom type sprayers. The herbicide material not intercepted by the weed canopy is caught and contained by a catchment tank device then recirculated through the system. Solid stream nozzles are used to minimize the waste usually associated with conventional broadcast spraying methods and reduce the number of small droplets which might fall on the crop or non-target pest. The catch tank is open on both sides, and has an angular partition to divert the solid stream into the bottom of the tank and prevent splash back of material. Trash and weed seed collected in the catch tank are removed by filtering through both the rectangular mesh strainer located in the base of the catch tank and through an in-line strainer.

For effective weed control with the RCS, the weeds must have a height in excess of the crop. The control of large weeds in the middle of the season with the RCS will not result in yields equal to that of weed free crops. However, control provided in July or August accomplishes three goals: (a) production of weed seed is reduced thus reducing subsequent weed populations; (b) late season treatments can reduce the number of perennial weeds for the subsequent season; and

RCS

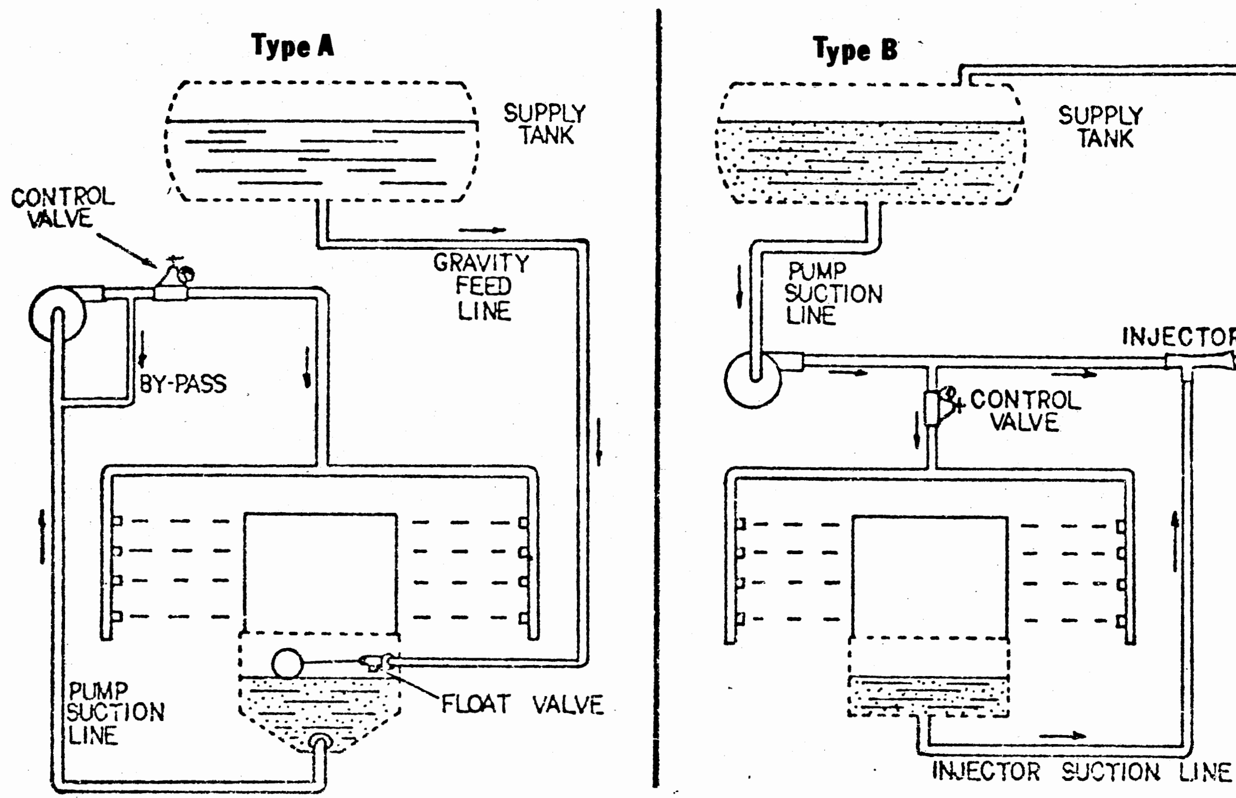


Figure 1. Flow Diagram of Type A and Type B Recirculating Sprayer.

(c) adequate control of existing weeds can contribute to increased harvesting efficiency and higher crop yields (25).

The most important factor responsible for the renewed interest in research with the recirculating sprayer was the development of a new, translocated herbicide with limited selectivity, glyphosate (common names found in Table I) (2, 5, 14, 16, 19, 34, 40, 43).

Research in the last six (6, 9, 10, 11, 12, 15, 19, 25, 29, 31, 37, 42) years has shown that glyphosate is very effective for controlling many perennial weeds including johnsongrass (binomial names found in Table II). Mature johnsongrass plants are reported to be more susceptible to glyphosate than young plants. Glyphosate application to johnsongrass less than 20 cm tall resulted in ineffective control (11, 30). At the present time there are no foliar applied herbicides labeled for selective control of johnsongrass in agronomic crops. McWhorter (30) selectively applied glyphosate with a recirculating sprayer to johnsongrass growing above a crop canopy and successfully controlled johnsongrass with a minimum amount of crop injury.

Johnsongrass is one of the most difficult to control perennial weeds on crop land in the southern United States. It is among the few most costly weeds in the 13 southern states, excluding Florida (22), causing yield and profit losses in most agronomic crops and many vegetable crops. In the last few years glyphosate has shown a great potential for the control of johnsongrass applied in a recirculating sprayer over agronomic crops. Therefore the objectives of this research were to determine: (a) glyphosate rate, water carrier volume and height differential between johonsgrass and 4 agronomic row crops required for effective johnsongrass control using a RCS; (b) the effect of se-

TABLE I

COMMON AND SCIENTIFIC NAMES OF PLANTS

Common Name	Scientific Name
Bermudagrass	*Cynodon dactylon* (L.) Pers.
Canada thistle	*Cirsium arvense* (L.) Scop.
Carrot	*Daucus carota* L.
Cocklebur	*Xanthium strumarium* L.
Common milkweed	*Asclepis syriaca* L.
Cotton	*Gossypium hirsutum* L.
Green algae	*Scenedesmus* spp.
Hemp dogbane	*Apocynum cannabinum* L.
Hemp sesbania	*Sesbania exaltata* (Raf.) Cory
Johnsongrass	*Sorghum halapense* L.
Leafy spurge	*Euphorbia esula* L.
Quackgrass	*Agropyron repens* L.
Peanuts	*Arachis hypogaea* L.
Pigweed	*Amaranthus* spp.
Soybeans	*Glycine max* (L.) Merr.
Sorghum	*Sorghum bicolor* (L.) Moench
Spinach	*Spinacia oleracea* L.
Tobacco	*Nicotiana tabacum* (L.) cv. Xanth
Torpedograss	*Panicum repens* L.
Wheat	*Triticum aestivum* L.

TABLE II

COMMON AND CHEMICAL NAMES OF HERBICIDES

Common Name	Chemical Name
Acifluorfen	5[2-chloro-4-(trifluoromethyl)phenoxy]-2 -nitrobenzoic acid
Amitrole	3-amino-1,2,4-triazole
Asulam	methyl sulfanilycarbamate
Butylate	S-ethyl diisobutylthiocarbamate
Butralin	N-sec-butyl-4-tert-butyl-2,6-dinitroaniline
Dalapon	2,2-dichloropropionic acid
Dicamba	3,6-dichloro-o-anisic acid
DSMA	Disodium methanearsonate
EPTC	S-ethyl dipropylthiocarbamate
Glyphosate	N-(phosphonomethyl)glycine
MSMA	Monosodium methanearsonate
Nitralin	4-(methylsulfonyl)-2,6-dinitro-N, N-dipropylaniline
Paraquat	1,1'-dimethyl-4, 4'bipyridinium ion
Profluralin	N-(cyclopropylmethyl)-a,a,a-trifluoro-2,6-dinitro -N-propyl-p-toluidine
Trifluralin	a,a,a-trifluoro-2,6-dinitro-N,N-dipropyl-o-toluidine
2,4-D	(2,4-dichlorophenoxy)acetic acid
2,4-DB	4-(2,4-dichlorophenoxy)butyric acid

quential glyphosate applications with a RCS on johnsongrass control; (c) the stage of johnsongrass growth required for effective control with selected herbicides and herbicide combinations; and (d) the effectiveness of the RCS for control of annual weeds in 2 agronomic crops.

CHAPTER II

LITERATURE REVIEW

Johnsongrass Origin and Development

The question of the origin of johnsongrass has resulted in many cytological and genetic studies (3), with the general consensus being that [Sorghum halapense (L.) Pers.] was evolved by doubling the chromosomes of a hybrid between (Sorghum vulgare Pers.) and some related 20-chromosome species of Sorghum. Celarier (7) believed that (S. halapense) might have originated in Indochina and Burma where a cross occurred between (S. propinquum Hitchc.) and a local 20-chromosome species. This cross resulted in doubling of the chromosome number. Bhatti et al. (3) has shown strong probability that (S. virgatum Stapf.) is native to that same area considered to be the origin of (S. halapense). They showed cytological behavior of the S. vulgare - S. virgatum hybrids being the same that is reported for (S. halapense). They also observed that pairing in metaphase I of S. vulgare - S. virgatum was the same as in metaphase I of (S. halapense).

It is generally believed that johnsongrass is a native to Mediterranean region from Asia Minor to Madeira Islands and southeastern Europe (26, 39). Many closely related forms of (Sorghum halapense) originated in India, the Philippines and Malay Peninsula (26).

As many as 8 different Latin names and 40 common names were used to describe johnsongrass prior to 1875 making it rather difficult to establish when it was introduced into the United States. It is generally agreed that johnsongrass was introduced into the United States sometime in the early nineteenth century. The first known written use of the word johnsongrass was in a letter from John Haralson of Selma, Alabama, to George Vasey in 1874. This letter and another were extremely important in the establishment of johnsongrass as a common name (26).

Anderson et al. (1) found that the initiation of rhizomes from seedlings occurred approximately 4 to 5 weeks after emergence, with well developed rhizomes appearing after 6 to 8 weeks of growth. McWhorter (23) reported that johnsongrass grown from both seeds and rhizomes will flower in 47 days. Initially there is slow rhizome growth and rapid vegetative growth until blooming, this is followed by rapid rhizome development and slower vegetative growth until maturity. McWhorter (23) further reported that 65 meters of rhizome johnsongrass growth was obtained 152 days after johnsongrass was established from seed.

Different soil types have been shown to affect johnsongrass growth and development (27). Johnsongrass grown in a clay soil produced 80% of its rhizomes in the top 7.5 cm compared to that grown in a sandy loam soil where 80% of the rhizomes were located in the top 12.5 cm (27).

Several environmental factors have been shown to affect rhizome viability (1, 27). Drying rhizomes to 20, 25 and 40% of their initial weight resulted in no shoot development, sporadic shoot development, and normal shoot development, respectively (1). Loss of bud viability was shown by exposure of rhizome buds to temperatures of 50 to 60 C for 1 to 3 days or -3 to -5 C for 8 hours (27).

McWhorter (23) found that 13 day old seedlings could be killed by clipping the top vegetative growth. He also found that 8 weekly clippings did not kill johnsongrass plants when first clipped at 20 days after johnsongrass emergence. Johnsongrass plants grown from rhizomes responded similarly to those grown from seed.

Before the introduction of glyphosate, Oyer et al. (36) reported that johnsongrass had to be treated before the seven leaf stage of growth for effective control. At that growth stage, preemergence herbicides or contact killing could play an important role in its control. They also reported that after johnsongrass had produced rhizomes the problem of control was multiplied many times over. After rhizome production is initiated a herbicide must be translocated into all of the rhizome buds, and must inhibit further growth of these buds to be effective.

Season-long or permanent johnsongrass control is difficult to achieve with most herbicides available today without causing serious injury to crops. McWhorter (24) reported effective aerial control or burn-back of johnsongrass with 2.24 kg/ha of DSMA applied postemergence to johnsongrass. Maximum burn-back was obtained 2 to 3 weeks after treatment; however, burn-back decreased to 50% after 6 to 7 weeks, and no effect was apparent after 9 weeks. Paraquat applied 8 times at 1.12 kg.ha, dalapon applied 4 times at 4.14 kg/ha, and DSMA applied 7 times at 2.24 kg/ha gave 55, 82, and 85% johnsongrass foliage burn-down, respectively. Rhizome control was not obtained with these treatments. Other researchers (20, 32, 33) have reported similar results with dalapon and/or DSMA.

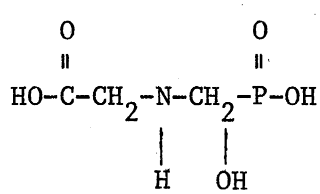
Several soil applied herbicides have been evaluated for both seeding and rhizome johnsongrass control. Roeth (41) reported less than 60% rhizome and seedling johnsongrass control with preplant incorporated (PPI) treatments of butylate at 4.5, 9.0 and 13.3 kg/ha and EPTC at 3.4 kg/ha after one treatment. Retreatment of the experiment the following season resulted in 79 to 93% control with these herbicides.

McWhorter (28) reported poor early season control of johnsongrass grown from seeds and rhizomes with trifluralin and nitralin at rates of .56 to 3.36 kg/ha. Two successive years of treatment with trifluralin and nitralin applied at 1.12 to 2.24 kg/ha and incorporated immediately effectively controlled johnsongrass from rhizomes without soybean injury. McWhorter later reported better than average johnsongrass control over a two year period with profluralin at 1.7 kg/ha and butralin at 3.4 kg/ha.

Glyphosate is one of the most effective herbicides used today for johnsongrass control. Glyphosate rates as low as 0.56 kg/ha have been reported (19, 30) to give as much as 80% rhizome johnsongrass control. More consistent control was reported by McWhorter (29) when glyphosate was applied at 0.56 to 1.12 kg/ha. Derting _et al_. (11) reported the results of 55 experiments, where effective johnsongrass control was obtained when applied to johnsongrass at all of several growth stages. They also reported sequential applications of glyphosate at 2.24 kg/ha followed by a later treatment at 2.24 kg/ha resulted in 99% control of rhizome johnsongrass 453 days after first application. Fall applications of glyphosate were shown to be more effective than spring applications. This was explained by greater rhizome commitment in the fall, larger receptive canopy, more active transport throughout the plant, and the prevention of recovery during the winter months.

Glyphosate

Glyphosate is a broad spectrum, postemergence applied herbicide showing great potential as a foliar treatment for control of both annual and perennial grasses and broadleaf weeds. Glyphosate shows very little foliar selectivity, killing or damaging most green and growing vegetation. There is little, if any, activity from soil applied glyphosate (43, 44). The structure of glyphosate is:



Glyphosate is a white, odorless, solid, soluble in water at about 1 g per 100 ml of water at 25°C. It is presently formulated as the isopropylamine salt for an aqueous spray. The commercially formulated material sold as Roundup contains .36 kg/l acid equivalent of glyphosate and a nonionic surfactant. Many of the references on glyphosate (10, 11, 12, 15, 19, 30) have shown the experimental code number Mon-2139, Mon-0139, and CP-70139.

Glyphosate Mode of Action

The complete mode of action of glyphosate has not been fully established; however, certain sites of activity have been identified. Jaworski (16) reported that glyphosate inhibited the synthesis of aromatic amino acids. He also proposed that glyphosate affected the shikimic acid pathway by suppressing the enzymes chorismate mutase and/or prophenate dehydratase. This was substantiated by Nilsson (34). Haderlie et al. (14) showed that glyphosate concentration of 0.5 to 1.5 mmoles inhibited carrot and tobacco cell growth by 79%. This inhibition was reversed by adding combinations of phenylalanine, tyrosine, tryptophan or casein hydrolysate. Casein hydrolysate and phenylalanine plus tyrosine plus tryptophan were the most effective treatments. Reversal of glyphosate induced inhibition occurred only if the aromatic amino acids were added during the first 8 days of glyphosate incubations.

Campbell et al. (5) proposed that glyphosate enhances the senescence process, probably by changing membrane permeability which subsequently leads to altered osmotic potentials. The continued breakdown of the cells after treatment could be explained by the disfunction of the tonoplast, thereby releasing hydrolytic enzymes into the cell. Cellular damage to naturally growing quackgrass was evaluated with an electron microscope 24 hours after treatment with glyphosate applied at 0.56 to 4.49 kg/ha. The type of damage noted was swelling of the rough endoplasmic reticulum with subsequent formation of vesicles and partial to complete disruption of the chloroplast envelope, causing disruption of the chloroplasts.

Nilsson (34) reported spring wheat plants grown in a nutrient solution and treated with 0.1 or 0.01% solution of glyphosate (formulation containing 480 g/l of the isopropylamine-salt) caused an increase of free amino acids compared to the bound acids, resulting in an increase of relative amounts of glutamic acid, glutamine, asparagine, and a decrease of tyrosine and phenylalanine. He further states the increase of free amino acids and a nearly unchanged total amount suggests a decrease in the rate of protein synthesis in the leaves.

Rensen (40) showed that glyphosate could inhibit oxygen evolution in the green alga (Scenedesmus) with the inhibition increasing with time. The inhibition could be partly reduced by washing the cells, exposing the cells to higher light intensity, or increasing the temperature. From electron transport studies with isolated spinach chloroplasts Rensen (40) concluded that glyphosate inhibited electron transport in or near photosystem II.

Fate of Glyphosate in Soil

Sprankle et al. (43, 44) have reported little to no activity of glyphosate in the soil. They showed glyphosate was readily bound to clay and organic matter, possibly through the phosphoric acid moiety of glyphosate. Phosphates were found to compete with glyphosate for binding sites on soils and was influenced by soil pH, phosphate level, and soil type. The glyphosate adsorption could be reversed with a increase in phosphate content because of competition for the binding sites. This rapid inactivation was not found with washed quartz sand. They also stated 45% free and bound glyphosate was degraded in a Conover sandy clay loam soil in 28 days, with the first step in glyphosate inactivation being rapid binding to the soil followed by chemical and/or microbial degradation.

Effect of Carrier and Tillage On Glyphosate Activity

Several researchs have shown that carrier and tillage methods influence glyphosate activity (2, 10, 21, 23, 29, 37, 38). Derting (10) reported 10% control of hemp sesbania with a rate of 2.24 kg/ha without surfactant and 80% control with the addition of a surfactant. However, soybean injury was increased to an unacceptable level due to an excessive foaming problem produced with the addition of a surfactant. McWhorter (29) reported that the addition of .25 to .5% v/v surfactant to glyphosate applied with a RCS increased johnsongrass control and soybean injury by 15 to 35%. The addition of a thicking agent at .10% v/v reduced soybean injury but did not increase johnsongrass control. Appleby et al. (2) found that the addition of a surfactant increased phytotoxicity of glyphosate to wheat. They obtained complete wheat kill with .42 kg/ha of glyphosate, with surfactant, while .84 kg/ha without a surfactant was needed for complete kill.

Phillips (38) showed phytotoxic action of glyphosate to grain sorghum when applied at 0.56 kg/ha in carrier volumes 94, 188, and 374 l/ha of distilled water. Nearly complete inhibition of glyphosate activity was obtained when $CaCl_2$ concentrations in the carrier water volumes of 188 and 375 l/ha where raised to .01 and .02 molar. Adding a wetting agent at rates up to 4% v/v did not overcome antagonism. Glyphosate activity was also reduced when applied in carrier solutions containing inorganic salts of iron, calcium, and aluminum. Solutions containing zinc and magnesium caused some phytotoxic reduction, with potassium and sodium salts causing no phytotoxic reduction.

Delaying tillage following glyphosate application has been shown to increase quackgrass (21) torpedograss (4) and johnsongrass (37) control. Lee (21) applied glyphosate at 1.5 and 2.25 kg/ha to quackgrass and deep plowed 1 day and 10 days after application. The 10 day delay of tillage resulted in complete control while the 1 day delay resulted in inadequate control. Parochetti et al. (37) noted a trend of increased johnsongrass control when tillage was delayed from 4 to 21 days following glyphosate application. Burt and Dudeck (4) reported similar results with torpedograss, where rototilling was delayed 1, 3 and 7 days after glyphosate treatment of 0.56, 1.12, 2.24 and 4.48 kg/ha. The best control was obtained when rototilling was delayed for 7 days, with no control from plots tilled 1 day after application.

Crop Tolerance

Selectivity to some crops has been shown with glyphosate. Overton et al. (35) reported that cotton was tolerant to glyphosate at 0.56 kg/ha when applied to cotton 61 cm tall, but at a rate of 2.24 kg/ha cotton was highly susceptible. Jordan and Bridge (19) reported similar results with 400 breeder strains of cotton. They reported finding 20 strains resistant to glyphosate applied at 0.56 and 1.12 kg/ha. Jeffery et al. (17) reported that soybean susceptibility to glyphosate was affected by cultivar and stage of growth at the time of application. Glyphosate applied at 1.12 kg/ha was less injurious to 51 cm tall soybeans than 102 cm tall soybeans. The cultivars 'Bragg' and 'Pickett 71' were more resistant than 'Dare', 'Forrest', or 'York'; however, glyphosate reduced yields of all cultivars regardless of height at the time of treatment. Overton et al. (35) reported some soybean tolerance to glyphosate applied at 0.56 kg/ha to soybeans 31, 41 and 61 cm high.

Translocation and Metabolism

Several factors have been found that effect glyphosate translocation and metabolism. Jordan (18) found that both temperature and relative humidity affect the absorption, translocation and toxicity of glyphosate to bermudagrass. Increasing the temperature from 22 to 32 C at 40% relative humidity increased glyphosate activity and absorption; however, no translocation differences were reported with 100% relative humidity. Jordan also reported six times more translocation at 100% relative humidity than at 40% at either 22 or 32 C. Fresh weight measurements taken from glyphosate treated bermudagrass plants showed significantly greater toxicity at 32 C than at 22 C at 40% relative humidity; however, no differences were found at 100% relative humidity. Whitwell (46) reported similar results in that young roots and rapidly growing stolons of bermudagrass were sites of accumulation of ^{14}C-glyphosate. He found more glyphosate retention in the treated shoot at 31 C at low relative humidity, compared to those shoots treated at high relative humidity. Studies on bermudagrass foliage showed higher levels of ^{14}C-glyphosate accumulation at 31 C at high humidity than at 22 C at low relative humidity. Whitwell also reported increased uptake of ^{14}C-glyphosate from leaf tips of bermudagrass compared to uptake from stem sections.

Gottrup et al. (13) studies the uptake, translocation and metabolism of glyphosate in Canada thistle and leafy spurge. They reported that glyphosate was readily translocated to young leaves and roots via the symplast and the apoplast, with an increase in translocation noted by the addition of surfactant or increase in relative humidity. One week after treatment no metabolites were detected in either foliage or roots. They further reported no decrease or increase in ^{14}C-glyphosate during the experimental period, suggesting little or no production of metabolites.

Claus and Behrens (8) reported that foliar applications of glyphosate at 0.28, 0.56, and 0.84 kg/ha resulted in nearly complete control of quackgrass when rhizomes contained 10 nodes, but higher survival rates were observed in quackgrass rhizomes of 20 to 90 nodes. They also reported the greatest glyphosate concentration in the tips of rhizome buds located closest to the treated mother shoot.

Wyrill and Burnside (47) studied the differences in susceptibility of hemp dogbane and common mildweed to glyphosate and 2,4-D. In both species glyphosate absorption was less than 2,4-D. They also reported more glyphosate and 2,4-D absorption in common milkweed than in hemp dogbane. This was attributed to less cuticle, less epiculticular wax, and a lower contact angle at application than hemp dogbane. Enhanced glyphosate accumulation in areas of high meristematic and metabolic activity were reported. Laboratory studies showed common milkweed roots contained more glyphosate than 2,4-D one day after treatment, with the increased percentage of glyphosate found in the roots not significantly changing over a 20 day period indicating that translocation to the roots occurs within the first day after application. Radioautograph studies support this statement, showing considerable translocation of both glyphosate and 2,4-D within the first day after application. Field and greenhouse data indicates glyphosate and 2,4-D are translocated via the phloem; however, because glyphosate is more soluble in the symplasts it was translocated faster than 2,4-D. Also little or no metabolism of glyphosate was reported in roots of seedlings or leaves above those treated (47).

Recirculating Sprayer

Several annual weeds have been successfully controlled with the use of herbicides and a RCS (6, 10, 19, 31). Derting (10) obtained 90% control of 81 to 132 cm cocklebur and redroot pigweed plants when only 8 to 15 cm of the tops were contacted with a RCS, with a rate of glyphosate at 1.12 kg/ha. McWhorter (31) reported 65 to 95% control of pigweed 8 weeks after application with glyphosate applied at 1.12 and 1.68 kg/ha applied in a RCS. Increased activity was noted from the addition of a surfactant to an application rate of 1.12 kg/ha. Excellent control of hemp sesbania was provided by glyphosate applied at 1.68 kg/ha in a RCS if a antidrift polymer at .1% and/or a surfactant at 1% were used. This was compared to only 53% control achieved with no adjuvant addition (31). McWhorter (25) reported that 2,4-D applied at .56 and 1.12 kg/ha at 934 l/ha in a RCS provided good to excellent control of hemp sesbania and pigweed in soybeans. Carlson and Burnside (6) observed 73 to 88% control of common milkweed one year after treatment from glyphosate applied at 1.12 to 4.48 kg/ha in a RCS.

Jordan and Bridge (19) compared the application of glyphosate postemergence over-the-top at .56 kg/ha to the application through a RCS at 1.68 kg/ha. They determined that either treatment method or rate provided 83 to 90% johnsongrass control, with the highest cotton yield obtained when glyphosate was applied with a surfactant in a RCS.

Timing of Glyphosate Application with a Recirculating Sprayer

Time of application with a RCS has been shown to be somewhat critical in overall control of johnsongrass (10, 15). Derting (10) reported late in the season (August 6 to 17) glyphosate applications provided better control of johnsongrass than early season (June 16 to July 5) applications. Glyphosate application made early in the season (June 16 to July 5) was effective only on the johnsongrass plants tall enough to intercept the horizontal stream. This application time however, resulted in missing many johnsongrass plants located below the crop canopy. Data such as this indicated a need for sequential applications for effective control.

Water Volume and Carrier Recovery

Several researchers (10, 25, 29, 41) have reported a relationship between water carrier volume and the control obtained with glyphosate. Derting (10) evaluated glyphosate activity on hemp sesbania as affected by water carrier volumes of 94, 187 and 374 l/ha. Ratings made 35 days after treatment showed decreased hemp sesbania control with increased carrier volumes. He suggests that the relationship is a function of the amount of active ingredient deposited per individual plant rather than per hectare. McWhorter (29) reported similar results were glyphosate applied in a RCS provided 10 to 20% more control of johnsongrass when applied at 94 and 187 l/ha than when applied at 374 and 748 l/ha.

McWhorter (25) and Carlson and Burnside (6) reported 70 to 95% recovery of spray solution when applied in a carrier volume of 942 l/ha with a RCS to plant populations of 2,470 to 12,350 plants/ha. Fluorescent dye experiments indicate that approximately 5% of the spray solution was deflected and not deposited on the treated plants. The amount of material deflected was dependent on number, size, and species of weeds present at time of treatment. In similar research Rollison (42) found that pigweed and cocklebur deflected twice as much glyphosate as sesbania or johnsongrass.

Nozzles Types

Two basic horizontal nozzle types have been evaluated (10, 15) for use in the RCS, straight-stream, and 15-degree fan nozzles. No conclusive differences in weed control or crop injury were reported. However, Hurst (15) reported that applications of glyphosate with the solid stream nozzle injured the cotton more than with a 15-degree fan nozzle at the same spray volume. Derting (10) reported that 15-degree nozzle tips caused more rapid discoloration of foliage than straight-stream nozzle tips. He also reported that the best control with an RCS was obtained by maintaining the filiment stream just above the crop canopy, permitting occasional contact with the larger crop plants. However, he reported objectionable crop injury was obtained with glyphosate applied at 3.36 and 4.48 kg/ha when boom height was not maintained above the crop canopy.

Travel Speed

Several problems have been reported from increased speeds during herbicide application with a RCS (10, 30). Derting (10) found good activity with glyphosate applied in a RCS at a speed of 3.2 to 12.9

km/hr, with a trend towards slightly less control as speed increased above 9.7 km/hr. He stated two problems as speed increased: (a) number of grass stems pushed aside by the RCS increased as speed increased; and (b) there is increased difficulty in keeping the RCS centered between the crop rows.

CHAPTER III

METHODS AND MATERIAL

The introduction of glyphosate and the recognition of its limited selectivity has caused renewed interest in research pertaining to safe and effective methods of application. One method being evaluated for glyphosate application is the RCS. Several types of RCS systems are available; however, only two basic types were used in this research. These will be referred to as Type A, manufactured by Porter Manufacturing Corporation, Lubbock, Texas, and Type B manufactured by Wylie Manufacturing Company, Petersburg, Texas, Figure 1, p. 3.

Type A is equipped with stainless steel catch tanks, galvanized steel booms, and a polyethylene supply tank. A gravity feed line is used in the delivery of herbicide solution from the main tank to the catch tank. The pumping system employed in Type A is a centrifugal pump driven by either a power take off system or hydraulic motor. The pump pulls herbicide solution from the catch tank and recirculates this solution through the spraying system and back into the catch tank. The catch tank has a vertical 45^{o} baffle to reduce splashing, with a mesh screen in the bottom to improve filtration. This system confines all contamination from dust and pollen in the herbicide solution to the catch tank. The catch tank and entire assembly is designed for mounting on a standard tool bar. The catch tank with Type A will not allow the unit to be lowered less than 31 cm off the ground (45).

Type B features a fiberglass supply tank, polyethylene catch tank, and aluminum booms. It has a centrifugal pump driven by a hydraulic motor and employs a venturi-pump type return system. The high capacity pump requirement to operate the venturi pump tends to create a foaming problem. The small compact design of the catch tank allows the unit to be lowered to about 15 cm off the ground (45).

Both Type A and B were utilized in this research. Although no research was performed to compare effectiveness of Type A or B for weed control, it is the author's opinion that no differences were apparent. As far as the use of Types A or B in research work, Type A is more versatile in changing herbicide rates and carrier volumes. This opinion is solely dependent on the fact that Type A does not recirculate through the main supply tank.

Nozzle tip spacing was approximately 9 and 10 cm for Type A and B, respectively. Nozzles used were TeeJet diaphram check valve nozzles, with spray tips being hardened stainless steel D type orifice discs. These tips allowed a solid stream of herbicide solution to be projected over and across the crop rows.

Two glyphosate rate formulations were used in this research depending on the crop utilized in each experiment. This was done to fulfill an Environmental Protection Agency experimental use permit requirement. In all cotton and soybean experiments CP-70139, containing an active ingredient of 0.48 kg/l was used. Peanut and sorghum experiments were treated with Mon-0139, containing a 0.36 kg/l active ingredient.

Soybean RCS Experiments

Five soybean RCS studies were conducted in Oklahoma. These studies will be referred to as locations I through V. All soybean RCS experiments were conducted under dryland conditions. The statistical design for each experiment was a randomized complete block design with 2 replications at locations I, II, and V; 3 replications at location III; and 4 replications at location IV. Plot size at each location was as follows: location I, 2 by 402 m; II, 2 by 805 m; III, 2 by 46 m; IV, 2 by 91 m; and V, 2 by 18 m. Plot information and spraying conditions for all soybean experiments are shown in Appendix, Table X. The glyphosate rate and carrier volumes used at all 5 locations were 1.68 and 2.52 kg/ha applied in 122, 187, and 374 l/ha; however, the carrier volume at location IV was 374 l/ha and at location V carrier volume was 122 and 187 l/ha.

Treatments were made at locations I and II on August 5, 1977, with ratings made on August 27, 1977, and September 17, 1977. Location III was treated on August 11, 1977, followed by visual ratings on September 10 and 24, 1977. Soybean yields were taken with a Gleaner combine on the entire plot area on November 18, 1977. Location IV was treated on May 20, 1978, followed by visual ratings on August 1, 17, and 24, 1978. Location V was treated on July 17, 1977, and August 11, 1977, followed by visual ratings on July 26, August 12 and 23 and September 7, 1977.

Cotton RCS Experiments

Six experiments with the RCS and cotton were conducted at several locations in Oklahoma. These studies will be referred to as location

VI through XI. Furrow irrigation was applied at locations VI, IX, X and XI when needed during the duration of the experiment. The statistical design for each study was a randomized complete block. Locations VI through VIII were replicated 2 times and locations IX through XI were replicated 4 times. Plot size at each location was as follows: VI and VII, 2 by 61 m; VIII, 2 by 18 m; IX, 2 by 43 m; X, 4 by 805 m; and XI, 4 by 46 m. All treatments were applied with either a 2 row or 4 row recirculating sprayer. Glyphosate rates and carrier volumes used for each location were as follows: locations VI, VII, and IX, rates of 1.68 and 2.52 kg/ha applied in water carrier volumes of 122 and 187 l/ha; location IX, rates of 1.68 and 2.52 kg/ha were applied in water carrier volumes of 122, 187, 374, 655 and 1309 l/ha; locations X and XI were treated with glyphosate at a rate of 2.52 kg/ha in a water carrier volume of 187 l/ha. Spraying conditions and plot information for experiments VI through VIII, IX, and X to XI are given in Appendix, Tables XI, XII, and XIII, respectively. The effects of glyphosate were evaluated with visual observations of 4 different plant responses. All visual observations are based on a 0 to 100 scale where 0 equaled no effect and 100 equaled complete effect. The plant responses measured were percent crop injury, percent total johnsongrass foliage necrosis, percent drop of necrotic johnsongrass foliage below the crop canopy, and percent johnsongrass control at the end of the first season. The method of visual ratings was applied to all experiments contained within this thesis, unless otherwise stated.

Treatments at locations VI and VII were applied on July 28, 1977, and July 27, 1977, respectively. Visual observations at location VI were taken August 9, 27 and September 11, 1977. Visual observations at location VII were taken on August 8, 24 and September 5, 1977.

Treatments at location VIII were applied on July 17 and August 11, 1977, in a johnsongrass two stage height experiment. The height of johnsongrass at each stage was 51 to 76 cm and 122 to 244 cm, respectively. Visual observations were made on July 26, August 12, 23 and September 7, 1977. Cotton yields were handpicked on October 15, 1977, from the entire plot.

Location IX was selected as a site for evaluating the effects of glyphosate applied in water carrier volumes of 122, 187, 374, 654, and 1308 l/ha. Treatments were applied on July 17, 1978, with an RCS calibrated on a broadcast basis. Visual observations were taken on July 28 and 31 and August 7 and 22, 1978.

Locations X and XI were the sites of glyphosate evaluation in the form of sequential RCS applications. Treatment particulars were T_1, the initial application followed by T_1 plus 21 days, T_1 plus 28 days, 21 days, and 28 day treatment. Both experiments were initiated on June 27, 1978, with sequential applications applied at location X on July 24, 1978, and on location XI on July 18 and 24, 1978. Visual ratings were taken at location X on July 11 and 25 and September 7, 1978, and at location XI on July 11, 25 and 31 and August 7 and 22, 1978.

Peanut RCS Experiment

An RCS experiment was conducted near Ft. Cobb, Oklahoma, on peanuts referred to as location XII. Plot size was 2 by 46 meters, with 2 replications in a randomized complete block design. Sprinkler irrigation was used throughout the growing season. Plot information and spraying conditions can be found in Appendix, Table XIV.Treatments with the RCS were made on July 27, 1977. Visual ratings were made on August 25, 1977, and September 10, 1977. Entire plots were harvested with a small plot peanut thrasher on October 18, 1977.

Sorghum RCS Experiments

Sorghum RCS experiments were located at Altus and Ponca City, Oklahoma, as locations XIII and XIV, respectively. Location XIII was conducted under furrow irrigation, whereas location XIV was under dry-land conditions. Statistical design at both locations was a randomized complete block design with 2 and 4 replications, respectively. Plot size at location XIII was 8 by 183 m, and at location XIV, 2 by 67 m. Plot information and spraying conditions for both RCS sorghum experiments are shown in Appendix, Table XIV. Glyphosate rate and water carrier volume used at location XIII was 1.68 and 2.52 kg/ha applied in 140 l/ha, with rates of glyphosate at 2.24 and 3.36 kg/ha applied in water volumes of 122, 187 and 374 l/ha at location XIV. Location XIII was treated on August 26, 1977, followed by visual ratings on September 1 and 11, 1977. Treatments were applied on location XIV on July 18, 1978, followed by visual ratings on August 1 and 9, 1978.

Non-Cropland Johnsongrass Control

A non-crop, postemergence, three stage, johnsongrass control study was initiated at Lake Carl Blackwell near Stillwater, Oklahoma. This study will be referred to as location XV. Statistical design for this study was a randomized complete block, replicated 4 times with a plot size of 9 by 9 m. Plot information and spraying conditions are shown in Appendix, Table XV. Visual ratings are based on a 0 to 100 scale where 0 equaled no effect and 100 equaled complete effect.

Johnsongrass treatments were applied on June 15, 29 and August 11, 1978. These application dates resulted in the johnsongrass being treated at heights of 10 to 20, 36 to 46, and 76 to 102 cm. Visual ratings were taken on June 23 and 29, July 14, August 11 and 24, and September 26, 1978.

RCS Pigweed Control in Soybeans and Peanuts

Experiments were conducted in soybeans and peanuts to determine the potential use of the RCS for pigweed control. Several selective and non-selective herbicides were included in this experiment. The experiments in soybeans and peanuts will be referred to as locations XVI and XVII respectively. Both studies were conducted in a noncultivated native stand of pigweeds under dryland conditions, with statistical design for each study being a randomzied complete block with plot size of 2 by 18 m. Both locations were replicated 4 times. Plot information and spraying conditions are shown in Appendix, Table XVI. Both locations were rated on a scale of 0 to 100 where 0 equaled no effect and 100 equaled complete effect. Treatments with the RCS over soybeans and peanuts were applied on July 26, 1978, and finished on July 28, 1978, due to approximately 0.25 cm of rainfall on July 26, 1978. Visual ratings were taken at both locations August 1 and 23, 1978.

CHAPTER IV

RESULTS AND DISCUSSION

Crop Injury with an RCS

Glyphosate injury to soybeans, cotton, peanuts and sorghum ranged from 0 to 36% depending on crop evaluated, glyphosate rate, and water carrier volume used (Table III). Individual experiment data for soybeans, cotton, peanuts and sorghum is shown in Appendix, Tables XVII through XXI. The least crop injury was found in peanuts where the highest height differential existed between johnsongrass and the crop plants. This height differential allowed for maximum johnsongrass foliage coverage, and minimum crop herbicide interaction. Sorghum consistently showed higher injury levels than cotton, peanuts, or soybeans. Higher sorghum injury was observed because of two basic reasons: (a) small height differentials between the sorghum and johnsongrass; and (b) in sorghum experiments the botton tip of the RCS was run from 0 to 10 cm above and below the top of the crop canopy to achieve johnsongrass coverage, because of the minimum height differential.

Although crop injury noted was negligible in soybeans, cotton, and peanuts, the type of injury noted was leaf burn followed by leaf necrosis. When leaf necrosis was noted the leaves in question would dry and senesce at the leaf stipule. Within 2 to 3 weeks these dropped leaves were not apparent as new leaves replaced them in the crop canopy. It

TABLE III

AVERAGE CROP INJURY RATINGS IN SOYBEANS, COTTON, AND PEANUT EXPERIMENTS

Crop		Glyphosate Rate (kg/ha) 1.68					2.24		2.52					3.36		
		Carrier Volume (l/ha)														
		122	140	169	187	374	122	187	122	140	169	187	374	122	187	374
Soybeans																
Location	I	0	-	-	0	-	-	-	0	-	-	0	-	-	-	-
"	II	0	-	-	0	-	-	-	0	-	-	0	-	-	-	-
"	III	0	-	-	0	-	-	-	0	-	-	0	-	-	-	-
"	IV	3	-	-	2	17	-	-	13	-	-	16	3	-	-	-
"	V	0	-	-	0	-	-	-	2	-	-	2	-	-	-	-
Cotton																
Location	VI	0	-	-	0	-	-	-	2	-	-	0	-	-	-	-
"	VII	2	-	-	3	-	-	-	0	-	-	3	-	-	-	-
"	VIII	0	-	-	1	-	-	-	0	-	-	1	-	-	-	-
Peanuts																
Location	XII	0	-	0	-	-	-	-	0	-	0	-	-	-	-	-
Sorghum																
Location	XIII	-	0	-	-	-	-	-	-	0	-	-	-	-	-	-
"	XIV	-	-	-	-	-	18	21	-	-	-	-	-	36	29	33
*Avg.		1	-	0	1	17	-	-	2	-	0	3	3	-	-	-

*Averages over soybeans, cotton, and peanuts only.

appeared that the only leaves injured were those that directly intercepted the herbicide filament stream. No injury to the crop stems was noted at any time during the duration of these experiments.

Johnsongrass Foliage Necrosis

Johnsongrass foliage necrosis increased when the glyphosate rate was increased from 1.68 to 2.52 kg/ha (Table IV). Foliage necrosis was not appreciably affected by water carrier volume when averaged over all experiments. In a few cases there appeared to be a trend of increased foliage necrosis with increasing water carrier volume; however, there was as much variation within water carrier volume as was apparent between water carrier volumes. Individual experiment data for soybeans, cotton, peanuts, and sorghum is given in Appendix, Tables XVII through XXI.

It appears from visual observations that glyphosate applied at a rate of 1.68 or 2.52 kg/ha in a water carrier volume of 187 l/ha provided johnsongrass foliage necrosis generally longer than glyphosate applied at 122 l/ha. Although glyphosate at either rate applied at a water carrier volume of 122 l/ha achieved quicker initial johnsongrass foliage necrosis.

Less johnsongrass foliage necrosis was noted in sorghum experiments with all glyphosate rates and water carrier volumes as compared to the other three crops. Foliage necrosis ranged from 15% obtained with glyphosate applied at 1.68 kg/ha in a water carrier volume of 140 l/ha to 50% johnsongrass foliage necrosis obtained with glyphosate applied at 3.36 kg/ha in a water carrier volume of 187 l/ha. Although not as evident, a slight trend in decreased foliage necrosis was evi-

TABLE IV

AVERAGE JOHNSONGRASS FOLIAGE NECROSIS IN SOYBEANS, COTTON, AND PEANUT EXPERIMENTS

	Glyphosate Rate (kg/ha)														
	1.68					2.24		2.52					3.36		
	Carrier Volume (l/ha)														
Crop	122	140	169	187	374	122	187	122	140	169	187	374	122	187	374
Soybeans															
Location I	30	-	-	55	-	-	-	50	-	-	35	-	-	-	-
" II	30	-	-	35	-	-	-	30	-	-	40	-	-	-	-
" III	47	-	-	57	-	-	-	74	-	-	65	-	-	-	-
" IV	47	-	-	37	49	-	-	74	-	-	74	73	-	-	-
" V	33	-	-	45	-	-	-	58	-	-	65	-	-	-	-
Cotton															
Location VI	33	-	-	60	-	-	-	78	-	-	73	-	-	-	-
" VII	80	-	-	37	-	-	-	80	-	-	82	-	-	-	-
" VIII	35	-	-	63	-	-	-	55	-	-	65	-	-	-	-
Peanuts															
Location XII	68	-	78	-	-	-	-	85	-	58	-	-	-	-	-
Sorghum															
Location XIII	-	15	-	-	-	-	-	-	23	-	-	-	-	-	-
" XIV	-	-	-	-	-	38	34	-	-	-	-	-	48	50	38
*Avg.	45	-	78	49	49	-	-	65	-	58	63	73	-	-	-

*Averages over soybeans, cotton, and peanuts only.

dent as carrier volume increased. The reason for lower foliage necrosis in sorghum can be explained by the reduced coverage obtained, this is attributed to the minimal height differential between the johnsongrass and sorghum at time of RCS application.

It was also noted that when johnsongrass treated with glyphosate before or during early anthesis the panicle inflorescence dried and the florets aborted before reaching physiological maturity. The degree to which this phenomenon occurred generally increased with increasing rate of glyphosate applied, and with increasing johnsongrass foliage necrosis.

Johnsongrass Foliage Drop

The amount of johnsongrass foliage drop below the crop canopy appears to agree with johnsongrass foliage necrosis data (Table V). Johnsongrass foliage drop generally increased with increased glyphosate rates. Individual experiment data for soybeans, cotton and peanuts are given in Appendix, Tables XVII through XX, respectively. Although no data was available, it was observed that little, if any, foliage drop occurred in sorghum experiments at all rates of glyphosate and water carrier volumes used. This event was apparently due to: (a) minimal amount of johnsongrass coverage obtained resulting in minimum johnsongrass control; and (b) the simple physical support of the johnsongrass by the sorghum due to the minimum height differential.

Johnsongrass Control After First Season

Individual experiment data for soybeans, cotton, and peanuts are given in Appendix, Tables XVII through XX, respectively.

TABLE V

AVERAGE JOHNSONGRASS FOLIAGE DROP IN SOYBEAN, COTTON, AND PEANUT EXPERIMENTS

	Glyphosate Rate (kg/ha)							
	1.68				2.52			
	Carrier Volume (l/ha)							
Crop	122	169	187	374	122	169	187	374
Soybeans								
Location I	8	-	10	-	10	-	8	-
" II	0	-	33	-	25	-	33	-
" III	20	-	23	-	42	-	33	-
" IV	19	-	11	22	37	-	42	37
" V	18	-	25	-	38	-	13	-
Cotton								
Location VI	32	-	33	-	50	-	48	-
" VII	30	-	8	-	38	-	35	-
" VIII	20	-	18	-	25	-	5	-
Peanuts								
Location XII	58	43	-	-	65	23	-	-
Avg.	23	43	20	22	38	23	30	37

Johnsongrass control averaged over soybeans, cotton, and peanuts did not appear to be affected by the water carrier volume in which glyphosate at a rate of 1.68 and 2.52 kg/ha was applied (Table VI). The difference in johnsongrass control obtained was due mainly on the rate of glyphosate applied. Generally more johnsongrass control was obtained with 2.52 kg/ha of glyphosate than at the 1.68 kg/ha rate. The glyphosate rate of 1.68 applied in water carrier volumes of 122, 169, 186 and 374 l/ha provided 45, 40, 59, and 57% johnsongrass control, respectively. Glyphosate applied at a rate of 2.52 kg/ha in water carrier volumes of 122, 169, 186, and 374 l/ha provided 56, 65, 74, and 92% johnsongrass control, respectively. Visual observations noted that exceptionally large johnsongrass plants (183 to 305 cm) were very difficult to control. As the RCS passed over these large plants they would not spring back up until the herbicide filament stream had already passed over them. This problem would have been minimized if higher clearance ground equipment would have been utilized in this research.

Crop Yields

Analysis of yield data from the soybean experiment designated as location III (Table VII) showed no significant yield differences between glyphosate treatments and the check. There were possible trends in increased soybean yields with the use of glyphosate at rates of 1.68 and 2.52 kg/ha applied in a RCS over soybeans.

Yields from a cotton RCS study location VIII (Table VII) showed no significant differences between glyphosate treatments.

Yields taken on a peanut experiment (Table VII) location XII showed that although there was a sizeable difference in yield of peanuts be-

TABLE VI

AVERAGE JOHNSONGRASS CONTROL IN SOYBEAN, COTTON, AND PEANUT EXPERIMENTS

	Glyphosate Rate (kg/ha)							
	1.68				2.52			
	Carrier Volume (l/ha)							
Crop	122	169	187	374	122	169	187	374
Soybeans								
Location I	45	-	48	-	45	-	60	-
" II	65	-	60	-	90	-	70	-
" III	57	-	77	-	33	-	73	-
" IV	37	-	31	57	77	-	85	92
" V	65	-	80	-	65	-	95	-
Cotton								
Location VI	28	-	68	-	68	-	63	-
" VII	45	-	15	-	55	-	75	-
" VIII	35	-	90	-	40	-	-	-
Peanuts								
Location XII	30	40	-	-	35	65	-	-
Avg.	45	40	59	57	56	65	74	92

TABLE VII

CROP YIELDS FOR SOYBEANS, COTTON, AND PEANUT RCS EXPERIMENTS

Treatment	Rate (kg/ha)	Johnsongrass Height (cm)	Carrier Volume (l/ha)	Yield* (kg/ha)
Soybeans				
Glyphosate	2.24	152	122	719
	3.36			679
	2.24		187	558
	3.36			470
Check	-	-	-	605
Cotton				
Glyphosate	1.68	31 to 76	122	128
	2.52			217
	1.68		187	306
	2.52			224
	1.68	122 to 244	122	222
	2.52			206
	1.68		187	228
	2.52			114
Check	-	-	-	130
Peanuts				
Glyphosate	2.24	91 to 152	122	1815
	3.36			1844
	2.24		187	1873
	3.36			1617
Check	-	-	-	1398

*Yields on the cotton experiment are presented as seed cotton.

tween the check (1398 kg/ha) and the highest yielding treatment (1873 kg/ha) no significant differences were obtained. Several reasons could be responsible for not obtaining significant yield differences the first season in all three crops above: (a) comparatively low yields obtained in the soybean and cotton experiments; (b) although significant johnsongrass foliage burn did occur, because of the stage of maturity of the crop at the time of application and the fact that the weed crop competition had already occurred, crop production was not influenced; and (c) only one glyphosate RCS application per growing season did not provide adequate johnsongrass control for significant yield differences to be obtained. Although no significatn yield differences were obtained from glyphosate applied in a RCS, advantages are apparent: (a) increased harvest efficiency by controlling johnsongrass foliage; (b) reduction of johnsongrass floret production, thereby reducing johnsongrass seedlings for subsequent seasons.

Two Stage RCS Johnsongrass Rate and Gallonage Studies

Visual crop injury ratings, johnsongrass foliage necrosis, johnsongrass foliage drop and johnsongrass control will be found in Appendix, Table XXII and XXIII for the two locations. Visual ratings show initial johnsongrass foliage necrosis of 23% with glyphosate applied at a rate of 1.68 kg/ha in a water carrier volume of 187 l/ha (Figure 2). This increased to 63% after approximately 5 weeks. Glyphosate applied at a rate of 2.52 kg/ha in a water carrier volume of 187 l/ha caused initial foliage necrosis of 56%, and increased after approximately 5 weeks to 76%. This is compared to glyphosate applied at a

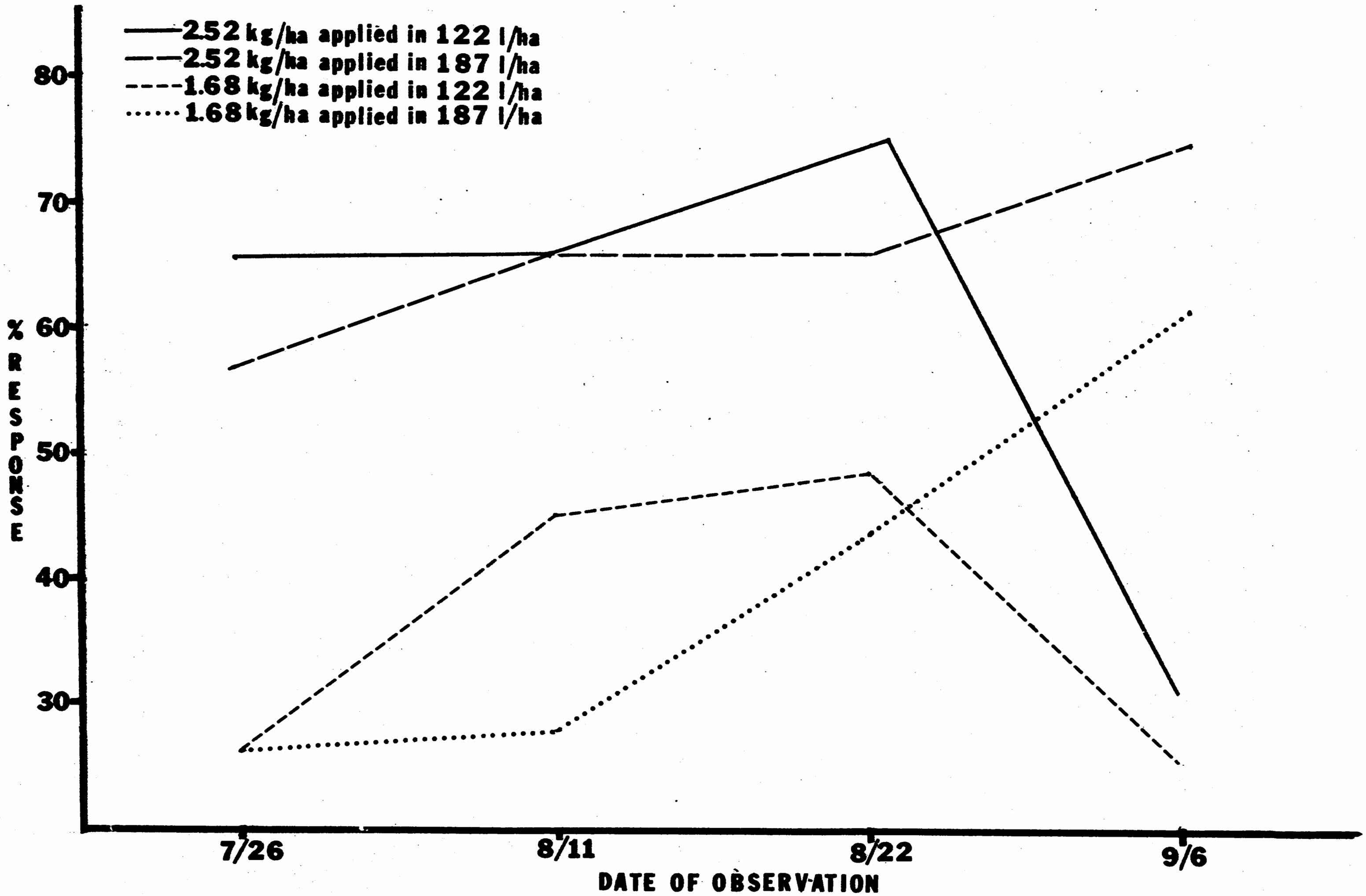


Figure 2. Effect of Glyphosate Applied at Two Rates in Two Water Carrier Volumes to Johnsongrass.

rate of 1.68 kg/ha in a water carrier volume of 122 l/ha which provided initial foliage necrosis of 23% and increased to 49% after 4 weeks, then declining to only 23% after approximately 5 weeks. Glyphosate applied at 2.52 kg/ha in water carrier volume of 122 l/ha caused initial foliage necrosis of 65%, and increased after 4 weeks to 75%. After 5 weeks, johnsongrass foliage necrosis declined sharply. These results showed that the water carrier volume used was very important in the degree of johnsongrass foliage necrosis obtained. Glyphosate applied at either 1.68 or 2.52 kg/ha in a water carrier volume of 187 l/ha provided 63 and 76% johnsongrass foliage necrosis after 5 weeks. This was compared to only 23 and 32% johnsongrass foliage necrosis obtained after 5 weeks with glyphosate rates of 1.68 and 2.52 kg/ha applied in a water carrier volume of 122 l/ha. Visual observations obtained from both experiments indicated that the height stage of johnsongrass at time of RCS treatment with both glyphosate rates (1.68 and 2.52) and water carrier volumes (122 and 187) did not seem to influence the amount of johnsongrass foliage necrosis, foliage drop or first season johnsongrass control obtained.

From these visual results of the effects of water carrier volume and johnsongrass control experiments were initiated to determine the effects of water carrier volume in the control of johnsongrass with glyphosate.

Glyphosate Carrier Volume Study

An RCS carrier volume study, designated as location IX, was initiated in 1978 to determine the effects of different water carrier volumes on the phytotoxicity of glyphosate applied at 1.68 and 2.52 kg/ha.

Individual treatment data is given in Appendix, Table XXIV. On the basis of visual ratings glyphosate applied at 1.68 kg/ha in a water carrier volume of 122 l/ha provided initial johnsongrass foliage necrosis of 15%. This decreased to 14% with a carrier volume of 187 l/ha (Figure 3). Johnsongrass foliage necrosis showed a steady decline to 6% when glyphosate was applied in water carrier volumes of 374 to 1308 l/ha. Similar results were found with glyphosate applied at 2.52 kg/ha in a water carrier volume of 122 l/ha, providing initial johnsongrass foliage necrosis of 24%, followed by an increase to 28% johnsongrass foliage necrosis with a water carrier volume of 187 l/ha. Johnsongrass foliage necrosis showed a steady decline to 8% with glyphosate applied in water carrier volumes of 374 to 1308 l/ha.

Glyphosate applied at 1.68 and 2.52 kg/ha in all water carrier volumes caused only slight cotton injury. Cotton injury noted was in the form of leaf burn and leaf necrosis. When leaf necrosis was noted, the cotton leaves would senesce off at the stipule, followed by replacement of new leaves in the canopy in 2 to 3 weeks. It appeared that the only leaf injury was from direct contact from the herbicide stream. Johnsongrass treated before or during early anthesis resulted in panicle inflorescence drying and the florets aborting before reaching physiological maturity.

Johnsongrass Control with Sequential RCS Treatments

Two experiments were initiated to determine the effects of sequential glyphosate treatments applied with a RCS. Although only location

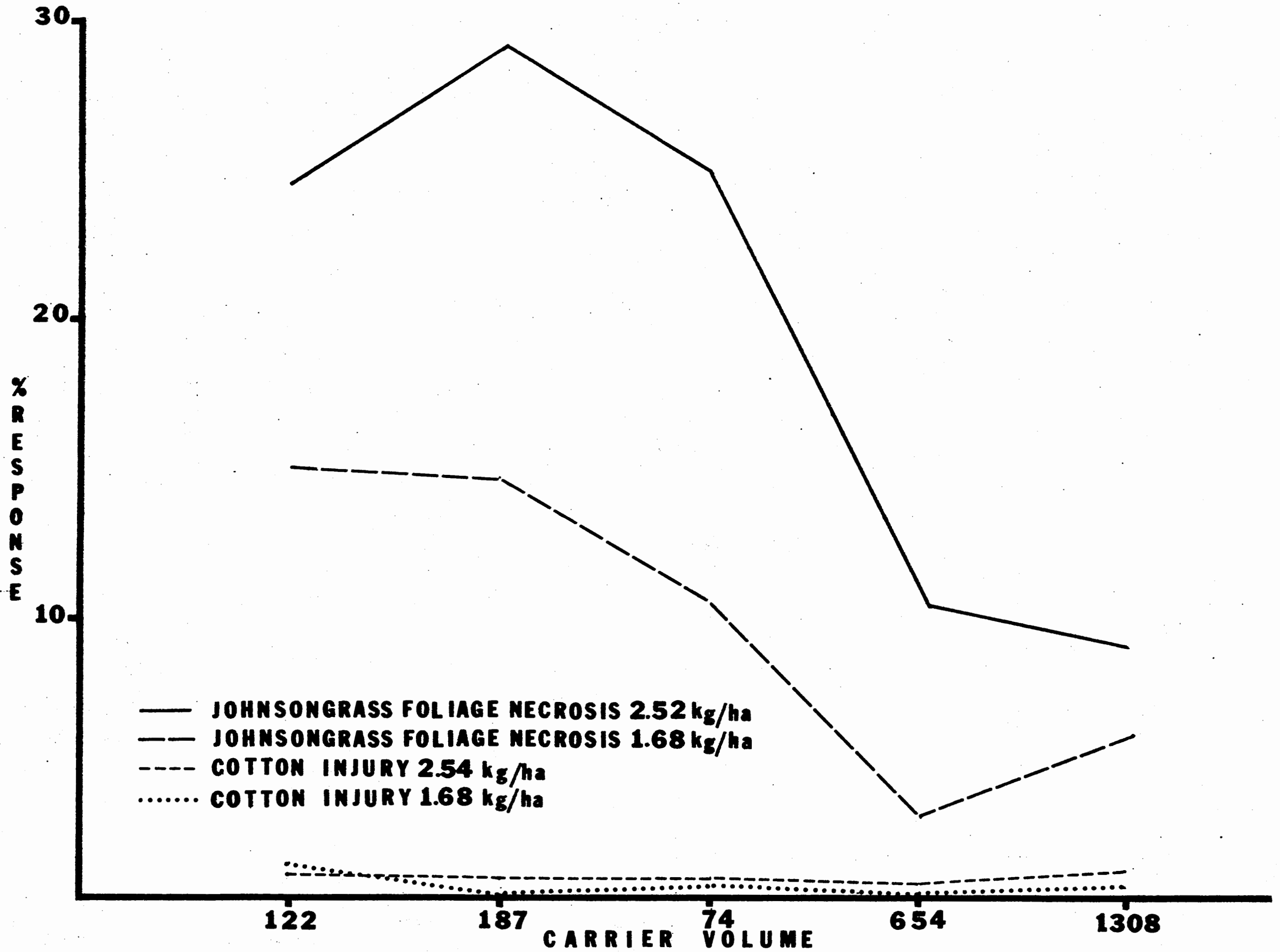


Figure 3. Effects of Rate of Glyphosate Applied in Several Carrier Volumes on Cotton and Johnsongrass.

XI will be discussed (Figure 4), all sequential data for both locations are given in Appendix, Table XXV.

Glyphosate applied at 2.52 kg/ha in a water carrier volume of 140 l/ha were initiated on day T_1, followed by sequential applications at T_1 plus 21 days, and T_1 plus 28 days, with single treatments on 21, and 28 days. The 21 and 28 day treatments were single treatments applied at the time of sequential applications for those intervals.

The sequence resulting in the best johnsongrass foliage necrosis and lowest cotton injury was the T_1 plus 28 days (Figure 4). Johnsongrass foliage drop and first season johnsongrass control followed the same pattern with the most effective johnsongrass foliage drop (49%), and the highest first season johnsongrass control (84%) being caused by treatments at T_1 plus a sequential application 28 days later.

This study indicates the need in many cases for a sequential glyphosate application for effective season long johnsongrass control. Also the sequential application 28 days later shows more promise in the control of johnsongrass than a sequential treatment 21 days after the initial treatment.

Non-Cropland Johnsongrass Control

A non-crop, postemergence, three-stage, johnsongrass control study, referred to as location XV, was initiated to determine the effects of several herbicides on johnsongrass control.

All herbicide treatments applied to johnsongrass 10 to 20 cm tall resulted in unacceptable control (Table VIII). Treatment of 36 to 46 cm tall johnsongrass resulted in several herbicides giving acceptable control (70 to 100%). Those treatments were as follows: glyphosate at

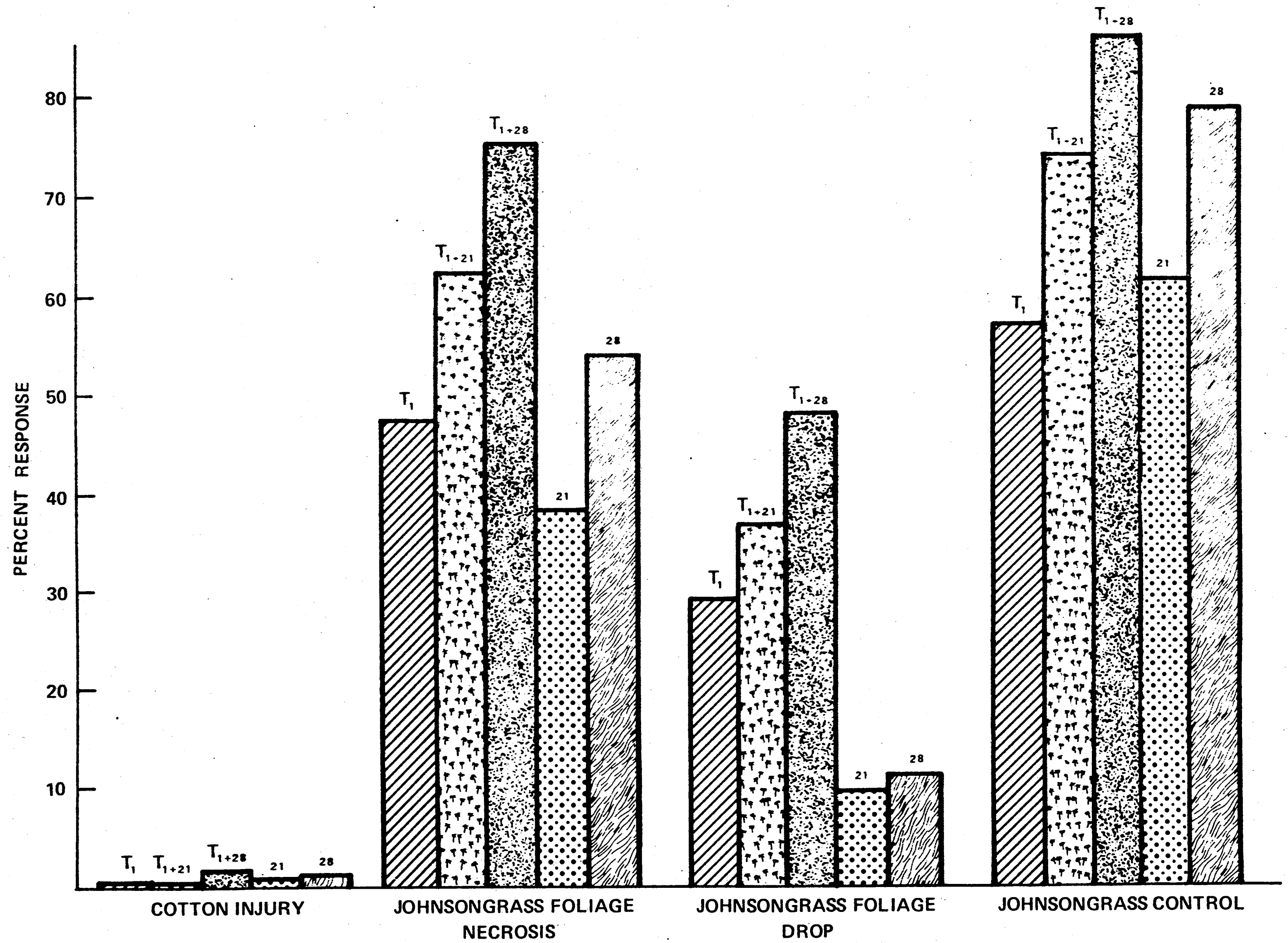


Figure 4. Johnsongrass Control with RCS Sequential Treatments.

TABLE VIII

RELATIONSHIP OF JOHNSONGRASS CONTROL TO HEIGHT AT THE TIME OF TREATMENT WITH POSTEMERGENCE APPLIED HERBICIDES (1978)

Treatment	Rate (kg/ha)	Johnsongrass Height at Time of Application (cm)	Visual Ratings: Percent Johnsongrass Control 6/23	6/29	7/14	8/11	8/24	9/26	10/12	$\bar{X}$
Glyphosate	1.12	10 to 20	50	53	40	3.0	--	--	0	29
	2.24		78	73	45	10	--	--	30	47
	3.36		88	80	27	13	--	--	38	49
Ethephon + Glyphosate	1.12 + 1.12		25	28	7.5	3.0	--	--	5	14
	1.12 + 2.24		55	58	32	13	--	--	20	36
Ethephon	1.12		0	0	0	0	--	--	3	1
MBR-18337	1.12		0	28	50	23	--	--	3	21
	3.36		11	40	72	40	--	--	15	36
Chlorflurenol + Glyphosate	2.24 + 2.24		68	65	45	15	--	--	23	43
Mefluridide + Glyphosate	2.24 + 2.24		85	50	71	15	--	--	38	52
Check	--		0	0	0	0	--	--	0	0
Glyphosate	1.12	36 to 46	--	--	94	85	68	--	60	77
	2.24		--	--	99	91	90	--	53	83
	3.36		--	--	100	95	--	--	47	81
Ethephon + Glyphosate	1.12 + 1.12		--	--	95	85	43	--	60	71
	1.12 + 2.24		--	--	100	87	48	--	35	68
Ethephon	1.12		--	--	2.5	60	58	--	63	46
MBR-18337	1.12		--	--	5.0	60	50	--	63	45
	3.36		--	--	2.5	0	15	--	5	6
Chlorflurenol + Glyphosate	2.24 + 2.24		--	--	100	85	73	--	60	80
Mefluidide + Glyphosate	2.24 + 2.24		--	--	97	93	90	--	60	85
Check	--		--	--	0	0	0	--	0	0
Glyphosate	1.12	76 to 102	--	--	--	--	38	52	58	49
	2.24		--	--	--	--	70	80	85	78
	3.36		--	--	--	--	90	80	85	85
Ethephon + Glyphosate	1.12 + 1.12		--	--	--	--	45	62	63	57
	1.12 + 2.24		--	--	--	--	3.0	15	15	11
Ethephon	1.12		--	--	--	--	18	25	18	20
MBR-18337	1.12		--	--	--	--	20	40	38	33
	3.36		--	--	--	--	68	80	85	78
Chlorflurenol + Glyphosate	2.24 + 2.24		--	--	--	--	68	82	80	77
Mefluidide + Glyphosate	2.24 + 2.24		--	--	--	--	53	72	78	68
Check	--		--	--	--	--	0	0	0	0

1.12, 2.24 and 3.36 kg/ha; chlorflurenol and mefluidide in combination with glyphosate at 2.24 plus 2.24 kg/ha. Herbicide treatments to johnsongrass 76 to 102 cm tall resulted in acceptable control in the following treatments: glyphosate at 2.24 and 3.36 kg/ha; MBR-18337 at 3.36 kg/ha; and chlorflurenol in combination with glyphosate at 2.24 plus 2.24 kg/ha.

In general, the effects noted on johnsongrass at all 3 heights were leaf burn and foliage necrosis except for the following herbicides: MBR-18337 at 1.12 and 3.36 kg/ha, caused stunting; while ethephon at a rate of 1.12 kg/ha caused stunting at all 3 treatment heights, and terminal bud necrosis at only the 36 to 46 cm height.

RCS Pigweed Control in Soybeans and Peanuts

Two experiments referred to as location XVI and XVII were conducted in soybeans and peanuts to determine the potential use of the RCS for pigweed control. Several selective and non-selective herbicides were included in these two experiments.

Only minor peanut injury was observed from any of the herbicides applied with the highest injury being 5 and 8% obtained with dicamba at 1.12 and 2.24 kg/ha after 4 weeks after application (Table IX). The minimal peanut injury noted was mainly due to the height differential between the peanuts and the pigweed. This height differential allowed for coverage of the pigweeds without allowing the herbicide stream to contact the peanuts. Several RCS treatments applied in soybeans did cause objectionable crop injury, mainly in the form of dead plants after 4 weeks after application. These treatments were as follows: glypho-

TABLE IX

PIGWEED CONTROL IN SOYBEANS AND PEANUTS WITH SELECTED HERBICIDES APPLIED WITH A RCS

			Percent Response*							
			Soybeans				Peanuts			
	Rate	Carrier Volume	Crop Injury		Pigweed Control		Crop Injury		Pigweed Control	
Treatment	(kg/ha)	(1/ha)	8/1	8/23	8/1	8/23	8/1	8/23	8/1	8/23
Glyphosate	2.24	187	5	23	25	45	0	0	8	13
	3.36		0	30	13	48	1	0	25	23
Glyphosate + Dicamba	2.24 + 1.12		60	90	78	74	0	0	0	0
	1.12 + 2.24		70	93	85	70	-	-	-	-
MSMA	1.12		0	0	0	8	0	0	0	0
	2.24		0	18	0	15	0	0	0	0
Dicamba	1.12		55	48	70	45	30	5	53	18
	2.24		68	90	78	60	23	8	73	30
2,4-DB	.84		30	13	45	30	5	0	48	18
	1.68		13	15	30	23	5	0	28	10
Paraquat	1.12		70	36	75	70	5	0	58	23
	2.24		78	68	85	84	13	0	68	39
Amitrol	2.24		25	15	35	28	1	0	15	4
Acifluorfen	1.12		0	0	18	3	0	0	13	0
Check	--		0	0	0	0	0	0	0	0

* Ratings taken 8/1 reflect early injury symptoms of chlorsis, leafburn, and stem curl. Ratings on 8/23 reflect dead plants, stem curl and leafburn. The higher injury ratings are generally the result of dead plants.

sate at 3.36 kg/ha; glyphosate in combination with dicamba at 2.24 plus 1.12 and 1.12 plus 2.24 kg/ha; dicamba applied at 1.12 and 2.24 kg/ha; and paraquat applied at 1.12 and 2.24 kg/ha.

Pigweed control averaged over both experiments 4 weeks after application showed varying levels of control depending on herbicide used and rate evaluated. The control of pigweed 4 weeks after application was generally observed as dead plants or necrotic top growth, with results as follows: unacceptable control (0 to 50%) with glyphosate applied at 2.24 and 3.36 kg/ha; MSMA applied at 1.12 and 2.24 kg/ha; dicamba applied at 1.12 and 2.24 kg/ha; 2,4-DB applied at .84 and 1.68 kg/ha; paraquat applied at 1.12 kg/ha; amitrol applied at 2.24 kg/ha; and RH-6201 applied at 1.12 kg/ha. Those treatments resulting in moderate control (60 to 75%) are as follows: glyphosate in combination with dicamba applied at 2.24 plus 1.12 and 1.12 plus 2.24 kg/ha; and paraquat applied at 2.24 kg/ha. No treatments evaluated provided greater than 75% pigweed control.

Mist and splash back from the catch tank during application with all herbicides except CP-70139 or Mon-0139 were observed; however, this was not excessive. No foaming problem was evident during application with any material used.

CHAPTER V

SUMMARY AND CONCLUSIONS

Field studies initiated in 4 agronomic crops utilizing an RCS revealed that regardless of height differential, or rate of glyphosate used, crop injury was not objectionable except possible with sorghum, where the glyphosate filament stream was maintained 0 to 10 cm below and above the crop canopy.

Johnsongrass foliage necrosis and johnsongrass foliage drop below the crop canopy were affected by increased glyphosate rate. Overall johnsongrass foliage necrosis and foliage drop increased in all 4 crops as the rate of glyphosate was increased. In respect to the effects of water carrier volume on johnsongrass foliage necrosis and foliage drop, it was found that both were not appreciably affected by water carrier volume when averaged over all experiments. In a few cases there appeared to be a trend of increased foliage necrosis with increasing water carrier volume; however, there was as much variation within water carrier volume as was apparent between water carrier volumes.

Results obtained from the RCS water carrier volume study showed that water carrier volume had a major effect on the amount of johnsongrass foliage necrosis and foliage drop with glyphosate applied at both 1.68 and 2.52 kg/ha. This water carrier volume effect was found with glyphosate at a rate of 2.52 kg/ha, and not found with the averages over all 4 crops, was apparently due to the minimal johnsongrass foliage necrosis and foliage drop obtained in the carrier volume study, thereby increasing the opportunity for water carrier volume to influence the effects obtained with glyphosate applied at 2.52 kg/ha at water carrier volumes of 122 to 1378 l/ha.

In respect to first season johnsongrass control the l/ha in which glyphosate at 1.68 and 2.52 kg/ha was applied did not appear to have a major effect on the amount of johnsongrass control. The differences in first season johnsongrass control was based mainly on the rate of glyphosate applied, with rates of glyphosate of 2.52 kg/ha averaging greater control than glyphosate applied at 1.68 kg/ha.

The two glyphosate sequential experiments initiated at a rate of glyphosate at 2.52 kg/ha in a water carrier volume of 187 l/ha demonstrated that sequential treatments are needed for the effective control of johnsongrass in row crops. Comparing the series of single and sequential treatments, the most effective treatment was T_1 plus a sequential application 23 days later. The highest johnsongrass control ratings and lowest crop injury ratings resulted from this particular sequence.

The two experiments in soybeans and peanuts to determine the potential use of the RCS for pigweed control resulted in varying degrees of crop injury and pigweed control. In general soybean injury was unacceptable compared to minimal injury noted in peanuts. A few treatments from both experiments showed a potential as possible treatments for further research in the control of pigweeds with an RCS. Those treatments showing this potential are as follows: glyphosate in combination with dicamba applied at 2.24 plus 1.12 kg/ha and 1.12 plus 2.24 kg/ha; and paraquat applied at 2.24 kg/ha. Although the other herbicides and combinations used provided unacceptable control, further research needs to be initiated with different rates and water carrier volumes to determine if the comparable results are obtained.

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APPENDIX

TABLE X

SPRAYING CONDITIONS AND PLOT INFORMATION FOR RCS SOYBEAN EXPERIMENTS (1977 to 1978)

	Location					
	I	II	III	IV	V	
Treatment Date	August 5, 1977	August 5, 1977	August 11, 1977	May 20, 1978	July 17, 1977	August 11, 1977
Experiment No.	WF7-1	WF7-2	HN7-4	MC8-1	BN7-3	
Location in Oklahoma	Webber Falls	Webber Falls	Haskell	Porter	Lake Carl Blackwell	
Travel Speed (km/hr)	8	8	8	8	8	
Row Spacing (cm)	102	102	102	102	102	
Tip Spacing (cm)	9	9	9	9	9	
Tip Size	D-2, D-3	D-2, D-3	D-2, D-3	D-2, D-2, D-5	D-2, D-2, D-3	
Pressure (g/cm^2)	703, 914	703, 914	703, 914	703, 914, 773	703, 1617, 703, 914	
Number of Tips	8	8	8	8	8	
Distance between Booms (cm)	203	203	203	203	203	
Soil Type	Mason clay loam Typic Arquistoll	Choska sandy loam Flurientic Haplustoll	Choteau silt Typic Paleudoll	Mason silt loam Typic Arguistoll	Port clay loam Flurientic Haplustoll	
% Sand	--	--	--	34	--	
% Silt	--	--	--	48	--	
% Clay	--	--	--	18	--	
% OM	--	--	--	1.5	--	
pH/Buffer Index	--	--	--	6.2/7.2	--	
CEC	--	--	--	13.2	--	
Crop Variety	--	Forrest	Forrest	Essex	Lee-74	
Crop Planted	--	--	--	May 20, 1978	July 11, 1977	
Air Temperature (°C)	32	36	--	39	36	21
Soil Temperature (°C)	30	34	--	38	39	20
Soil Moisture	Good	Good	Good	Dry	Dry	Good
Sky Conditions	Bright	Bright	Bright	Bright	Bright	Cloudy
Wind (km/hr)	3 to 5	3 to 5	--	3 to 6	0 to 8	Calm
Cotton Height (cm)	Fullbloom	Fullbloom	71	46 to 64	15 to 38	
Stage II	--	--	--	--	51 to 76	
Johnsongrass Height (cm)	152	Flowering	152	91 to 183	31 to 76	
Stage II					122 to 244	

TABLE XI

SPRAYING CONDITIONS AND PLOT INFORMATION FOR COTTON RCS EXPERIMENTS (1977)

	Location						
	VI		VII		VIII		
Treatment Date	July 28, 1977		July 27, 1977		July 17, 1977		August 11, 1977
Experiment No.	AN7-3		AN7-1		BN7-2		
Location in Oklahoma	Blair		Anadarko		Lake Carl Blackwell		
Travel Speed (km/hr)	8		8		8		
Row Spacing (cm)	102		102		102		
Tip Spacing (cm)	9		9		9		
Tip Size	D-2	D-2	D-2	D-2	D-2	D-2	D-3
Pressure (g/cm^2)	703	1617	703	1617	703, 1617	703	914
Number of tips	8		8		8		
Distance between booms (cm)	203		203		203		
Soil Type	Miles fsl		Cobb fsl		Port clay loam		
	Udic Paleustalf		Udic Haplustoll		Flurientic Haplustoll		
Crop Variety	Lankart 57		--		Westburn-M		
Crop planted	May 25, 1977		May 15, 1977		July 11, 1977		
Air Temperature (°C)	36		30		36		21
Soil Temperature (°C)	32		29		39		20
Soil Moisture	Good		Good		Dry		Good
Sky Conditions	Bright		Cloudy		Bright		Cloudy
Wind (km/hr)	0 to 8.0		0 to 5		0 to 8		Calm
Cotton Height (cm)	51 to 76		51 to 101			15 to 38	
Stage II	--		--			51 to 76	
Johnsongrass Height (cm)	122 to 181		122 to 181			31 to 76	
Stage II	--		--			122 to 244	

TABLE XII

SPRAYING CONDITIONS AND PLOT INFORMATION FOR RCS GALLONAGE STUDY (1978)

	Location				
	IX				
Treatment Date	July 17, 1978				
Experiment No.	MC8-2				
Location in Oklahoma	Altus				
Travel Speed (km/hr)	8	8	8	8	4
Row Spacing (cm)	102				
Tip Spacing (cm)	9				
Tip Size	D-2	D-2	D-5	D-6	D-6
Pressure (g/cm^2)	703	1617	844	773	773
Carrier Volume (l/ha)	122	187	374	654	1308
Number of Tips	8				
Distance between booms (cm)	203				
Soil Type	Tillman clay loam Typic Paleustoll				
% Sand	29				
% Silt	40				
% Clay	31				
% OM	0.6				
pH	6.8				
CEC	21.3				
Crop Variety	Westburn-M				
Crop Planted	May 10, 1978				
Air Temperature (°C)	38.9				
Soil Temperature (°C)	40				
Sky Conditions	Partly cloudy				
Soil Moisture	Good				
Wind (km/hr)	6 to 13				
Cotton Height (cm)	20 to 38				
Johnsongrass Height (cm)	61 to 91				

TABLE XIII

SPRAYING CONDITIONS AND PLOT INFORMATION FOR SEQUENTIAL RCS TREATMENTS (1978)

	Location				
	X		XI		
Treatment Date	June 27, July 24, 1978		June 27, July 18 & 24, 1978		
Experiment No.	AL8-4		AL8-3		
Location in Oklahoma	Altus		Altus		
Travel Speed (km/hr)	8		8		
Row Spacing (cm)	102		102		
Tip Spacing (cm)	9		9		
Tip Size	D-2	D-2	D-2	D-2	D-2
Pressure (g/cm^2)	1287	1287	1287	1617	1287
Number of Tips	16	16	16	8	16
Distance between booms (cm)	183	183	183	203	183
Soil Type	Tipton loam		Tillman clay loam		
	Padric Arguistoll		Typic Paleustoll		
% Sand	33		20		
% Silt	38		43		
% Clay	29		37		
% OM	1.1		1.4		
pH	6.8		6.6		
CEC	20.7		23.1		
Crop Variety	Westburn-M		Westburn-M		
Crop Planted	May 13, 1978		May 12, 1978		
Air Temperature (°C)	28	34	31	32	37
Soil Temperature (°C)	26	43	30	32	39
Sky Conditions	Partly cloudy		Partly cloudy		
Soil Moisture	Dry	Good	Dry	Good	Dry
Wind (km/hr)	13 to 19, 0 to 10		8 to 14, 6 to 13, 8 to 15		
Cotton Height (cm)					
T_1	10 to 15		20		
T_1 + 21 days			25 to 31		
T_1 + 28 days	51 to 76		31 to 64		
21 days			25 to 31		
28 days	51 to 76		31 to 64		
Johnsongrass Height (cm)					
T_1	31 to 61		31 to 61		
T_1 + 21 days			31 to 61		
T_1 + 28 days	61 to 91		31 to 64		
21 days			76 to 122		
28 days	91 to 127		91 to 114		

TABLE XIV

SPRAYING CONDITIONS AND PLOT INFORMATION FOR RCS JOHNSONGRASS CONTROL IN PEANUTS AND SORGHUM

	Location		
	XII	XIII	XIV
Treatment Date	July 27, 1977	August 26, 1977	July 18, 1978
Experiment No.	FT7-1	AN7-4	MC8-3
Location in Oklahoma	Ft. Cobb	Altus	Ponca City
Travel Speed (km/hr)	8	8	8
Row Spacing (cm)	102	102	102
Tip Spacing (cm)	9	10	9
Tip Size	D-2 D-3	D-2	D-2 D-2 D-5
Pressure (g/cm^2)	703 914	1055	703 1617 773
Number of Tips	8	8	8
Distance between booms (cm)	203	203	203
Soil Type	Lucien-Dill fsl Typic Haplustoll	Tillman clay loam Typic Palenstoll	Kirkland silt loam Abruptic Paleustoll
% Sand	--	--	20
% Silt	--	--	51
% Clay	--	--	29
% OM	--	--	2.2
pH/Buffer Index	--	--	5.5/6.9
CEC		--	17.2
Crop Variety	Tamnut	--	Paymaster R-1014
Crop Planted	June 27, 1977	1977	June 16, 1978
Air Temperature (^{o}C)	36.7	36.7	36.7
Soil Temperature (^{o}C)	30.	28.3	35.6
Soil Moisture	Good	Good	Good
Sky Conditions	Cloudy	Bright	Bright
Wind (km/hr)	0 to 3.2	11 to 15	3.2 to 8.0
Sorghum Height (cm)	--	89 to 102	51 to 61
Peanut Width (cm)	25 to 38	--	--
Johnsongrass Height (cm)	91 to 152	91 to 152	71 to 122

TABLE XV

SPRAYING CONDITIONS AND PLOT INFORMATION FOR NON-CROP POSTEMERGENCE JOHNSONGRASS CONTROL

	Location		
	Stage		
	I	II	III
Treatment Date	June 15, 1978	June 29, 1978	August 11, 1978
Experiment No.	LC8-1	LC8-1	LC8-1
Location in Oklahoma	LCB	LCB	LCB
Travel Speed (km/hr)	8	8	8
Tip Spacing (cm)	51	51	51
Tip Size	11004	11004	9504
Pressure (g/cm^2)	1547	1724	1687
Number of Tips	6	6	6
Soil Type		Port clay loam Flurientic Haplustoll	
% Sand	56	56	56
% Silt	34	34	34
% Clay	20	20	20
% OM	0.7	0.7	0.7
pH	6.7	6.7	6.7
CEC	10.6	10.6	10.6
Air Temperature (^{o}C)	30	34	29
Soil Temperature (^{o}C)	31	32	26
Sky Conditions	Bright	Bright	Bright
Soil Moisture	Good	Dry	Wet
Wind (km/hr)	10 to 14	0 to 6	3 to 10
Johnsongrass Height (cm)	10 to 13	36 to 46	76 to 102

TABLE XVI

SPRAYING CONDITIONS AND PLOT INFORMATION FOR PIGWEED CONTROL IN SOYBEANS AND PEANUTS WITH A RCS

	Location			
	Soybeans XVI		Peanuts XVII	
Treatment Date	July 26 & 28, 1978		July 26 & 28, 1978	
Experiment No.	PE8-7		PE8-6	
Location in Oklahoma	Perkins		Perkins	
Travel Speed (km/hr)	8		8	
Row Spacing (cm)	91		91	
Tip Spacing (cm)	9		9	
Tip Size	D-2		D-2	
Pressure (g/cm^2)	1617		1617	
Number of Tips	8		8	
Distance between booms (cm)	203		203	
Soil Type	Teller fsl Udic Arguistoll		Teller fsl Udic Arguistoll	
% Sand	50		64	
% Silt	32		24	
% Clay	18		12	
% OM	0.7		1.1	
pH/Buffer Index	6.3/7.0		5.3/6.9	
CEC	3.5		4.3	
Crop Variety	Forest		Spanhoma	
Crop Planted	June 14, 1978		June 14, 1978	
Air Temperature (°C)	37	21	37	21
Soil Temperature (°C)	35	26	35	26
Soil Moisture	Dry	Good	Dry	Dry
Sky Conditions	Partly cloudy,	Clear	Partly cloudy,	Clear
Wind (km/hr)	10	0 to 2	8	0 to 2
Soybean Hieght (cm)	10 to 20		--	
Peanut Width (cm)	--		15 to 20	
Pigweed Height (cm)	61 to 91		61 to 91	

TABLE XVII

JOHNSONGRASS CONTROL IN SOYBEANS WITH GLYPHOSATE APPLIED WITH A RECIRCULATING SPRAYER (1977)

		Percent Response by Visual Ratings																				
								Johnsongrass														
Glyphosate Rate (kg/ha)	Carrier Volume (l/ha)	Soybean Injury						Foliage Necrosis						Foliage Drop						Control		
		WF7-1		WF7-2		HN7-1		WF7-1		WF7-2		HN7-1		WF7-1		WF7-2		HN7-1		WF7-1	WF7-2	HN7-1
		8/24	9/19	8/24	9/19	8/24	9/2	8/24	9/19	8/24	9/19	8/29	9/2	8/24	9/19	8/24	9/19	8/29	9/2	9/19	9/19	9/2
1.68	122	0	0	0	0	0	0	40	20	40	20	40	53	0	15	0	0	0	40	45	65	57
	187	0	0	0	0	0	0	70	40	50	20	50	63	0	20	50	15	13	33	45	60	77
	122	0	0	0	0	0	0	60	40	40	20	66	82	0	20	0	50	16	67	45	90	33
	187	0	0	0	0	0	0	30	40	50	30	53	77	0	15	50	15	13	53	60	70	73
Check	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE XVIII

JOHNSONGRASS CONTROL IN SOYBEANS WITH GLYPHOSATE APPLIED WITH A RECIRCULATING SPRAYER (1978)

Glyphosate Rate (kg/ha)	Carrier Volume (l/ha)	Percent Response by Visual Ratings: Soybean Injury 8/1	Soybean Injury 8/17	Soybean Injury 8/24	Johnsongrass: Foliage Necrosis 8/1	Foliage Necrosis 8/17	Foliage Necrosis 8/24	Foliage Drop 8/1	Foliage Drop 8/24	Control 8/24
1.68	122	3.7	5	0	43	55	43	15	23	37
	187	0	2.5	3	40	35	35	3	18	31
	374	25		0	43	38	65	8	36	57
2.52	122	15	22	3	78	70	75	33	40	77
	187	11	25	13	68	73	80	33	50	85
	374	5	5	0	65	68	87	25	48	92
Check	-	0	0	0	0	0	0	0	0	0

TABLE XIX

JOHNSONGRASS CONTROL IN COTTON WITH GLYPHOSATE APPLIED WITH A RECIRCULATING SPRAYER (1977)

		Percent Response by Visual Ratings																				
								Johnsongrass														
Glyphosate Rate (kg/ha)	Carrier Volume (l/ha)	Cotton Injury						Foliage Necrosis						Foliage Drop						Control		
		AN8-3			AN8-1			AN8-3			AN8-1			AN8-3			AN8-1			AN8-3		AN8-1
		8/9	8/18	9/10	8/13	8/29	9/9	8/9	8/18	9/10	8/13	8/29	9/9	8/9	8/18	9/10	8/13	8/29	9/9	8/9	8/18	9/9
1.68	122	0	0	0	0	5	0	50	25	25	80	90	70	30	50	15	25	25	40	35	20	45
	187	0	0	0	0	10	0	55	55	70	40	40	30	15	40	45	5	10	10	70	65	15
2.52	122	0	5	0	0	0	0	60	90	85	75	90	75	25	60	65	45	25	45	85	50	55
	187	0	0	0	0	10	0	65	90	65	80	90	75	20	60	65	40	15	50	80	45	75
Check	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE XX

JOHNSONGRASS CONTROL IN PEANUTS WITH GLYPHOSATE APPLIED WITH A RECIRCULATING SPRAYER (1977)

Glyphosate Rate (kg/ha)	Carrier Volume (l/ha)	Peanut Injury 8/25	Peanut Injury 9/10	Johnsongrass Foliage Necrosis 8/25	Johnsongrass Foliage Necrosis 9/10	Johnsongrass Foliage Drop 8/25	Johnsongrass Foliage Drop 9/10	Johnsongrass Control 9/10
		Percent Responses by Visual Ratings						
1.68	122	0	0	60	75	35	80	30
	169	0	0	85	60	50	35	40
2.52	122	0	0	85	85	55	75	35
	169	0	0	40	75	10	35	65
Check	-	0	0	0	0	0	0	0

TABLE XXI

JOHNSONGRASS CONTROL IN GRAIN SORGHUM WITH GLYPHOSATE APPLIED WITH A RECIRCULATING SPRAYER

Glyphosate Rate (kg/ha)	Carrier Volume (l/ha)	Percent Response by Visual Ratings: Sorghum Injury 1977 8/5	1977 8/14	1978 8/1	1978 8/9	Johnsongrass Foliage Necrosis 1977 8/5	1977 8/14	1978 8/1	1978 8/9
1.68	140	0	0	–	–	20	10	–	–
2.24	122	–	–	15	20	–	–	48	28
	187	–	–	18	23	–	–	35	33
2.52	140	0	0	–	–	25	20	–	–
3.36	122	–	–	33	38	–	–	55	40
	187	–	–	27	30	–	–	60	40
	374	–	–	30	35	–	–	43	33
Check	–	0	0	0	0	0	0	0	0

TABLE XXII

EFFECT OF GLYPHOSATE RATE, RECIRCULATING SPRAYER CARRIER VOLUME, AND HEIGHT AT TIME OF APPLICATION ON SOYBEANS, AND JOHNSONGRASS INJURY (1977)

Glyphosate Rate (kg/ha)	Carrier Volume (l/ha)	Height at Time of Application		Percent Response by Visual Ratings														
				Soybean Injury				Johnsongrass										
								Foliage Necrosis				Foliage Drop				Control		
		Soybeans	Johnsongrass	7/26	8/11	8/22	9/6	7/26	8/11	8/22	9/6	7/26	8/11	8/22	9/6	8/11	8/22	9/6
1.68	122	15 to 38 cm	51 to 76 cm	5	0	0	0	15	45	60	25	0	15	60	25	40	50	50
	187			5	0	0	0	30	30	60	65	0	20	60	25	45	25	100
2.52	122			10	0	0	0	80	80	75	35	10	45	70	40	70	70	70
	187			10	0	0	0	65	80	85	75	10	55	80	45	75	60	90
1.68	122	30 to 76 cm	122 to 244 cm	–	0	0	0	–	–	50	15	–	–	0	35	–	–	65
	187			–	0	0	0	–	–	35	55	–	–	–	25	–	–	80
2.52	122			–	0	5	0	–	–	75	40	–	–	10	65	–	–	65
	187			–	0	0	5	–	–	55	75	–	–	0	25	–	–	95
Check		--	--	–	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE XXIII

EFFECT OF GLYPHOSATE RATE, RECIRCULATING SPRAYER CARRIER VOLUME, AND HEIGHT AT TIME OF APPLICATION ON COTTON AND JOHNSONGRASS INJURY (1977)

Glyphosate Rate (kg/ha)	Carrier Volume (l/ha)	Height of Time of Application		Percent Response by Visual Ratings																		
				Cotton Injury				Johnsongrass												
								Foliage Necrosis				Foliage Drop				Control		
		Cotton	Johnsongrass	7/26	8/11	8/22	9/6	7/26	8/11	8/22	9/6	7/26	8/11	8/22	9/6	8/11	8/22	9/26
1.68	122	15 to 38 cm	51 to 76 cm	0	0	0	0	30	45	45	20	0	30	40	30	40	40	35
	187			0	0	0	5	15	20	25	60	0	10	25	20	30	30	100
2.52	122			0	0	0	0	50	50	70	20	0	30	80	20	50	45	40
	187			0	0	0	8	50	50	65	82	0	45	45	55	55	45	90
1.68	122	30 to 76 cm	122 to 244 cm	0	0	0	0	-	-	40	30	-	-	0	40	-	-	35
	187			0	0	0	5	-	-	55	70	-	-	10	25	-	-	90
2.52	122			0	0	0	0	-	-	80	30	-	-	10	40	-	-	40
	187			0	0	0	3	-	-	60	70	-	-	0	10	-	-	-
Check		--	--	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE XXIV

RELATIONSHIP OF WATER CARRIER VOLUME AND GLYPHOSATE RATE ON JOHNSONGRASS CONTROL AND COTTON INJURY (1978)

Glyphosate Rate (kg/ha)	Carrier Volume (l/ha)	Percent Response from Visual Ratings								
		Cotton Injury				Foliage Necrosis				Foliage Drop
		7/28	7/31	8/7	8/22	7/28	7/31	8/7	8/22	8/7
1.68	122	3	0	1	0	3	23	25	9	3
	187	0	0	0	0	3	23	19	9	5
	374	0	0	1	0	1	14	20	10	0
	654	0	0	0	0	0	5	3	5	0
	1308	0	1	1	0	1	13	6	4	0
2.52	122	1	1	1	0	9	37	35	13	10
	187	0	0	3	0	9	43	43	18	13
	374	1	1	0	0	9	45	30	16	8
	654	1	1	0	0	4	20	10	7	0
	1308	0	1	3	0	0	13	11	9	0
Check	-	0	0	0	0	0	0	0	0	0

TABLE XXV

JOHNSONGRASS CONTROL IN COTTON WITH SEQUENTIAL GLYPHOSATE TREATMENTS APPLIED WITH A RECIRCULATING SPRAYER (1978)

			Percent Response by Visual Ratings								
	Glyphosate	Carrier	Cotton Injury								
Time of	Rate	Volume	AL8-4			AL8-3					
Application	(kg/ha)	(l/ha)	7/11	7/25	9/7	7/11	7/25	7/31	8/7	8/22	$\bar{X}$
T_1	2.52	140	0	0	0	0	0	0	1	0	.1
T_1 + 21			–	–	–	0	0	0	0	0	0
T_1 + 28			0	0	0	0	3	3	1	0	.9
21			–	–	–	–	0	3	0	0	.8
28			–	–	0	0	0	0	3	0	.5
Check	–	–	0	0	0	0	0	0	0	0	0
			Johnsongrass Foliage Necrosis								
T_1	2.52	140	46	33	13	50	60	43	50	29	41
T_1 + 21			–	–	–	53	73	70	65	49	62
T_1 + 28			58	73	17	45	73	90	90	78	66
21			–	–	–	–	40	38	43	34	39
28			–	–	45	–	3	63	80	71	52
Check	–	–	0	0	0	0	1	0	0	0	0
			Johnsongrass Foliage Drop								
T_1	2.52	140	28	15	–	23	55	33	30	10	28
T_1 + 21			–	–	–	21	53	30	43	30	35
T_1 + 28			35	30	–	20	73	55	53	46	45
21			–	–	–	–	13	8	15	8	11
28			–	–	–	0	0	10	25	29	13
Check	–	–	0	0	–	0	0	0	0	0	0
			Johnsongrass Control								
T_1	2.52	140	–	77	0	–	92	65	55	25	52
T_1 + 21			–	–	–	–	96	85	67	42	73
T_1 + 28			–	77	12	–	90	87	90	69	71
21			–	–	–	–	100	72	50	20	61
28			–	–	44	–	–	85	85	57	68
Check	–	–	–	0	0	–	0	0	0	0	0

VITA[2]

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