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The effects of fall applications of glyphosate on johnsongrass, soy beans, and corn

Jewell R. English Jr.

To the Graduate Council:

I am submitting herewith a thesis written by Jewell R. English Jr. entitled "The effects of fall applications of glyphosate on johnsongrass, soy beans, and corn." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Plant, Soil and Environmental Sciences.

Larry S. Jeffery, Major Professor

We have read this thesis and recommend its acceptance:

Laurence N. Skold, Elmer L. Ashburn

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

To the Graduate Council:

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We have read this thesis and recommend its acceptance:

Elmer L. Ashburn

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THE EFFECTS OF FALL APPLICATIONS OF GLYPHOSATE ON JOHNSONGRASS, SOYBEANS, AND CORN

A Thesis
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ABSTRACT

Controlling johnsongrass [*Sorghum halepense* (L). Pers.] in such agronomic crops as corn (*Zea mays* L.) and soybeans [*Glycine max* (L.) Merr.] presents a major problem to many farmers. Although several preemergence herbicides have been developed to control seedling johnsongrass, in general rhizome johnsongrass is primarily responsive only to foliar-applied chemicals. One such postemergence chemical which gives excellent control of rhizome johnsongrass is glyphosate (N-phosphonomethyl glycine). If glyphosate is applied in the spring, a waiting period is required both before spraying to allow johnsongrass foliage to develop and then for translocation of the herbicide following application. As this waiting period may cause an undesirable delay in planting date, a fall application would be more favorable.

The objectives of this study were (1) to determine the effectiveness of fall applications of glyphosate for controlling rhizome johnsongrass, (2) to determine the response of corn and soybeans to glyphosate applications made immediately prior to crop maturity, at maturity, and following maturity.

A field experiment was conducted at Ames Plantation, Grand Junction, Tennessee, and at the Knoxville Plant Science Field Laboratory, Knoxville, Tennessee. The corn treatments were applied at various grain moisture levels beginning at about 45 percent and continuing through 15 percent. Soybean treatments were applied at one week intervals beginning at three weeks prior to crop maturity and continuing

through two weeks past maturity. Johnsongrass treatments corresponded to soybean treatments, except for one early fall treatment applied on August 29. Due to calibration error, the rates of glyphosate application varied between locations. The resulting rates were 1.68 kg/ha at Ames Plantation and 2.24 kg/ha at Knoxville.

The glyphosate application made at Knoxville on corn at the 47 percent grain moisture level caused a significant reduction in seed moisture and weight at harvest. However, when the corn was treated at grain moisture levels of 40 to 15 percent, the glyphosate had no effect on lodging, yield, seed moisture, or seed weight at either location. Corn progeny germination was not affected by any of the glyphosate applications. Nevertheless, treatments at grain moisture levels of 35 percent and higher caused serious reductions in progeny seedling emergence, vigor, and weight at 21 days. The emergence of abnormal progeny seedlings was also increased by these same treatments. In addition, there tended to be a reduction in primary root length of these injured seedlings.

The glyphosate application made three weeks prior to soybean maturity at Ames reduced seed weight. This treatment also produced drastic reductions in progeny seedling emergence, vigor, weight at 21 days, and primary root length. Furthermore, this treatment increased dry matter content of the seedlings. The subsequent treatments at Ames, as well as all the treatments at Knoxville were applied after the onset of soybean senescence. Consequently, these treatments caused no effect whatsoever on the treated soybeans or their progeny.

Protein and oil content of the corn and soybean seed from treated plants was not affected by any of the fall applications of glyphosate.

The earliest glyphosate treatments produced the best control of rhizome johnsongrass. Applications made between August 29 and October 18 resulted in 80-95 percent rhizome control. Treatments made on October 24 and 31 gave only fair rhizome control, while no control resulted from a November 7 application.

From these data, the optimum treatment stage for controlling johnsongrass in corn or soybeans would appear to be (1) when the corn grain moisture level is below 35 percent, (2) after the onset of soybean senescence, and (3) prior to mid October if johnsongrass is to be controlled in either crop.

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CHAPTER I

INTRODUCTION

Johnsongrass [Sorghum halepense (L.) Pers.] is listed internationally as one of the ten worst weeds and occurs in all the major agricultural areas of the warm regions of the world (27). Tennessee is no exception to this problem. Johnsongrass continues to rob Tennessee farmers of profits by decreasing yields of cotton, soybeans, corn, and other important agricultural crops by competing for nutrients, light, and water and by interfering with harvesting efficiency (56).

By means of rhizomes and seeds, this weed is rapidly infesting much of the valuable crop land. In recent years, researchers have discovered both cultural and chemical controls which effectively reduce populations of seedling johnsongrass, but are less successful on rhizome johnsongrass. For best results, these chemicals require a waiting period of two to three weeks prior to planting in the spring. This period is necessary for the development of johnsongrass foliage prior to the application of the herbicides, and for translocation of the chemicals throughout the johnsongrass before tillage. Most farmers find themselves in a rushed planting season each spring and short of time. Consequently, a two to three week preplanting period is not always practical. One of the cultural practices for johnsongrass control includes a series of diskings, and thus presents the same "time problem" as do the previously mentioned herbicides.

Glyphosate (N-phosphonomethyl glycine), commercially available as "RoundUp," was recently introduced by Monsanto as a foliar herbicide for johnsongrass control. The activity of this herbicide is similar to that of dalapon (2, 2-dichloropropionic acid), except it seems to be less sensitive to environmental conditions at the time of application. A foliar application of either herbicide is absorbed by the johnsongrass and translocated to all parts of the plant, including the root system. Since glyphosate is not specific for johnsongrass, it is also toxic to corn, soybeans, and other crops. In the spring, it must be applied to the johnsongrass before the crop is planted. The johnsongrass must be ten to fifteen inches tall at the time of application. A waiting period also is required to allow time for translocation of the herbicide into all portions of the johnsongrass plant. This total waiting period may cause more delay than most farmers would care to have.

A fall application may be more desirable. If a johnsongrass-infested crop could be sprayed with glyphosate at a time which would result in no crop damage and yet obtain the desired johnsongrass control, a practical method of control would have been discovered.

Experiments are needed to determine appropriate dates for glyphosate application to control johnsongrass without injury to the crop. Residual glyphosate in the crop and the effects of the herbicide on progeny of the treated plants should be determined.

The objectives of this experiment were:

1. Determine the effectiveness of fall applications of glyphosate for controlling johnsongrass.

2. Determine the effect of fall applications of glyphosate on corn when applied immediately prior to corn maturity, at maturity, and following maturity.
3. Determine the effect of fall applications of glyphosate on soybeans when applied immediately prior to soybean maturity, at maturity, and following maturity.

CHAPTER II

LITERATURE REVIEW

Glyphosate (N-phosphonomethyl glycine) is a member of a new class of herbicides with an exceptional degree of herbicidal activity. Members of the group also have a capacity to translocate readily and thereby kill many annual weeds, as well as perennial weeds having vegetative propagules such as rhizomes and tubers (8).

Application rates necessary for control vary with weed species. Baker (10) reported that glyphosate at 1.12[1] to 4.48 kg/ha applied before water-sowing rice into a stale seedbed gave excellent control of red rice (Oryza sativa L.). Welker and Reimer (57) found that 3.36 to 6.72 kg/ha completely controlled waterlily [Nymphaea odorata (L.) Ait.] and spatterdock (Nuphar sp. Sm.) within two months of application. Cooley and Smith (19) achieved 97 percent control of silverleaf nightshade [Solanum elaeagnifolium (L.) Cav.] with 1.7 kg/ha of glyphosate. Research by Kirby and Santelmann (30) showed that 90-100 percent control of Carolina horsenettle (Solanum carolinense L.) could be obtained from 2.24, 3.36, or 4.48 kg/ha of glyphosate, and that the optimum time of application was at the postbloom to fruit set stage. Carpenter and Hensley (16) attained 99 percent control of field bindweed (Convolvulus arvensis L.) with two 4.48 kg/ha applications of glyphosate.

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[1]Unless otherwise indicated, all herbicide rates are reported as kilograms per hectare of active ingredient.

Messersmith (35) acquired a 99 percent reduction of leafy spurge (Euphorbia esula L.) and a 97 percent reduction of Canada thistle [Cirsium arvense (L.) Scop.] with 2.24 kg/ha of glyphosate.

Three exceptionally troublesome weeds which have shown susceptibility to glyphosate are nutsedge (Cyperus sp. L.), quackgrass [Agropyron repens (L.) Beauv.], and johnsongrass [Sorghum halepense (L.) Pers.]. Zandstra et al. (60) found that three applications of glyphosate at 2.24 or 4.48 kg/ha during an 8 month period followed by rotary cultivation to a depth of 15 cm and two further applications of glyphosate, reduced purple nutsedge (Cyperus rotundus L.) tuber production by 92 percent compared with an untreated control. Tweedy et al. (53) confirmed this low tolerance of nutsedge to glyphosate by achieving excellent control of purple nutsedge and yellow nutsedge (C. esculentus L.) using glyphosate at 3.36 kg/ha in split applications at the 6-, 9-, and 12-leaf stages. Stoller and Wax (47) agreed that 2.24 and 4.48 kg/ha of glyphosate applications gave 100 percent control of yellow nutsedge.

Baird and Begeman (5) reported that 2.24 kg/ha of glyphosate applied in the spring provided greater than 90 percent control of quackgrass for longer than four months and that no advantage was observed where a similar application had been made in the autumn. Valgardson and Corns (55) found that late summer spraying was as effective as spring spraying in achieving at least a 90 percent reduction of quackgrass foliage and rhizomes using 2.8 kg/ha of glyphosate. Hall and Parochetti (25) verified that glyphosate at

1.68 kg/ha or 3.36 kg/ha gave a good knockdown of quackgrass foliage. The 3.36 kg/ha rate gave the greatest kill of rhizomes and at 10 months later showed better control than the 1.68 kg/ha rate. Application time was studied by Brockman et al. (14) and found to be correlated with the quackgrass control obtained from glyphosate. Applications were more effective at the 4- to 6-leaf than at the 2- to 3-leaf stage. This work concurred with Baird and Begeman's finding that glyphosate applied at the 4-leaf stage was more effective than when applied at the 1-1/2- to 2-leaf stage.

Johnsongrass control with glyphosate has been consistently good in research at various locations. Rom and Talbert (43) noted that glyphosate at 2.24 kg/ha applied on May 9 followed by 1.12 kg/ha on June 17 showed 97 percent control of 6- to 9-inch high johnsongrass on September 1 and gave similar control of established bermudagrass [Cynodon dactylon (L.) Pers.]. Glyphosate at 3.36 kg/ha applied on June 26 following terbacil (3-tert-butyl-5-chloro-6-methyluracil) application at 2.24 kg/ha in April eliminated johnsongrass within 60 days. Terbacil was used to control seedling johnsongrass. Roeth (41) found that glyphosate at 1.12 to 2.24 kg/ha applied to johnsongrass foliage in June reduced rhizome stem emergence by 85-95 percent. Overton et al. (36) stated that over-the-top applications of glyphosate at 0.56 kg/ha gave approximately 80 percent control of johnsongrass regardless of growth stage, but that directed applications in soybeans were less effective. McWhorter (34) reported that from April to August overall applications of glyphosate at 0.84 to 4.48 kg/ha gave excellent control of johnsongrass from rhizomes. Rates of 0.56 to 1.12 kg/ha applied to the lower 25 cm of 60-cm-high johnsongrass plants provided 50 to 90 percent control for several weeks (34). Likewise, Crawford and Rogers (20) demonstrated that glyphosate at 1.68 and 3.36 kg/ha gave excellent control of rhizome johnsongrass when applied before soybean seedbed preparation, resulting in considerable increases in the yield of soybeans. Furthermore, Dowland and Tweedy (23) ascertained that johnsongrass plants 45, 120, and 200 cm high were adequately controlled by glyphosate at 2.24 and 3.36 kg/ha and that rhizome damage was greatest when glyphosate was applied to the more mature plants.

Extensive work has also been done to determine the physiological and biochemical behavior of glyphosate on plants. Terry (49) found that glyphosate at 2 kg/ha was most effective when applied to vigorous shoots of purple nutsedge with a sufficiently large leaf area to absorb the herbicide. After absorption glyphosate appears to move rapidly into the underground storage organs of perennial weeds. Trials by Terry also showed that cutting one day after treatment did not reduce glyphosate effects, indicating rapid translocation of the herbicide. Claus and Behrens (18) discovered that when all quackgrass rhizome buds were not killed by glyphosate translocation, those closest to the mother shoot survived. The C^{14} accumulation following applications of C^{14}-glyphosate was greatest in nodes near the rhizome tip and least in nodes near the mother shoot. This suggests that greater bud kill near the rhizome tip was due to larger accumulation of glyphosate in this part of the rhizome. While studying glyphosate's mechanism of action on quackgrass, Rioux et al. (40) noted that when only one shoot was sprayed on a rhizome supporting two shoots of the same leaf stage, glyphosate inhibited leaf growth on the untreated shoot at the two-leaf but not at the four-leaf stage. Similarly, glyphosate inhibited leaf growth on tillers when only the main shoot was sprayed. When only the tiller was sprayed, however, leaf production on the main shoot was not affected, suggesting that glyphosate is phloem mobile.

From research of glyphosate effects on chloroplast ultrastructure of quackgrass, Campbell et al. (15) noticed that glyphosate at 0.56, 1.12, 1.68, 2.24, and 4.49 kg/ha caused yellowing of the leaves after 72 hours at the higher rates and after 120 hours at the lower rates. Leaf discs harvested at 24 hours and examined under electron microscope showed partial to complete disruption of the chloroplast envelope and damage to other cell organelles even at the lowest rates.

Williams and Foley (58) pointed out that glyphosate sprayed at 1.1, 2.2, 4.5, or 6.7 kg/ha on bracken [Pterdidium aquilinum (L.) Kuhn] decreased the total carbohydrate content of the storage rhizome.

Glyphosate studies on yellow nutsedge by Boldt and Sweet (11) revealed that the numbers of tubers formed in each treatment were lower than those from untreated plants. Tuber germination was not reduced by the 1 to 3 kg/ha glyphosate applications except in plants treated when 25 cm high. Shoots of tubers from treated plants were normal in appearance. However, an increased number of shoots were formed by tubers from plants treated when 25-30 cm high. Applications made before plants reach 20 cm high were less effective than later applications. Magambo and Terry (32) noted that glyphosate appeared to induce or prolong purple nutsedge tuber dormancy or to inhibit normal sprouting mechanisms. Sprouting inhibition was even apparent in tubers taken from depths of 40-60 cm indicating that translocation had occurred.

Jaworski's (28) research on the mode of action of glyphosate revealed an apparent inhibition of the aromatic amino acid biosynthetic pathway. The growth inhibition of duckweed (Lemma gibba L.) in the presence of glyphosate could be alleviated by the addition of L-phenylalanine and L-tyrosine. The data suggest that glyphosate may inhibit or repress chorismate mutase or prephenate dehydratase, or both.

Roisch and Lingens' (42) research results were very similar to those of Jaworski. They found that the growth of Escherichia coli was completely inhibited by glyphosate at a concentration of 2×10^{-3}M. This inhibitory effect was partially removed by addition of phenylalanine. Tyrosine at the same concentration counteracted the inhibition to a lesser extent, while the effect of tryptophan was slight. The activity of glyphosate could be nullified by the addition of a mixture of all three amino acids. Glyphosate inhibited the enzyme 3-deoxy-2-oxo-D-arabinoheptonic acid 7-phosphate synthetase and 5-dehydroquinic acid. Both inhibitory effects were removed by the addition of Co^{2+}.

Research has revealed the lack of apparent preemergence or residual effect of glyphosate in the soil thus permitting seeding or transplanting of crops into the treated area immediately after application. Brewster and Appleby (13) incorporated 0, 33.6, and 67.2 kg/ha of glyphosate in a sandy loam soil prior to sowing winter wheat. No differences were found in the rate or the number of plants emerging and no visible injury was recorded. In a further study, a glyphosate drench was applied to wheat seeds 1, 2, and 4 days after sowing in moist soil and pots were irrigated immediately. Plants were injured by glyphosate at rates as low as 1.68 kg/ha suggesting that the herbicide is not instantly inactivated in soil, particularly in moist soil.

Sprankle (45) also studied factors affecting glyphosate activity in the soil. In a field study, glyphosate at 1.12 and 2.24 kg/ha applied in the late spring produced no injury to subsequent sowings of such crops as corn, soybeans, or navy beans. Glasshouse studies showed that glyphosate was readily deactivated in the soil but was absorbed in small quantities by corn and soybeans. Although 1.2×10^{-4}M glyphosate caused phytotoxicity to wheat grown in nutrient solution, wheat grown in clay loam or muck soil treated with 56 kg/ha of glyphosate showed no injury. Herbicide availability for plant uptake increased with increasing pH and phosphate levels in the soil. Glyphosate appeared to be bound rapidly in the soil with adsorption inversely related to the phosphate level in the soil. The herbicide was relatively immobile in the soil and was degraded to CO_2 (45).

After placing seed of Kentucky bluegrass, red fescue, and tall fescue on the soil surface and spraying with 4.48 kg/ha of glyphosate, Klingman (31) observed no significant differences between treatments.

In the glasshouse, Sprankle et al. (46) assayed the binding of glyphosate to bentonite clay with glyphosate-sensitive wheat seedlings. The glyphosate was strongly bound to clay complexed with Al, Fe, Zn, or Mn. Clay complexed with Mg, Ca, or Na did not bind the herbicide. Organic soil and charcoal also bound the herbicide, whereas ethyl cellulose did not. Phosphorus may compete with the glyphosate for binding sites in soil. A surface application of 56 kg/ha of the herbicide to a sandy loam soil did not affect the growth of the wheat seedlings in the bioassay. However, if 448 kg/ha of P_2O_5 was simultaneously applied, a significant reduction in the growth of the wheat seedlings occurred. Phosphate application one week after glyphosate application had no effect. As the pH of the soil decreased from 6.7 to 5.1, binding of the herbicide increased. Removal of glyphosate from solution by a sandy loam soil occurred within the first hour of contact and did not increase with time. It is postulated that initial inactivation of glyphosate in soil is by reversible adsorption to clay and organic matter through the phosphonic acid moiety (46).

Glyphosate has shown great potential for weed control in minimum tillage crops. Glyphosate plus residual herbicides have given excellent weed control and thus higher yields in no-tillage corn and soybeans (26, 37, 38, 59). This usage of glyphosate has led to much research dealing with the compatibility of glyphosate with other chemicals.

Suwunnamek and Parker (48) reported that most herbicides tended to have an antagonistic effect with glyphosate, especially those which inhibit photosynthesis. On the other hand, 2,4-D amine

[(2,4-dichlorophenoxy) acetic acid] and amitrole (3-amino-s-triazole) showed at least additive and sometimes synergistic effects. Striking activation was obtained with ammonium sulphate added at rates between 1.25 and 10 kg/ha. Other compounds causing almost equal activation were several ammonium phosphates and urea. Tucker (52) also pointed out that glyphosate appeared to suffer a slight reduction in initial activity when applied in mixtures with soil-acting herbicides. Bailey and Davison (4) likewise suggested that while a suitable soil acting herbicide should be used in conjunction with glyphosate, they should not be applied simultaneously.

Baird et al. (6) found that some residual herbicides, especially dicamba (3,6-dichloro-o-anisic acid) and bifenox [methyl 5-(2,4-dichlorophenoxy)-2-nitro-benzoate], appeared to be antagonistic in mixtures with glyphosate. From their results, translocational antagonism was suggested.

Somabhi (44) reported antagonistic effects on quackgrass, corn, and beans as a result of applications of glyphosate combined with herbicides such as simazine [2-chloro-4,6-bis(ethylamino)-s-triazine], alachlor, and 2,4-D. In all cases the interaction was overcome by increasing the rate of glyphosate. Simultaneous application of simazine on different leaves of the same plants or to the soil while glyphosate was applied to the foliage did not produce any visible interaction. In a subsequent experiment, rate of the inert ingredients used in a commercial formulation of simazine also reduced the activity of glyphosate.

In a preliminary report on the effect of mixing liquid fertilizers with glyphosate, Peters et al. (39) stated that most NPK carriers reduced the activity of 0.84 to 1.68 kg/ha of glyphosate. However, the activity of glyphosate at 1.68 kg/ha was not reduced by a polyphosphoric acid based carrier.

Environmental factors influencing phytotoxicity of glyphosate include humidity, light intensity, temperature, and rainfall. Caseley (17) reported that light level did not have a precise effect on ultimate survival of quackgrass treated with glyphosate, but that low temperature and high humidity appeared to enhance glyphosate activity. Baird et al. (9) agreed that glyphosate activity was best at relatively low temperatures (approximately 16°C) and when a rain-free period of 4 to 8 hours followed the herbicide application.

In glasshouse trials, Upchurch and Baird (54) found that johnsongrass plants were more effectively controlled under 2000 foot-candles of light than under 500 foot-candles whether exposed at 32°C or 16°C. Reduced light intensity also decreased glyphosate activity on Kentucky bluegrass (Poa pratensis L.). Photoperiods of 8 and 14 hours had no influence on the activity of glyphosate on johnsongrass plants.

Controlling weeds by postemergence broadcast applications of glyphosate in certain agronomic crops such as cotton, soybeans, corn, or other row crops is a problem because of low crop tolerance to the herbicide. After studying the response of cotton and soybeans to glyphosate applications at 0.56, 1.12, and 2.24 kg/ha, Overton et al. (36) found that cotton was most sensitive when treated at 30 cm high.

Soybeans showed some tolerance at all growth stages when the 0.56 kg/ha rate was used. The 2.24 kg/ha rate was toxic to both cotton and soybeans and the 1.12 kg/ha caused severe injury in most cases. Stoller and Wax (47) reported corn and soybean injury from applications of glyphosate at 2.24 and 4.48 kg/ha. Jeffery et al. (29) also encountered soybean injury and yield reductions resulting from postemergence applications of glyphosate at 0.56 and 1.12 kg/ha. Soybean susceptibility varied according to stage of growth at the time of application.

McWhorter (34) found that glyphosate rates of 0.56 to 1.12 kg/ha applied to soybeans caused 65 to 75 percent injury but the soybeans recovered to yield 2016 to 2352 kg/ha, compared with 538 kg/ha on untreated plots of soybeans infested with johnsongrass. Directed sprays of 1.12 to 2.24 kg/ha caused 33 to 53 percent injury when applied to soybeans 15 to 20 cm high and only slight injury when soybeans were 25 to 40 cm high. In efforts to control yellow nutsedge with glyphosate at 3.36 kg/ha in split applications at the 6-, 9-, and 12-leaf stages of the weed, Tweedy et al. (53) concurred that the treated soybeans sustained severe injury. Baird and Upchurch (7) reported that glyphosate applied as directed sprays to the basal 8 to 12 cm of the plant showed more activity against johnsongrass than against cotton, corn or soybeans, However, the low degree of selectivity evident was inadequate.

Autumn application of glyphosate has been studied extensively because of its advantages both on weed control and as a crop desiccant.

Derting et al. (22) discovered that the optimum time for controlling johnsongrass was in the late summer or early autumn when the plants were mature. Fell et al. (24) agreed that autumn applications of glyphosate were very effective for the control of rhizome johnsongrass. Arenstein found that when applied in late August, 0.36 and 0.72 kg/ha of glyphosate sprayed on grasses 40-60 cm tall killed all johnsongrass plants, including root systems (3). August applications of glyphosate were also found to be more effective than June applications on bermudagrass. The research results of Andrews et al. (2) likewise revealed that glyphosate was more active against johnsongrass and bermudagrass when applied in the summer or autumn than in the spring.

Derting (21) evaluated systems of weed control in soybeans with glyphosate at 24 locations in Arkansas and Mississippi. The highest levels of johnsongrass control were obtained from a system involving preharvest applications of glyphosate in the fall plus residual herbicides the following spring. Glyphosate applications at 1.12 to 2.24 kg/ha between September 7 and October 19 resulted in 80 to 90 percent control of johnsongrass. Progeny from the soybean plants treated prior to maturity exhibited a reduction in germination and seedling vigor. However, progeny from the soybean plants treated after maturity were unaffected by the glyphosate applications. Progeny from treated johnsongrass plants showed an increase in germination at the 1.68 kg/ha, but not at the 2.24 kg/ha rate of glyphosate, when compared to progeny from untreated plants. Seedling vigor was only slightly reduced. This system seems highly practical for grower adoption on early maturing varieties of soybeans after senescence and prior to frost and harvest. It aids in the harvest of the fall-treated crop while providing johnsongrass rhizome control during the following growing season without requiring a delay in planting date. Derting suggested that autumn applications are more effective on johnsongrass because of four factors: (1) more complete emergence of the infestation, (2) more favorable shoot/rhizome ratio, (3) more active transport into rhizomes, and (4) the prevention of recovery by oncoming senescence and cold weather.

One drawback to autumn applications of glyphosate is the detrimental effect of the herbicide on the seed of treated plants, including crops. May (33) found that localized application of a 10 percent solution of glyphosate to inflorescences of wild oat (Avena fatua L.) at the soft and hard cheese stages prevented formation of any seed capable of producing healthy plants.

Autumn applications of glyphosate have been made to grain sorghum [Sorghum bicolor (L.) Moench] for preharvest desiccation. Bovey et al. (12) found that glyphosate was more effective than sodium chlorate or paraquat [1,1'-dimethyl-4,4'-bipyridinium ion (as dichloride salts)] in reducing grain, leaf, and stem moisture content. The herbicide also reduced grain moisture content to 13 percent or lower within one week after treatment from original grain moisture content of 20, 30, or 40 percent. Glyphosate inhibited growth of auxiliary buds of grain sorghum and killed all established johnsongrass in treated areas. Lodging of grain sorghum was insignificant for three weeks following glyphosate treatment, despite heavy rainfall and high wind velocity. Standard 5-day germination tests indicated that rates of 2.24 and 4.48 kg/ha of glyphosate reduced germination of progeny from grain sorghum plants treated at 31 percent grain moisture content. The number of abnormal seedlings from treated plants was also increased with high rates of glyphosate. When grain sorghum was treated at grain moisture content of 20 percent, glyphosate at 2.24 kg/ha reduced germination and increased the number of abnormal seedlings. Germination of progeny from treated plants was not affected by glyphosate at rates of 0.56 and 1.12 kg/ha. Germination percentages were higher, and number of abnormal seedlings was lower on grain from plants treated with glyphosate when the seed head was covered during spraying. The low mammalian toxicity and the absence of phytoxicity from soil residue suggest that glyphosate may be a valuable preharvest grain sorghum desiccant.

CHAPTER III

METHODS AND MATERIALS

I. FIELD RESEARCH

This study was conducted at Ames Plantation near Grand Junction, Tennessee, and at the Knoxville Plant Science Field Laboratory, Knoxville, Tennessee. Thus a representative location was acquired in both ends of the state.

Plot Establishment

Prior to seedbed preparation, plot areas received broadcast applications of fertilizer according to soil test analysis and crop requirement. Recommended seedbed preparation practices were followed in preparing all plots for planting.

The corn plots at Ames Plantation (Ames) received nitrogen, phosphate, and potash at the rates of 168, 67, and 67 kg/ha, respectively. On April 22, 1975, conforming to University of Tennessee recommendations, the plots were planted with 'Pioneer 3147' corn, and then were treated with alachlor [2-chloro-r-(ethylamino)-6'diethyl-N-(methoxymethyl) acetanilide] and atrazine [2-chloro-r-(ethylamino)-6-(isopropylamino)-S-triazine] at 1.68 and 1.68 kg/ha, respectively.

The corn plots at the Knoxville Plant Science Field Laboratory (Knoxville) were also fertilized with 168, 67, and 67 kg/ha of N,

P_2O_5, and K_2O, respectively. After 4.48 kg/ha of EPTC (S-ethyl-dipropylthiocarbamate) + R-25788 antidote and 2.24 kg/ha of atrazine were applied on May 1, the plots were planted with 'Pioneer 3147' corn.

The soybean plots at Ames received 67 kg/ha of P_2O_5 and 67 kg/ha of K_2O. On April 24, profluralin [N-(cyclopropylmethyl)-a,a,a-trifluoro-2,6-dinitro-N-propyl-p-toluidine] was incorporated at the specified rate. On April 28, the plots were planted with 'Forrest' soybeans and treated with 0.84 kg/ha of linuron [3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea (N'-(3,4-dichlorophenyl)-N-methoxy-N-methylurea].

The Knoxville soybean plots were fertilized with 45 kg/ha of P_2O_5 and 45 kg/ha of K_2O. The plots were then planted with 'Forrest' soybeans on May 23 and received a cracking stage application of naptalam (N-1-naphthylphthalamic acid) plus dinoseb [2-sec-butyl-4,6-dinitrophenol (2-(1-methylpropyl)-4,-6-dinitrophenol)] on May 28, at 3.36 and 1.68 kg/ha, respectively.

The johnsongrass plots at Ames were located in poorly established stands and were not fertilized. As a result, the information obtained from these plots was not used for the conclusions of this research.

The johnsongrass plots at Knoxville were located in relatively moderate stands of established johnsongrass. However, to insure an adequate infestation, these plots were disked sufficiently to prepare a seedbed. Following seedbed preparation, johnsongrass seed and ammonium nitrate were broadcast June 4 at the rate of 83 kg/ha and 376 kg/ha, respectively.

All planting dates mentioned are within the range of recommended planting dates for corn, soybeans, and summer forage grasses in

Tennessee. To maintain weed-free plots, the corn and soybean tracts were cultivated and hand-hoed as necessary throughout the growing season.

Experimental Design

The experimental design used at each location was a randomized complete block with four replications. The treatments consisted of glyphosate applications to the corn, soybeans, and johnsongrass at various stages of development. These treatments were arranged consecutively beginning just prior to crop maturity and continuing until shortly after crop maturity.

The corn applications were based on and coordinated around the 35 percent moisture level of mature corn seed. Consequently, the intended moisture levels for glyphosate treatment were set at 55, 45, 35, 25, and 15 percent. The actual moisture levels at which the corn was treated with glyphosate varied slightly from the original proposal. Glyphosate applications to corn were conducted as described in Table 1.

Table 1. Corn Moisture Percentages at Various Glyphosate Treatment Dates at Ames Plantation and the Knoxville Plant Science Field Laboratory, 1975.

	AMES		KNOXVILLE	
TMT	% Moisture	Date	% Moisture	Date
1	--	--	47	August 18
2	38	August 22	41	August 25
3	32	September 9	35	August 29
4	25	September 23	26	September 9
5	15	October 9	20	October 10

The soybean application dates were arranged in accordance with the predicted maturity date for 'Forrest' soybeans at each location. Based on data from previous years, the maturity dates for the soybeans at Ames and Knoxville were anticipated to be October 14 and October 25, respectively. Therefore, the target dates for glyphosate treatment were set at one week intervals with three treatments preceding soybean maturation, one treatment at maturation, and two treatments succeeding soybean maturation. Specified plots were sprayed as close as the weather permitted to the original intended dates. The actual treatment dates are described in Table 2.

Table 2. Soybean Growth Stages at Various Glyphosate Treatment Dates at Ames Plantation and the Knoxville Plant Science Field Laboratory, 1975.

TMT	Soybean Growth Stage	Ames Date	Knoxville Date
1	Three Weeks Before Maturity	September 23	October 2
2	Two Weeks Before Maturity	September 30	October 10
3	One Week Before Maturity	October 9	October 18
4	Maturity	October 14	October 24
5	One Week Following Maturity	October 21	October 31
6	Two Weeks Following Maturity	October 28	November 7

The first application of glyphosate to the johnsongrass plots was scheduled for September 1 at both locations. The early treatment was so planned in order to determine the effect of the herbicide on johnsongrass which was vigorously growing. The control of johnsongrass obtained by a glyphosate application at this stage of active translocation would approximate the maximum johnsongrass control which glyphosate can provide (20). The remaining johnsongrass treatment dates were scheduled to coincide with the soybean treatment dates. This spray schedule allowed at least one simultaneous application of glyphosate to corn and johnsongrass at each location. By observing the effect that glyphosate has on corn, soybeans, and johnsongrass when applied on these dates, an optimum application date for each crop would be determined. An application of glyphosate on this chosen optimum date would allow maximum johnsongrass control with minimum crop damage.

Plot Size

Corn and soybean plot size varied between locations. The replications at Ames consisted of 4.1 x 18.3 meter plots and were separated by 4.6 meter alleys. At Knoxville, the plots had dimensions of 4.1 x 9.1 meters. The corn replications at the latter location were spaced by 1.0 meter alleys, while the soybean replications were arranged with 3.0 meter alleys between replications.

The johnsongrass replications at each location were comprised of 2.0 x 7.6 meter plots and separated by 1.0 meter alleys. A border strip measuring 1.6 x 7.6 meters was clipped as necessary between each plot.

Herbicide Application

When the fall treatments began, only the corn and soybeans occupying the two center rows in each plot were sprayed. In the johnsongrass areas, however, glyphosate was applied over the entire plot.

On the soybeans and johnsongrass at Ames the herbicide was applied in a spray volume of 187 L/ha at 2.1 kg/cm^2 of pressure using a tractor mounted plot sprayer. A CO_2 pressured back pack sprayer was used to deliver the same spray volume and pressure on the corn plots at Ames and on all the plots at Knoxville. The rate of herbicide application was based on pounds of active ingredient per gallon at Ames, and on pounds of acid equivalent per gallon at Knoxville. The resulting rates of application were 1.68 kg/ha at Ames and 2.24 kg/ha at Knoxville.

Data Collection

The corn and soybean plots at each location consisted of four rows spaced 1 meter apart. Data were collected from the middle 12.2 meters and 6.1 meters of the center two rows at Ames and Knoxville, respectively. Plant desiccation resulting from glyphosate treatments was observed and noted throughout the period of applications. At harvest, grain moisture levels, visual ratings of lodging, and yields were used as criteria for measuring crop response to glyphosate applications. As no corn lodging was observed, no visual ratings were necessary. The lodging data taken from the soybean plots were based on a scale of 0 to 100, with 0 being no lodging and 100 being complete lodging.

The soybeans and corn at Ames were machine harvested on October 31 and November 1, respectively, and the yields were converted to 13.5 and 15.5 percent moisture, respectively. At Knoxville, the soybeans and corn were manually harvested and then threshed on November 28 and October 25, respectively. These yields were also adjusted to the moisture levels mentioned above.

Two weeks after each glyphosate application to the johnsongrass plots at Knoxville, seed and plant residues were collected from each treated plot. Germination and residue studies were to be conducted on these materials. However, due to poor seed germination and the lack of a suitable method for the residue study, these two proposals were unsuccessful. Following the treatment period, the johnsongrass plots were left undisturbed until the next spring. The johnsongrass was then clipped and the soil surface of the plots treated with alachlor at the rate of 6.7 kg/ha to prevent the germination of any johnsongrass seed. From these plots, plant counts of rhizome johnsongrass and visual ratings of percent vigor reduction were used as criteria for measuring the effect of glyphosate on johnsongrass. The plant counts were taken from a random one square meter area per plot. The visual ratings were made on a 0 to 100 scale, with 0 being no reduction in plant population and vigor and 100 being complete kill of all plants. The degree of control was based on comparison with the untreated check in the same replication.

II. GREENHOUSE RESEARCH

To further investigate the effect of fall applications of glyphosate on corn and soybeans, seed from the fall treated plants were collected at harvest for germination and emergence tests. To check seed germination, 100 seeds from each plot were placed on a wet paper towel and maintained at a temperature of 75° F. in a growth chamber for one week. Water was applied as necessary to the towels to sustain adequate moisture for germination. After the one week period, percent germination of the seeds was tabulated.

For the seedling emergence tests, 200 seeds from each plot of fall treated plants were planted in flats containing a 50 percent perlite-50 percent peat media. The average daily high and low temperatures during the tests were 85° F. and 63° F., respectively. The seedlings were allowed to grow for a period of three weeks before being harvested.

Data collected included seedling emergence at 7, 10, and 21 days following planting. Other factors measured at 21 days involved seedling vigor reduction, total fresh and dry weight of seedling tops arising from 200 seeds, average fresh and dry weight per seedling top and per seedling root, dry matter percentage of seedling tops and of seedling roots, and average primary root length. The percentages of corn seeds yielding green, striated, and white seedlings were also recorded.

III. LABORATORY RESEARCH

Soybean and corn seed composition was also determined for possible glyphosate effects. Standard laboratory analysis procedures (1, 50) were employed to determine protein and oil content of the seed from fall treated plants.

CHAPTER IV

RESULTS AND DISCUSSION

I. FIELD RESEARCH

Ames Plantation

Corn

Seed yields. Corn seed yields produced by plants treated with glyphosate at the various grain moisture levels were not significantly different from the yields of untreated plants (Table 3).

Table 3. Yield, Seed Moisture, and Seed Weight of Corn Treated in the Fall With Glyphosate, Ames Plantation, 1975.

Time of Application (Moisture % of Corn)	Corn		
	Yield	Seed Moisture	Seed Weight
	kg/ha	%	mg/seed
38	7140 a*	13.8 a	301 a
32	7420 a	14.1 a	318 a
25	7330 a	14.3 a	302 a
15	7290 a	14.6 a	321 a
Check	7380 a	14.3 a	320 a

*Values for treatments followed by the same letter within columns are not significantly different at the 5 percent level of probability, according to Duncan's Multiple Range test.

Seed moisture. While glyphosate has been reported to act as a crop desiccant, seed moisture at harvest was unaffected by any of the glyphosate applications.

Seed weights. Corn seed weights of progeny from treated plants were not different from the seed weights of progeny from untreated plants.

Soybeans

Seed yields. Although soybean seed yield was reduced slightly by the preharvest glyphosate application on September 23, this reduction did not lead to a significant difference from the other treatments or the check (Table 4).

Table 4. Yield, Lodging, Seed Moisture, and Seed Weight of Soybeans Treated in the Fall With Glyphosate, Ames Plantation, 1975.

	Soybeans			
Application Date	Yield	Lodging	Seed Moisture	Seed Weight
	kg/ha	%	%	mg/seed
September 23	2910 a*	10.5 a	13.3 ab	133 a
September 30	3220 a	6.8 a	13.2 ab	141 b
October 9	3240 a	3.0 a	13.0 c	142 b
October 14	3220 a	4.5 a	13.1 bc	140 b
October 21	3250 a	4.0 a	13.1 bc	141 b
October 28	3240 a	7.5 a	13.3 ab	142 b
Check	3110 a	7.0 a	13.3 ab	140 b

*Values for treatments followed by the same letter within columns are not significantly different at the 5 percent level of probability, according to Duncan's Multiple Range test.

Lodging. Soybean lodging was increased somewhat by the September 23 treatment, however none of the treatments differed significantly from each other or the check.

Seed moisture. No definite trend in seed moisture resulted from any of the glyphosate applications. Only the October 9 treatment differed significantly from the check. The reasons for the reduction in seed moisture induced by this treatment are unknown.

Seed weight. Progeny from soybean plants treated with glyphosate on September 23 incurred a significant reduction in seed weight. This weight reduction suggests growth interference and retardation of the seed by the early glyphosate application. However, seed weight was unaffected by any of the remaining glyphosate treatments.

Knoxville Plant Science Field Laboratory

Corn

Seed yields. Due to a dry growing season corn yields were lowered. Corn seed yields produced by plants treated with glyphosate were affected only when the herbicide was applied at the 47 percent moisture level of the corn grain (Table 5). However, the reduced yields produced by this treatment were not significantly different from the yields produced by the check or the other treatments.

Seed moisture. Corn grain maintained a relatively high moisture level (above 15 percent) at harvest because of continued late season rainfall. Corn seed moisture was significantly reduced by the 47, 41, and 35 percent grain moisture treatments. Seed moisture was not influenced by subsequent glyphosate applications at grain moisture levels of 26 and 20 percent.

Table 5. Yield, Seed Moisture, and Seed Weight of Corn Treated in the Fall With Glyphosate, Knoxville Plant Science Field Laboratory, 1975.

Time of Application (Moisture % of Corn)	Corn		
	Yield	Seed Moisture	Seed Weight
	kg/ha	%	mg/seed
47	5400 a*	17.0 a	330 a
41	5880 a	17.4 ab	360 b
35	6190 a	17.7 b	362 b
26	5920 a	19.3 c	372 b
20	5910 a	19.4 c	367 b
Check	6250 a	18.9 c	362 b

*Values for treatments followed by the same letter within columns are not significantly different at the 5 percent level of probability, according to Duncan's Multiple Range test.

Seed weight. The glyphosate application to the corn plants at the 47 percent grain moisture level caused a significant decrease in seed weight at harvest. This reduction in seed weight indicates a retardation of grain development or possibly a desiccation effect on the grain. Corn seed weight was unaffected by glyphosate applied at lower grain moisture levels.

Soybean

Seed yields. No differences in soybean yields were prompted by any of the glyphosate applications made in October or November (Table 6).

Lodging. Soybean lodging at harvest was not affected by any of the fall applications of glyphosate.

Table 6. Yield, Lodging, Seed Moisture, and Seed Weight of Soybeans Treated in the Fall With Glyphosate, Knoxville Plant Science Field Laboratory, 1975.

Application Date	Soybeans			
	Yield	Lodging	Seed Moisture	Seed Weight
	kg/ha	%	%	mg/seed
October 2	1490 a*	26.3 a	13.6 a	121 a
October 10	1470 a	25.0 a	13.6 a	122 a
October 18	1580 a	41.3 a	14.0 a	128 a
October 24	1760 a	35.0 a	13.7 a	127 a
October 31	1500 a	33.8 a	13.6 a	123 a
November 7	1720 a	41.3 a	13.8 a	127 a
Check	1660 a	37.5 a	13.7 a	124 a

*Values for treatments followed by the same letter within columns are not significantly different at the 5 percent level of probability, according to Duncan's Multiple Range test.

Seed moisture. No seed moisture differences were observed in progeny from treated or untreated soybean plants.

Seed weight. Soybean seed weight showed no response to any of the glyphosate applications. This lack of response was probably due to the fact that all the glyphosate applications were made after the first signs of soybean senescence.

Johnsongrass

Spring rhizome johnsongrass counts. All glyphosate treatments except the one applied on November 7 produced significantly fewer rhizomes in the spring of 1976 than did the check (Table 7). As anticipated, the August 29 application controlled more rhizomes than any other treatment. This was significantly more control than was obtained from the October 31 and November 7 treatments. The first four October treatments led to significantly fewer spring rhizome plants than did the November 7 application.

Table 7. Spring Counts and Visual Control Ratings of Rhizome Johnsongrass in Plots Treated in the Fall With Glyphosate, Knoxville Plant Science Field Laboratory, 1975.

Application Date	Rhizome Johnsongrass		
	Plants/m^2	Visual Control Rating	
	----------4/15/76	-----------	6/21/76
		%	%
August 29	13 a	99 a	95 a
October 2	41 ab	89 a	75 a
October 10	50 ab	84 a	81 a
October 18	40 ab	84 a	79 a
October 24	39 ab	76 ab	53 b
October 31	86 bc	55 b	17 c
November 7	121 cd	20 c	6 c
Check	166 d	0 c	0 c

*Values for treatments followed by the same letter within columns are not significantly different at the 5 percent level of probability, according to Duncan's Multiple Range test.

Spring visual control rating. On April 15, 1976, rhizome johnsongrass control looked very good in the earlier glyphosate treatments. The control obtained from the glyphosate applications made from August 29 through October 24 did not vary significantly but was different from the control obtained by the November 7 treatment and the check. No difference in rhizome control occurred between the last two treatments applied in October, but both of these treatments controlled fewer rhizomes than did the November 7 treatment. The control obtained from the November 7 treatment did not differ from the check.

Summer visual control rating. On June 21, 1976, excellent rhizome control was prevalent from glyphosate treatments applied previously between August 29 and October 18. This control was significantly greater than that obtained by any treatment applied later than October 18. The October 18 treatment gave greater rhizome control than did the October 31 or November 7 treatment. There were no significant differences among the last two treatments and the nontreated check. This reduced johnsongrass control is probably due to a late season decrease in active growth and translocation in the treated plants.

II. GREENHOUSE RESEARCH

Ames Plantation

Corn

Seed germination. Corn seed from plants treated in the fall with glyphosate showed no decrease or increase in germination (Table 8).

Seedling emergence. When seedling emergence was evaluated at 7, 10, and 21 days after planting, the fall application of glyphosate to corn with a 38 percent grain moisture level caused a significant decrease in emergence. No significant differences were observed among the later treatments and the check.

Table 8. Germination and Emergence of Corn Seedlings Produced From Seeds of Plants Treated in the Fall With Glyphosate, Ames Plantation, 1975.

Time of Application (Moisture % of Corn)	Germination	Interval From Planting 7 Days	10 Days	21 Days
	%	----------% Emergence	--------	
38	93.5 a*	33.6 a	45.5 a	52.8 a
32	96.5 a	78.6 b	88.1 b	90.5 b
25	94.0 a	75.0 b	88.3 b	90.9 b
15	94.0 a	77.4 b	90.4 b	91.9 b
Check	95.3 a	75.5 b	88.8 b	91.5 b

*Values for treatments followed by the same letter within columns are not significantly different at the 5 percent level of probability, according to Duncan's Multiple Range test.

Seedling vigor reduction. Seedlings from corn plants treated at the 38 percent grain moisture level with glyphosate incurred a serious reduction in vigor (Table 9). The seedlings from all the later treatments and the check appeared normal and healthy.

Table 9. Vigor Reduction and Color of 21-Day-Old Corn Seedlings Produced From Seeds of Plants Treated in the Fall With Glyphosate, Ames Plantation, 1975.

Time of Application (Moisture % of Corn)	Vigor Reduction	Seedling Color Green	Striated	White
	%	-----% of Total Emergence	------	
38	55.0 a*	58.6 a	27.8 a	13.7 a
32	0.0 b	98.9 b	1.5 b	.4 b
25	0.0 b	99.3 b	.7 b	0.0 b
15	0.0 b	99.9 b	0.0 b	0.2 b
Check	0.0 b	100.0 b	0.0 b	0.0 b

*Values for treatments followed by the same letter within columns are not significantly different at the 5 percent level of probability, according to Duncan's Multiple Range test.

Seedling color. Seedlings from the corn plants treated at the 38 percent grain moisture level varied immensely in color. Shortly after emergence these seedlings appeared either green, white, or with green-white striations. A majority of the seedlings of plants which received a preharvest glyphosate application at the 38 percent grain moisture level were green. Green seedling emergence in this treatment was significantly lower than green seedling emergence from the check. The emergence of abnormal seedlings caused by glyphosate applied at the 38 percent grain moisture level was lower than green seedling emergence but still significantly greater than abnormal seedling emergence from all of the later treatments and the check. There were no significant atypical effects on seedling color produced by applying glyphosate to corn at the 32, 25, or 15 percent grain moisture level.

Apparently, the stronger response to glyphosate was evidenced by an increase in the amount of white area on the seedling. This abnormality in seedlings from plants treated in the fall with glyphosate agrees with the research of Bovey et al. (12) using glyphosate as a preharvest desiccation on grain sorghum.

Seedling weight and dry matter. The preharvest glyphosate application at the 38 percent grain moisture level caused significant reductions in both total fresh and dry weights of the 21-day-old corn seedlings (Table 10). No differences were observed among the other treatments and the check. No treatment affected the average fresh or dry weight per corn progeny seedling. The only preharvest glyphosate application affecting the percent dry matter of progeny seedlings was the 38 percent grain moisture level application. Percent dry matter was significantly increased by this treatment.

Table 10. Weight and Dry Matter Percentage of 21-Day-Old Corn Seedlings Produced From Seeds of Plants Treated in the Fall With Glyphosate, Ames Plantation, 1975.

Time of Application (Moisture % of Corn)	Fresh Weight		Dry Weight		Dry Matter
	Total	Average	Total	Average	
	g	mg/seedling	g	mg/seedling	%
38	30.5 a*	286 a	4.8 a	44.9 a	15.0 a
32	65.3 b	360 a	8.3 b	45.5 a	12.7 b
25	62.8 b	345 a	8.8 b	48.0 a	14.0 b
15	64.8 b	353 a	8.8 b	47.7 a	13.5 b
Check	61.0 b	334 a	8.3 b	45.1 a	13.6 b

*Values for treatments followed by the same letter within columns are not significantly different at the 5 percent level of probability, according to Duncan's Multiple Range test.

Seedling root weight, dry matter, and length. The average fresh or dry root weight of seedlings was reduced slightly by the preharvest glyphosate application at the 38 percent grain moisture level, but this reduction was not significantly different from the check (Table 11). Furthermore, no significant differences in average fresh or dry weights of the seedling roots existed among the glyphosate treatments. Moreover, the treatments had no effect on seedling root dry matter content. However, glyphosate applied preharvest to corn at the 38 percent grain moisture level significantly reduced primary root length of seedlings. No other treatments differed from the check.

Table 11. Weight, Dry Matter Percentage, and Length of 21-Day-Old Corn Seedling Roots Produced From Seeds of Plants Treated in the Fall With Glyphosate, Ames Plantation, 1975.

Time of Application (Moisture % of Corn)	Average Weight Per Root		Dry Matter	Primary Root Length
	Fresh	Dry		
	mg	mg	%	cm
38	1645 a*	168 a	10.2 a	23.9 a
32	2030 a	208 a	10.3 a	28.5 ab
25	2065 a	200 a	9.7 a	38.0 c
15	1995 a	200 a	10.0 a	33.0 bc
Check	1873 a	193 a	10.3 a	36.4 bc

*Values for treatments followed by the same letter within columns are not significantly different at the 5 percent level of probability, according to Duncan's Multiple Range test.

Soybeans

Seed germination. Soybean seeds from plants treated with glyphosate from three weeks prior to maturity (September 23) through two weeks after maturity (October 28) showed no reduction in germination (Table 12).

Seedling emergence. Soybean seedling emergence generally increased in treatments when evaluated at 7-, 10-, and 21-days after planting. Only soybean seed from the September 23 treatment showed significantly reduced seedling emergence. This treatment was applied before the onset of soybean senescence. All the later treatments were applied after the first signs of senescence and consequently caused no reduction in seedling emergence.

Table 12. Germination, Emergence, and Vigor Reduction of Soybean Seedlings Produced from Seeds of Plants Treated in the Fall With Glyphosate, Ames Plantation, 1975.

Application Date	Germination	Interval From Planting 7 Days	10 Days	21 Days	Vigor Reduction
	%	-------% Emergence-------			%
September 23	96.8 a*	70.3 a	86.4 a	86.4 a	80 a
September 30	99.5 a	86.9 b	94.1 b	96.3 b	0 b
October 9	99.3 a	93.8 b	95.3 b	93.5 b	0 b
October 14	98.3 a	94.8 b	96.9 b	96.9 b	0 b
October 21	98.0 a	93.0 b	94.3 b	96.5 b	0 b
October 28	98.0 a	94.8 b	96.0 b	95.6 b	0 b
Check	96.3 a	93.5 b	95.3 b	97.1 b	0 b

*Values for treatments followed by the same letter within columns are not significantly different at the 5 percent level of probability, according to Duncan's Multiple Range test.

Seedling vigor reduction. Soybean seedlings from plants treated with glyphosate on September 23 incurred an enormous loss of vigor. This response was probably due to a retardation of seed development caused by the glyphosate. Seedlings in all other treatments showed no vigor reduction.

Seedling weight and dry matter. Significant reductions occurred in total fresh and dry weights of 21-day-old seedlings from soybean plants treated three weeks prior to maturity (September 23) (Table 13). No other treatment produced seedlings having total fresh and dry weights different from those of the check. The September 23 treatment also caused a significant reduction in the average fresh weight per seedling. Average dry weight per seedling appeared to be reduced by this treatment, but was not significantly different from the check. Later applications of glyphosate did not reduce average fresh and dry weights per seedling. Although dry matter percent of the seedlings was increased significantly by the September 23 treatment, later glyphosate applications had no effect on seedling dry matter percentage.

Table 13. Weight and Dry Matter Percentage of 21-Day-Old Soybean Seedlings Produced From Seeds of Plants Treated in the Fall With Glyphosate, Ames Plantation, 1975.

Application Date	Fresh Weight		Dry Weight		Dry Matter
	Total	Average	Total	Average	
	g	mg/seedling	g	mg/seedling	%
September 23	106 a*	614 a	15.8 a	91.1 a	14.9 a
September 30	164 b	850 b	18.5 b	96.3 a	11.3 b
October 9	168 bc	895 bc	18.3 b	97.7 a	11.0 b
October 14	182 c	941 c	19.3 b	99.5 a	10.6 b
October 21	179 bc	926 c	19.0 b	98.6 a	10.7 b
October 28	178 bc	930 c	19.0 b	99.5 a	10.7 b
Check	176 bc	907 bc	18.5 b	95.2 a	10.5 b

*Values for treatments followed by the same letter within columns are not significantly different at the 5 percent level of probability, according to Duncan's Multiple Range test.

Seedling root weight, dry matter, and length. Glyphosate applied to soybean plants on September 23 seriously reduced the average fresh and dry weights of seedling roots (Table 14). Each October treatment produced a significant increase in average fresh weight per seedling root, but not in average dry weight per seedling root. This increase in fresh weight could be due to a slight stimulation of water uptake by the seedlings caused by the preharvest glyphosate treatments.

Table 14. Weight, Dry Matter Percentage, and Length of 21-Day-Old Soybean Seedling Roots Produced From Seeds of Plants Treated in the Fall With Glyphosate, Ames Plantation, 1975.

Application Date	Average Weight Per Root		Dry Matter	Primary Root Length
	Fresh	Dry		
	mg	mg	%	cm
September 23	105 a*	7.5 a	7.1 a	2.8 a
September 30	655 bc	31.6 b	4.9 bc	18.1 b
October 9	738 c	34.6 b	4.7 cd	22.9 c
October 14	732 c	31.6 b	4.3 cd	24.0 c
October 21	752 c	33.5 b	4.5 cd	24.1 c
October 28	714 c	29.6 b	4.2 d	20.2 bc
Check	584 b	31.1 b	5.3 b	21.7 bc

*Values for treatments followed by the same letter within columns are not significantly different at the 5 percent level of probability, according to Duncan's Multiple Range test.

The seedling roots of progeny from soybean plants treated with glyphosate three weeks prior to maturity (September 23) incurred a significant increase in dry matter percentage. All October treatments caused a significant decrease in dry matter percentage. This decrease in dry matter percentage may also be connected with an increase in water uptake by the seedling due to the fall glyphosate applications.

A drastic reduction in primary root length of the seedlings due to the September 23 treatment occurred. No other treatment differed significantly from the check.

Knoxville Plant Science Field Laboratory

Corn

Seed germination. The germination of seed from corn plants treated at various stages of grain moisture with glyphosate was not affected by the treatments (Table 15).

Table 15. Germination and Emergence of Corn Seedlings Produced From Seeds of Plants Treated in the Fall With Glyphosate, Knoxville Plant Science Field Laboratory, 1975.

Time of Application (Moisture % of Corn)	Germination	Interval From Planting 7 Days	10 Days	21 Days
	%	----------% Emergence---------		
47	95.5 a*	38.4 a	70.1 a	75.0 a
41	97.3 a	37.9 a	60.0 b	62.5 b
35	95.5 a	75.0 b	87.0 c	90.3 c
26	96.3 a	90.3 c	97.3 d	98.5 d
20	96.3 a	91.4 c	96.9 d	98.0 d
Check	94.8 a	83.5 bc	96.8 d	95.8 cd

*Values for treatments followed by the same letter within columns are not significantly different at the 5 percent level of probability, according to Duncan's Multiple Range test.

Seedling emergence. Regardless of preharvest treatment, emergence of the corn seedlings increased progressively at each evaluation taken 7-, 10-, and 21-days after planting. At the 7-day evaluation, seedling emergence was reduced significantly by preharvest glyphosate applications made when the seed was at the 47 or 41 percent grain moisture level. None of the last three treatments had any effect on emergence in comparison with the nontreated check. At the 10-day evaluation, the only seedlings not exhibiting a reduction in emergence were those arising from seeds of nontreated plants and of plants which received a preharvest application of glyphosate at the 26 or 20 percent grain moisture level. However, glyphosate applications at the 35, 41, and 47 percent grain moisture levels had produced progressively lower seedling progeny emergence, respectively. By the 21-day evaluation, only the seeds from plants treated with a preharvest application of glyphosate at the 47 or 41 percent grain moisture level still had emergences differing significantly from the check. The response shown by the seedling progeny to early treatments indicates that the preharvest glyphosate applications interfered with seed development.

Seedling vigor reduction. Corn seedling vigor was significantly reduced when preharvest glyphosate treatments were applied at the 47, 41, and 35 percent grain moisture levels (Table 16). No significant difference in vigor existed between seedlings arising from seeds treated with preharvest applications of glyphosate at the 47 and 41 percent grain moisture levels. However, these seedlings exhibited more vigor reduction than did seedlings from plants which received a preharvest glyphosate application at the 35 percent grain moisture level. A preharvest application of glyphosate at the 26 or 20 percent grain moisture level had no significant effect on progeny seedling vigor.

Seedling color. Corn progeny seedling appearance was unaffected by a preharvest glyphosate application at the 26 or 20 percent grain moisture level. Apparently, at these two stages the corn had matured sufficiently and did not translocate the herbicide through the plant. However, glyphosate applied at the 47, 41, or 35 percent grain moisture level resulted in a profound effect on seedling color. A preharvest glyphosate application at one of these three grain moisture levels caused seedlings to lack varying amounts of green pigmentation. These abnormal seedlings were either white or green and white striated. Abnormal white seedling emergence from seeds of plants treated at the 41 and 47 percent grain moisture levels were not different. However, a preharvest glyphosate application at the 47 percent grain moisture level produced significantly more abnormal striated and fewer normal green progeny seedlings than did an application at the 41 percent grain moisture level.

Table 16. Vigor Reduction and Color of 21-Day-Old Corn Seedlings Produced From Seeds of Plants Treated in the Fall With Glyphosate, Knoxville Plant Science Field Laboratory, 1975.

Time of Application (Moisture % of Corn)	Vigor Reduction	Seedling Color		
		Green	Striated	White
	%	-----% of Total Emergence------		
47	61.3 a*	34.3 a	41.3 a	24.4 a
41	53.8 a	48.8 b	30.0 b	21.2 a
35	18.8 b	75.5 c	16.8 c	7.7 b
26	5.0 c	100.0 d	0.0 d	0.0 c
20	8.8 bc	100.0 d	0.0 d	0.0 c
Check	0.0 c	100.0 d	0.0 d	0.0 c

*Values for treatments followed by the same letter within columns a are not significantly different at the 5 percent level of probability, according to Duncan's Multiple Range test.

A preharvest application of glyphosate at the 35 percent grain moisture level allowed an increase in emergence of green progeny seedlings that varied significantly from the first two treatments. Striated and white seedling emergence from progeny seeds of plants treated at the 35 percent grain moisture level were significantly less than that of plants treated at the 41 or 47 percent grain moisture level.

These data indicate that corn is still actively growing, translocating, and approaching maturity at the 47, 41, and 35 percent grain moisture levels.

Seedling weight and dry matter. Twenty-one-day-old seedlings from corn plants treated with glyphosate were harvested and weighed (Table 17). Significant reductions in total fresh and dry weights of seedlings were caused by the preharvest application of glyphosate at the 47 or 41 percent grain moisture level. Seedlings from these two treatments also incurred significant reductions in average fresh and dry weights. Progeny seedlings were unaffected by any of the subsequent treatments. The dry matter percentage of the corn seedlings was not influenced by any of the glyphosate treatments.

Seedling root weight, dry matter, and length. No apparent effect on seedling roots resulted from any of the treatments (Table 18). No differences were observed in average fresh or dry weight, dry matter percentage, or primary root length among the treatments.

Table 17. Weight and Dry Matter Percentage of 21-Day-Old Corn Seedlings Produced From Seeds of Plants Treated in the Fall With Glyphosate, Knoxville Plant Science Field Laboratory, 1975.

Time of Application (Moisture % of Corn)	Fresh Weight		Dry Weight		Dry Matter
	Total	Average	Total	Average	
	g	mg/seedling	g	mg/seedling	%
47	92 a*	612 a	9.8 a	65.0 a	10.6 a
41	80 a	637 ab	8.8 a	70.3 ab	11.1 a
35	140 b	777 abc	15.3 b	84.8 bc	10.9 a
26	150 b	765 abc	16.3 b	82.7 c	10.9 a
20	158 b	806 bc	17.8 b	90.7 c	11.4 a
Check	161 b	843 c	17.3 b	90.7 c	10.8 a

*Values for treatments followed by the same letter within columns are not significantly different at the 5 percent level of probability, according to Duncan's Multiple Range test.

Table 18. Weight, Dry Matter Percentage, and Length of 21-Day-Old Corn Seedling Roots Produced From Seeds of Plants Treated in the Fall With Glyphosate, Knoxville Plant Science Field Laboratory, 1975.

Time of Application (Moisture % of Corn)	Average Weight Per Root		Dry Matter	Primary Root Length
	Fresh	Dry		
	mg	mg	%	cm
47	1732 a*	159 a	9.1 a	22.6 a
41	1659 a	177 a	10.9 a	22.9 a
35	1862 a	176 a	9.5 a	22.9 a
26	1948 a	178 a	9.3 a	23.5 a
20	1769 a	186 a	10.6 a	27.3 a
Check	1760 a	176 a	10.0 a	26.2 a

*Values for treatments followed by the same letter within columns are not significantly different at the 5 percent level of probability, according to Duncan's Multiple Range test.

Soybeans

Seed germination. Soybean progeny germination was not affected by any of the preharvest treatments (Table 19).

Table 19. Germination, Emergence, and Vigor Reduction of Soybean Seedlings Produced From Seeds of Plants Treated in the Fall With Glyphosate, Knoxville Plant Science Field Laboratory, 1975.

Application Date	Germination	Interval From Planting 7 Days	10 Days	21 Days	Vigor Reduction
	%	-------% Emergence-------			
October 2	90.5 a*	63.1 a	72.9 a	75.4 a	2.5 a
October 10	81.5 a	64.6 a	71.4 a	73.0 a	0.0 a
October 18	76.8 a	65.1 a	68.9 a	69.5 a	1.3 a
October 24	84.0 a	62.3 a	69.9 a	70.4 a	1.3 a
October 31	87.8 a	57.1 a	63.8 a	64.5 a	1.3 a
November 7	87.3 a	61.8 a	67.8 a	69.6 a	1.3 a
Check	90.5 a	62.8 a	68.5 a	70.3 a	0.0 a

*Values for treatments followed by the same letter within columns are not significantly different at the 5 percent level of probability, according to Duncan's Multiple Range test.

Seedling emergence. When seedling emergence was evaluated at 7-, 10-, and 21-days from planting, no differences caused by the preharvest glyphosate treatments could be detected. This lack of response is probably due to the fact that the glyphosate applications in Knoxville followed the onset of soybean senescence.

Seedling vigor reduction. Due to senescence of the treated plants progeny seedling vigor also remained uninfluenced by any of the treatments.

Seedling weight and dry matter. When the 21-day-old soybean seedlings were harvested, no significant differences in total fresh and dry weights, average dry weight per seedling, or in seedling dry matter content were observed among the treatments (Table 20). The only measurable seedling response to the treatments was the average fresh weight per seedling. Progeny seedlings of plants treated with a preharvest application of glyphosate on October 2 exhibited a reduction in fresh weight per seedling, differing significantly from that of progeny seedlings from plants treated at later dates but not from the untreated check. Average fresh weights and dry matter percent of seedlings from plants treated with a preharvest glyphosate application between October 10 and November 7 tended to show that there had been an increase in water uptake by the seedlings due to the glyphosate treatment. None of the treatments, however, caused seedling fresh weights or dry matter content to vary significantly from the check. The reason for the lack of significant difference between the average seedling fresh weights of progeny from plants treated with a preharvest glyphosate application on October 2 from nontreated plants could be due to the reduced seedling fresh weight from plants in the check. No explanation can be offered for this reduced average seedling fresh weight.

Seedling root weight, dry matter, and length. A preharvest application of glyphosate on soybeans between October 10 and November 7 caused an increase in average fresh weight of progeny seedling roots but not in average dry weight of progeny seedling roots. This led to a

Table 20. Weight and Dry Matter Percentage of 21-Day-Old Soybean Seedlings Produced From Seeds of Plants Treated in the Fall With Glyphosate, Knoxville Plant Science Field Laboratory, 1975.

Application Date	Fresh Weight		Dry Weight		Dry Matter
	Total	Average	Total	Average	
	g	mg/seedling	g	mg/seedling	%
October 2	116 a*	770 a	15.5 a	103 a	13.4 a
October 10	124 a	845 b	15.8 a	108 a	12.7 a
October 18	120 a	859 b	15.3 a	110 a	12.7 a
October 24	121 a	865 b	15.5 a	111 a	12.9 a
October 31	112 a	873 b	14.0 a	110 a	12.7 a
November 7	120 a	861 b	15.3 a	110 a	12.7 a
Check	114 a	810 ab	14.3 a	109 a	13.4 a

*Values for treatments followed by the same letter within columns are not significantly different at the 5 percent level of probability, according to Duncan's Multiple Range test.

decrease in dry matter percentage of the progeny seedling roots (Table 21). This could be due to stimulated water uptake by the progeny seedlings caused by the glyphosate treatment.

Table 21. Weight, Dry Matter Percentage, and Length of 21-Day-Old Soybean Seedling Roots Produced From Seeds of Plants Treated in the Fall With Glyphosate, Knoxville Plant Science Field Laboratory, 1975.

Application Date	Average Weight Per Root		Dry Matter	Primary Root Length
	Fresh	Dry		
	mg	mg	%	
October 2	540 a*	33.9 a	6.3 a	18.2 a
October 10	690 bc	34.7 a	5.1 b	16.1 a
October 18	714 bc	35.3 a	5.0 b	19.3 a
October 24	691 bc	33.2 a	4.8 b	16.2 a
October 31	750 b	35.9 a	4.8 b	17.9 a
November 7	752 b	35.6 a	4.7 b	17.8 a
Check	577 ac	35.6 a	6.2 a	18.4 a

*Values for treatments followed by the same letter within columns are not significantly different at the 5 percent level of probability, according to Duncan's Multiple Range test.

The primary root length of progeny seedling roots remained unaffected by any of the preharvest glyphosate applications.

III. LABORATORY RESEARCH

Corn Seed Composition

None of the preharvest applications of glyphosate applied to corn at Ames or Knoxville exhibited any detectable effect on corn seed protein or oil percent (Tables 22 and 23).

Table 22. Protein and Oil Composition of Corn Seed From Plants Treated in the Fall With Glyphosate, Ames Plantation, 1975.

Time of Application (Moisture % of Corn)	Seed Composition	
	Protein	Ether Extract
	%	
38	10.7 a*	6.6 a
32	9.4 a	6.9 a
25	9.6 a	6.3 a
15	11.0 a	6.9 a
Check	10.3 a	6.6 a

*Values for treatments followed by the same letter within columns are not significantly different at the 5 percent level of probability, according to Duncan's Multiple Range test.

Table 23. Protein and Oil Composition of Corn Seed From Plants Treated in the Fall With Glyphosate, Knoxville Plant Science Field Laboratory, 1975.

Time of Application (Moisture % of Corn)	Seed Composition	
	Protein	Ether Extract
	%	
47	11.0 a*	10.4 a
41	11.1 a	11.2 a
35	11.4 a	11.1 a
26	10.3 a	11.6 a
20	10.5 a	11.1 a
Check	10.2 a	11.1 a

*Values for treatments followed by the same letter within columns are not significantly different at the 5 percent level of probability, according to Duncan's Multiple Range test.

Soybean Seed Composition

Soybean seed from plants treated at Ames and Knoxville with a preharvest application of glyphosate during a period from three weeks prior to maturity until two weeks following maturity showed no decrease or increase in protein or oil percent (Tables 24 and 25).

Table 24. Protein and Oil Composition of Soybean Seed From Plants Treated in the Fall With Glyphosate, Ames Plantation, 1975.

Application Date	Seed Composition	
	Protein	Ether Extract
	%	%
September 23	40.5 a*	21.1 a
September 30	41.0 a	20.8 a
October 9	42.3 a	20.3 a
October 14	40.2 a	20.6 a
October 21	42.4 a	20.0 a
October 28	41.4 a	20.0 a
Check	41.0 a	20.3 a

*Values for treatments followed by the same letter within columns are not significantly different at the 5 percent level of probability, according to Duncan's Multiple Range test.

Table 25. Protein and Oil Composition of Soybean Seed From Plants Treated in the Fall With Glyphosate, Knoxville Plant Science Field Laboratory, 1975.

Application Date	Seed Composition	
	Protein	Ether Extract
	%	
October 2	39.3 a*	15.1 a
October 10	40.2 a	16.5 a
October 18	42.3 a	12.7 a
October 24	35.7 a	16.1 a
October 31	40.8 a	15.5 a
November 7	33.3 a	15.8 a
Check	39.1 a	17.9 a

*Values for treatments followed by the same letter within columns are not significantly different at the 5 percent level of probability, according to Duncan's Multiple Range test.

CHAPTER V

SUMMARY AND CONCLUSIONS

This research was carried on to:

1. Determine the effectiveness of fall applications of glyphosate for controlling johnsongrass.
2. Determine the effect of fall applications of glyphosate on corn when applied immediately prior to corn maturity, at maturity and following maturity.
3. Determine the effect of fall applications of glyphosate on soybeans when applied immediately prior to soybean maturity, at maturity and following maturity.

The field experiment was conducted during the summer and fall of 1975 at Ames Plantation, Grand Junction, Tennessee, and at the Knoxville Plant Science Field Laboratory, Knoxville, Tennessee. Corn, soybeans, and johnsongrass received applications of glyphosate at various dates before, during, and after the maturity period of the two agronomic crops. At harvest, grain moisture levels, visual ratings on lodging, and yields were used as criteria for measuring crop response to glyphosate applications. Plant counts of rhizome johnsongrass and visual ratings of vigor reduction made in the spring following the fall application were used for measuring the response of johnsongrass to glyphosate applications. Seed from the treated and untreated crops at each location were examined in the greenhouse at Knoxville for germination, seedling emergence and vigor reduction, and seedling characteristics such as color, root length, and weight. The seeds were also analyzed in the laboratory at Knoxville for oil and protein content.

At Ames, data generally showed that a preharvest glyphosate application made on corn at the 38 percent grain moisture level exhibited no significant effect on lodging, yield, seed moisture, or seed weight. However, Knoxville data indicated that corn treated with glyphosate at the 47 percent grain moisture level incurred a significant reduction in seed moisture and weight, but not in lodging or yield. Treatments made after the 47 percent grain moisture level caused no yield or seed weight reductions.

Corn germination was not affected by any of the glyphosate applications. Emergence and vigor however, were significantly reduced by a preharvest glyphosate application at the 38 percent grain moisture level at Ames and at the 47, 41, and 35 percent grain moisture levels at Knoxville. The emergence of abnormal progeny seedlings was significantly increased by these same treatments. Total fresh and dry weights of seedlings arising from 200 seeds of plants treated with a preharvest application of glyphosate at the 38 percent grain moisture level at Ames and at the 47 and 41 percent grain moisture levels at Knoxville were significantly reduced. These two treatments at Knoxville also caused a decrease in the average fresh and dry weights per seedling. Corn seedling weights were unaffected by any of the subsequent treatments at either location. Only the seedlings from plants treated at the 38 percent grain moisture level at Ames exhibited an increase in dry matter percent. Dry matter percent of progeny seedlings was not affected by any of the treatments at Knoxville. The only effect of glyphosate detected on corn seedling roots was on primary root length. The only preharvest glyphosate applications at either location reducing primary root length were those applied at the 38 and 32 percent grain moisture levels at Ames. None of the glyphosate applications affected dry matter percent or weights of progeny seedling roots.

Only the glyphosate treatment made on soybeans at three weeks prior to maturity at Ames caused a significant reduction in seed weight. None of the subsequent treatments at Ames nor any of the treatments at Knoxville caused any reduction in seed weight. Glyphosate applications made as early as three weeks prior to soybean maturity produced no effect on yield, lodging, or seed moisture at either location.

Generally, the preharvest glyphosate applications on soybeans displayed no effect on seeds or seedlings of treated plants. This was probably due to the onset of soybean senescence prior to the applications. Only the glyphosate treatment three weeks prior to soybean maturity (September 23) at Ames caused injury to progeny seedlings. This treatment also increased the dry matter percent of seedlings. Furthermore, the roots of seedlings from this treatment incurred a significant reduction in average fresh and dry weights and in primary root length. Dry matter percent of these soybean seedling roots was increased significantly by this preharvest glyphosate application. Seedlings from treated soybean plants were not affected by any of the subsequent treatments at Ames, or by any treatments at Knoxville.

Protein and oil percent of the corn and soybean seed from treated plants was not affected by any of the fall applications of glyphosate.

Johnsongrass rhizome control at Knoxville resulting from fall glyphosate applications was good to excellent in all treatments made from August 29 through October 18. Treatments made on October 24 and 31 gave only fair rhizome control, while no control resulted from the November 7 treatment.

In conclusion, from the results of this research, an optimum fall application date for spraying glyphosate over-the-top of corn and soybeans to control johnsongrass can be described. This application date must give adequate johnsongrass control with minimum crop damage. For johnsongrass control in corn the best time to apply glyphosate is when the corn grain moisture is below 35 percent. A soybean application can be made safely after the onset of soybean leaf senescence (about two or three weeks prior to maturity). Best johnsongrass control will be obtained from treatments made not later than mid-October. This time will vary due to location and frost date.

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APPENDIX

Table A-1. Climatological Data for Ames Plantation and the Knoxville Plant Science Field Laboratory, April, 1975.

	Ames Plantation			Knoxville		
	Temperature, F.		Rainfall	Temperature, F.		Rainfall
Date	Max.	Min.	in.	Max.	Min.	in.
1	52	33		57	32	
2	72	35		68	45	
3	74	32		76	37	1.02
4	49	29		49	32	
5	56	32		52	35	
6	64	37		56	36	
7	65	39		57	29	
8	64	40		59	35	
9	64	51	.24	60	45	
10	68	51	1.40	68	53	
11	72	44		69	54	
12	51	32		67	40	
13	60	34		57	34	
14	63	36	.26	63	46	
15	56	46	.09	58	49	.20
16	64	43		57	38	
17	78	43		64	47	
18	73	58		77	59	
19	84	51	.50	79	55	.27
20	67	44		58	46	.33
21	69	40		69	42	
22	76	42		66	43	
23	81	47		73	49	
24	80	59		76	59	
25	83	60	.49	79	62	
26	82	61		80	59	
27	82	62		80	53	
28	86	64		82	57	
29	83	60	.42	84	66	
30	75	61	.53	78	58	
Temp. Ave.	69.8	45.5		67.3	46.5	
Total Rainfall			3.93			1.82

Table A-2. Climatological Data for Ames Plantation and the Knoxville Plant Science Field Laboratory, May, 1975.

	Ames Plantation			Knoxville		
	Temperature, F.		Rainfall	Temperature, F.		Rainfall
Date	Max.	Min.	in.	Max.	Min.	in.
1	77	58	.06	80	62	
2	72	48		77	57	
3	71	51	.31	67	53	
4	75	56		74	54	.08
5	77	52		78	45	
6	81	54		82	50	
7	80	62	.28	70	59	.20
8	78	62		78	58	.02
9	78	61	.13	79	61	.78
10	77	55		80	56	
11	81	57		78	53	
12	80	57	.22	77	59	.16
13	78	51		77	58	.19
14	77	52		79	52	
15	83	56	1.70	74	63	.04
16	68	58	.29	77	61	.94
17	70	58	.31	78	61	.02
18	71	55		79	65	
19	84	58		82	62	
20	86	62		84	58	
21	85	65		88	63	
22	86	65		87	65	
23	90	64		87	68	
24	88	68		88	67	
25	89	68		90	67	
26	87	68		83	65	
27	86	61	2.05	84	63	.29
28	85	64		84	63	
29	85	65	.78	82	65	.24
30	79	65	.47	82	65	.10
31	78	66	.20	74	65	.16
Temp. Ave.	80.1	59.4		80.0	60.1	
Total Rainfall			6.87			2.33

Table A-3. Climatological Data for Ames Plantation and the Knoxville Plant Science Field Laboratory, June, 1975.

	Ames Plantation			Knoxville		
	Temperature, F.		Rainfall	Temperature, F.		Rainfall
Date	Max.	Min.	in.	Max.	Min.	in.
1	76	56	.12	79	61	.73
2	77	54		81	55	
3	81	60	.11	81	58	
4	85	62		86	61	
5	88	65		87	65	
6	84	68	.06	85	63	.35
7	90	67		84	62	.03
8	80	59		82	55	
9	84	63		84	55	
10	79	65		75	67	.64
11	76	70	.10	78	66	.16
12	83	62	.53	83	64	.25
13	83	57		84	57	1.05
14	86	65		86	57	.33
15	88	63	.16	85	66	
16	82	61		83	64	.19
17	87	66		88	60	
18	89	71		90	69	
19	90	66		91	66	
20	89	65		89	67	
21	87	66		89	65	.58
22	91	69		86	68	.06
23	88	67		85	69	
24	89	62		87	68	
25	91	65		88	69	
26	91	69		84	68	.06
27	91	69		86	69	.02
28	90	66	1.97	88	69	
29	89	68		89	69	
30	90	68		89	67	
Temp. Ave.	85.8	64.5		85.1	64.0	
Total Rainfall			3.05			4.45

Table A-4. Climatological Data for Ames Plantation and the Knoxville Plant Science Field Laboratory, July, 1975.

	Ames Plantation			Knoxville		
	Temperature, F.		Rainfall	Temperature, F.		Rainfall
Date	Max.	Min.	in.	Max.	Min.	in.
1	91	66		89	68	
2	93	70		89	68	.03
3	90	68		86	68	
4	90	67		89	70	
5	93	69		90	64	
6	92	60	.48	88	66	.52
7	81	62	.31	89	68	.08
8	89	70		84	71	.35
9	90	67		85	68	
10	92	70		88	69	
11	92	67	.11	85	68	
12	91	61	.15	80	63	
13	80	58		83	63	
14	80	56		83	62	
15	84	56		86	69	
16	89	62		84	67	
17	90	66		88	66	.45
18	91	68		87	66	.56
19	94	70	.43	87	68	
20	92	69	.01	87	71	
21	77	67	.70	86	69	
22	93	71		90	71	
23	92	72		92	73	
24	90	72	.18	92	73	.15
25	90	70	.97	89	72	.02
26	81	68	1.00	87	71	
27	87	64		90	65	
28	88	66		89	65	
29	90	69		92	69	
30	90	69		95	69	
31	87	70		93	67	.05
Temp. Ave.	88.7	66.5		87.8	68.0	
Total Rainfall			4.24			2.21

Table A-5. Climatological Data for Ames Plantation and the Knoxville Plant Science Field Laboratory, August, 1975.

	Ames Plantation			Knoxville		
	Temperature, F.		Rainfall	Temperature, F.		Rainfall
Date	Max.	Min.	in.	Max.	Min.	in.
1	75	67	.94	90	72	
2	78	67	.34	91	69	
3	82	70	.10	91	70	
4	87	68	.49	89	70	.05
5	83	68	.09	89	70	.13
6	84	64		88	70	.29
7	85	62		82	67	
8	83	60		81	68	
9	84	61		86	67	
10	86	66		85	70	.20
11	89	66		77	67	.43
12	88	67		85	68	
13	93	69		88	69	
14	92	71		92	71	
15	93	72	.03	90	74	
16	90	70		90	70	.19
17	90	70	.18	89	69	
18	89	68	. 5	88	69	1.23
19	85	67	1.08	86	68	
20	88	69		87	69	
21	90	68		87	69	
22	92	70		91	72	
23	91	69		90	73	
24	90	70		90	73	
25	90	69		92	72	
26	91	69		93	73	
27	91	70		93	73	
28	92	67		93	69	
29	90	69		90	68	
30	88	69	.08	87	70	
31	87	64	.02	87	73	
Temp. Ave.	87.6	67.6		88.3	70.1	
Total Rainfall			3.60			2.52

Table A-6. Climatological Data for Ames Plantation and the Knoxville Plant Science Field Laboratory, September, 1975.

	Ames Plantation			Knoxville		
	Temperature, F.		Rainfall	Temperature, F.		Rainfall
Date	Max.	Min.	in.	Max.	Min.	in.
1	90	65		86	68	
2	90	68		88	69	
3	96	68		90	65	
4	97	67		95	69	
5	95	68		96	70	
6	86	69	3.37	91	69	.11
7	77	57		70	68	.18
8	82	58		77	65	
9	87	59		85	65	
10	89	65	.16	86	66	
11	90	69	.10	89	68	.02
12	85	66	1.00	84	69	.17
13	68	47	.02	79	54	.19
14	65	44		67	50	
15	73	47		71	57	
16	76	57		75		
17	77	63	.23	75	63	.09
18	71	58	.18	68	63	.66
19	79	61		79	64	.02
20	83	58	1.35	81	66	
21	75	48		82	58	.12
22	73	52		76	58	.02
23	64	54		63	56	1.62
24	57	52	.33	67	58	.41
25	55	51	.36	65	55	.03
26	59	45		61	53	.03
27	69	40		64	51	
28	71	40		67	50	
29	72	40		73	51	
30	78	44		76	54	
Temp. Ave.	77.6	56.0		77.5	61.0	
Total Rainfall			7.10			3.67

Table A-7. Climatological Data for Ames Plantation and the Knoxville Plant Science Field Laboratory, October, 1975.

Date	Ames Plantation Temperature, F. Max.	Ames Plantation Temperature, F. Min.	Ames Plantation Rainfall in.	Knoxville Temperature, F. Max.	Knoxville Temperature, F. Min.	Knoxville Rainfall in.
1	83	54		76	56	
2	70	41		63	52	.84
3	64	34		62	41	
4	69	35		66	47	
5	75	43		67	51	
6	69	56		68	57	
7	71	58		74	60	
8	70	63	.02	74	61	.08
9	82	52		70	58	1.24
10	84	55		76	55	
11	86	55		78	54	
12	89	59		79	56	
13	90	58		79	50	
14	89	56		79	55	
15	87	57		82	58	
16	84	62	.03	82	53	
17	66	56	1.70	82	62	
18	65	46	.01	73	50	.70
19	58	36		55	45	
20	64	35		54	43	
21	75	35		65	41	
22	80	44		72	45	
23	77	48		73	47	
24	77	49		76	47	
25	78	51	.70	77	47	.15
26	53	44	.44	76	49	.50
27	65	39		55	50	
28	61	41		67	50	
29	77	56		64	56	
30	72	40	.03	70	46	.50
31	64	34		59	38	
Temp. Ave.	74.0	48.1		70.7	51.0	
Total Rainfall			2.93			4.01

Table A-8. Climatological Data for Ames Plantation and the Knoxville Plant Science Field Laboratory, November, 1975.

	Ames Plantation			Knoxville		
	Temperature, F.		Rainfall	Temperature, F.		Rainfall
Date	Max.	Min.	in.	Max.	Min.	in.
1	70	36		61	38	
2	74	50		66	42	
3	76	51		68	44	
4	75	53	.22	73	54	
5	73	60	.30	75	51	
6	75	60	.36	75	54	
7	66	60	.67	73	58	.53
8	75	53		69	55	.08
9	79	57		76	53	
10	72	50	.17	76	58	.06
11	63	38		77	47	
12	68	42	.25	66	53	.22
13	58	38		62	38	1.19
14	40	23		41	34	.03
15	49	25		40	27	
16	64	29		54	32	
17	69	33		62	37	
18	69	32		66	37	
19	72	32		68	38	
20	73	37	.42	68	42	
21	53	35	.05	71	42	.26
22	40	35		58	37	.01
23	38	34		44	39	
24	44	35		47	31	
25	50	26		46	34	
26	43	27		44	28	
27	44	21	1.13	55	37	.12
28	45	21		50	29	
29	59	29	.14	55	29	
30	70	54	.74	67	43	
Temp. Ave.	61.5	39.2		61.8	41.4	
Total Rainfall			4.45			2.50

Table A-9. Analyses of Variance for Yield, Seed Moisture, and Seed Weight of Corn Treated in the Fall With Glyphosate, Ames Plantation, Grand Junction, TN, 1975.

Source of Variation	Degrees of Freedom	Mean Squares	F Values
	Seed Yields		
Replications	3	587434.04	
Glyphosate Treatments	4	49200.97	.14
Error	12	356169.66	
Total	19	328060.10	
	Seed Moisture		
Replications	3	.17	
Glyphosate Treatments	4	.35	2.75
Error	12	.13	
Total	19	.18	
	Seed Weight		
Replications	3	144.18	
Glyphosate Treatments	4	391.53	2.86
Error	12	136.86	
Total	19	191.63	

Table A-10. Analyses of Variance for Yield, Lodging, Seed Moisture, and Seed Weight of Soybeans Treated in the Fall With Glyphosate, Ames Plantation, Grand Junction, TN, 1975.

Source of Variation	Degrees of Freedom	Mean Squares	F Values
	Seed Yields		
Replications	3	110879.82	
Glyphosate Treatments	6	61510.96	1.94
Error	18	31736.66	
Total	27	47146.85	
	Lodging		
Replications	3	49.75	
Glyphosate Treatments	6	26.06	1.73
Error	18	15.03	
Total	27	21.34	
	Seed Moisture		
Replications	3	.08	
Glyphosate Treatments	6	.04	3.26*
Error	18	.01	
Total	27	.03	
	Seed Weight		
Replications	3	11.39	
Glyphosate Treatments	6	37.79	2.92*
Error	18	12.96	
Total	27	18.30	

*Significant at the .05 level of probability.

Table A-11. Analyses of Variance for Yield, Seed Moisture, and Seed Weight of Corn Treated in the Fall With Glyphosate, Knoxville Plant Science Field Laboratory, Knoxville, TN, 1975.

Source of Variation	Degrees of Freedom	Mean Squares	F Values
	Seed Yields		
Replications	3	10809592.38	
Glyphosate Treatments	5	360307.02	.44
Error	15	810200.87	
Total	23	2016666.32	
	Seed Moisture		
Replications	3	.17	
Glyphosate Treatments	5	4.33	22.84**
Error	15	.19	
Total	23	1.09	
	Seed Weight		
Replications	3	247.49	
Glyphosate Treatments	5	861.08	6.97**
Error	15	123.45	
Total	23	299.98	

**Significant at the .01 level of probability.

Table A-12. Analyses of Variance for Yield, Lodging, Seed Moisture, and Seed Weight of Soybeans Treated in the Fall With Glyphosate, Knoxville Plant Science Field Laboratory, Knoxville, TN, 1975.

Source of Variation	Degrees of Freedom	Mean Squares	F Values
	Seed Yields		
Replications	3	202158.23	
Glyphosate Treatments	6	56618.87	1.06
Error	18	53385.58	
Total	27	70634.38	
	Lodging		
Replications	3	445.24	
Glyphosate Treatments	6	172.62	.35
Error	18	498.02	
Total	27	419.84	
	Seed Moisture		
Replications	3	.11	
Glyphosate Treatments	6	.10	.86
Error	18	.11	
Total	27	.11	
	Seed Weight		
Replications	3	35.86	
Glyphosate Treatments	6	31.83	1.28
Error	18	24.80	
Total	27	27.59	

Table A-13. Analyses of Variance for Spring Counts and Visual Control Ratings of Rhizome Johnsongrass in Plots Treated in the Fall With Glyphosate, Knoxville Plant Science Field Laboratory, Knoxville, TN, 1975.

Source of Variation	Degrees of Freedom	Mean Squares	F Values
	Rhizome Plants Per Square Meter (4/15/75)		
Replications	3	661.88	
Glyphosate Treatments	7	10924.55	6.35**
Error	21	1720.07	
Total	31	3696.09	
	Percent Rhizome Control (4/15/75)		
Replications	3	105.21	
Glyphosate Treatments	7	5072.55	21.70**
Error	21	233.78	
Total	31	1313.96	
	Percent Rhizome Control (6/21/75)		
Replications	3	150.75	
Glyphosate Treatments	7	5658.71	27.43**
Error	21	206.22	
Total	31	1432.06	

**Significant at the .01 level of probability.

Table A-14. Analyses of Variance for Germination and Emergence of Corn Seedlings Produced From Seeds of Plants Treated in the Fall With Glyphosate, Ames Plantation, Grand Junction, TN, 1975.

Source of Variation	Degrees of Freedom	Mean Squares	F Values
	Seed Germination		
Replications	3	5.78	
Glyphosate Treatments	4	5.95	.27
Error	12	21.78	
Total	19	15.92	
	Seedling Emergence at 7 Days		
Replications	3	518.45	
Glyphosate Treatments	4	1487.67	29.77**
Error	12	49.98	
Total	19	426.62	
	Seedling Emergence at 10 Days		
Replications	3	52.61	
Glyphosate Treatments	4	1517.02	62.94**
Error	12	24.10	
Total	19	342.90	
	Seedling Emergence at 21 Days		
Replications	3	33.23	
Glyphosate Treatments	4	1183.09	72.28**
Error	12	16.37	
Total	19	264.66	

**Significant at the .01 level of probability.

Table A-15. Analyses of Variance for Vigor Reduction and Color of 21-Day-Old Corn Seedlings Produced From Seeds of Plants Treated in the Fall With Glyphosate, Ames Plantation, Grand Junction, TN, 1975.

Source of Variation	Degrees of Freedom	Mean Squares	F Values
	Percent Vigor Reduction		
Replications	3	6.67	
Glyphosate Treatments	4	2420.00	363.00**
Error	12	6.67	
Total	19	514.74	
	Green Seedling Emergence		
Replications	3	20.80	
Glyphosate Treatments	4	1325.76	99.45**
Error	12	13.33	
Total	19	290.81	
	Striated Seedling Emergence		
Replications	3	9.54	
Glyphosate Treatments	4	593.13	61.05**
Error	12	9.71	
Total	19	132.51	
	White Seedling Emergence		
Replications	3	5.43	
Glyphosate Treatments	4	146.05	24.46**
Error	12	5.96	
Total	19	35.38	

**Significant at the .01 level of probability.

Table A-16. Analyses of Variance for Weight and Dry Matter Percentage of 21-Day-Old Corn Seedlings Produced From Seeds of Plants Treated in the Fall With Glyphosate, Ames Plantation, Grand Junction, TN, 1975.

Source of Variation	Degrees of Freedom	Mean Squares	F Values
	Total Fresh Weight		
Replications	3	147.52	
Glyphosate Treatments	4	879.33	19.02**
Error	12	46.23	
Total	19	237.61	
	Average Fresh Weight		
Replications	3	3552.34	
Glyphosate Treatments	4	3430.39	2.17
Error	12	1579.76	
Total	19	2280.82	
	Total Dry Weight		
Replications	3	1.25	
Glyphosate Treatments	4	11.50	23.00**
Error	12	.50	
Total	19	2.93	
	Average Dry Weight		
Replications	3	34.22	
Glyphosate Treatments	4	9.05	.57
Error	12	15.96	
Total	19	17.39	
	Dry Matter Percentage		
Replications	3	2.80	
Glyphosate Treatments	4	6.08	5.68**
Error	12	1.07	
Total	19	2.40	

**Significant at the .01 level of probability.

Table A-17. Analyses of Variance for Weight, Dry Matter Percentage, and Length of 21-Day-Old Corn Seedling Roots Produced From Seeds of Plants Treated in the Fall With Glyphosate, Ames Plantation, Grand Junction, TN, 1975.

Source of Variation	Degrees of Freedom	Mean Squares	F Values
	Average Fresh Weight		
Replications	3	95565.00	
Glyphosate Treatments	4	116620.00	2.62
Error	12	44556.67	
Total	19	67781.84	
	Average Dry Weight		
Replications	3	991.67	
Glyphosate Treatments	4	957.50	1.84
Error	12	520.83	
Total	19	687.11	
	Dry Matter Percentage		
Replications	3	.13	
Glyphosate Treatments	4	.22	.38
Error	12	.58	
Total	19	.44	
	Primary Root Length		
Replications	3	44.91	
Glyphosate Treatments	4	134.87	4.65*
Error	12	29.02	
Total	19	53.82	

*Significant at the .05 level of probability.

Table A-18. Analyses of Variance for Germination, Emergence, and Vigor Reduction of Soybean Seedlings Produced From Seeds of Plants Treated in the Fall With Glyphosate, Ames Plantation, Grand Junction, TN, 1975.

Source of Variation	Degrees of Freedom	Mean Squares	F Values
	Seed Germination		
Replications	3	3.90	
Glyphosate Treatments	6	5.67	1.81
Error	18	3.13	
Total	27	3.78	
	Seedling Emergence at 7 Days		
Replications	3	55.84	
Glyphosate Treatments	6	319.25	13.91**
Error	18	22.95	
Total	27	92.45	
	Seedling Emergence at 10 Days		
Replications	3	13.32	
Glyphosate Treatments	6	49.07	11.34**
Error	18	4.33	
Total	27	15.27	
	Seedling Emergence at 21 Days		
Replications	3	4.89	
Glyphosate Treatments	6	58.53	7.87**
Error	18	7.43	
Total	27	18.51	
	Percent Vigor Reduction		
Replications	3	4.76	
Glyphosate Treatments	6	3657.14	768.00**
Error	18	4.76	
Total	27	816.40	

**Significant at the .01 level of probability.

Table A-19. Analyses of Variance for Weight and Dry Matter Percentage of 21-Day-Old Soybean Seedlings Produced From Seeds of Plants Treated in the Fall With Glyphosate, Ames Plantation, Grand Junction, TN, 1975.

Source of Variation	Degrees of Freedom	Mean Squares	F Values
	Total Fresh Weight		
Replications	3	462.89	
Glyphosate Treatments	6	2812.62	31.71**
Error	18	88.70	
Total	27	735.59	
	Average Fresh Weight		
Replications	3	14168.29	
Glyphosate Treatments	6	52885.42	24.86**
Error	18	2127.15	
Total	27	14744.67	
	Total Dry Weight		
Replications	3	6.32	
Glyphosate Treatments	6	5.64	9.00**
Error	18	.63	
Total	27	2.37	
	Average Dry Weight		
Replications	3	200.54	
Glyphosate Treatments	6	35.62	1.66
Error	18	21.41	
Total	27	44.47	
	Dry Matter Percentage		
Replications	3	.07	
Glyphosate Treatments	6	9.89	23.92
Error	18	.41	
Total	27	2.48	

**Significant at the .01 level of probability.

Table A-20. Analyses of Variance for Weight, Dry Matter Percentage, and Length of 21-Day-Old Soybean Seedling Roots Produced From Seeds of Plants Treated in the Fall With Glyphosate, Ames Plantation, Grand Junction, TN, 1975.

Source of Variation	Degrees of Freedom	Mean Squares	F Values
	Average Fresh Weight		
Replications	3	19962.22	36.11**
Glyphosate Treatments	6	213727.25	
Error	18	5918.85	
Total	27	53658.87	
	Average Dry Weight		
Replications	3	32.72	
Glyphosate Treatments	6	354.20	24.00**
Error	18	14.76	
Total	27	92.19	
	Dry Matter Percentage		
Replications	3	.05	
Glyphosate Treatments	6	4.12	29.16**
Error	18	.14	
Total	27	1.02	
	Primary Root Length		
Replications	3	8.64	
Glyphosate Treatments	6	225.85	29.47**
Error	18	7.66	
Total	27	56.26	

**Significant at the .01 level of probability.

Table A-21. Analyses of Variance for Germination and Emergence of Corn Seedlings Produced From Seeds of Plants Treated in the Fall With Glyphosate, Knoxville Plant Science Field Laboratory, Knoxville, TN, 1975.

ource of Variation	Degrees of Freedom	Mean Squares	F Values
	Seed Germination		
Replications	3	16.94	
Glyphosate Treatments	5	2.97	.27
Error	15	11.08	
Total	23	10.08	
	Seedling Emergence at 7 Days		
Replications	3	125.70	
Glyphosate Treatments	5	2483.34	40.50**
Error	15	61.31	
Total	23	596.24	
	Seedling Emergence at 10 Days		
Replications	3	15.83	
Glyphosate Treatments	5	1022.99	82.11**
Error	15	12.46	
Total	23	232.58	
	Seedling Emergence at 21 Days		
Replications	3	29.67	
Glyphosate Treatments	5	867.17	47.39**
Error	15	18.30	
Total	23	204.32	

**Significant at the .01 level of probability.

Table A-22. Analyses of Variance for Vigor Reduction and Color of 21-Day-Old Corn Seedlings Produced From Seeds of Plants Treated in the Fall With Glyphosate, Knoxville Plant Science Field Laboratory, Knoxville, TN, 1975.

Source of Variation	Degrees of Freedom	Mean Squares	F Values
	Percent Vigor Reduction		
Replications	3	15.28	
Glyphosate Treatments	5	2774.17	38.56**
Error	15	71.94	
Total	23	651.99	
	Green Seedling Emergence		
Replications	3	17.83	
Glyphosate Treatments	5	3370.26	
Error	15	40.33	
Total	23	261.33	
	Striated Seedling Emergence		
Replications	3	16.11	
Glyphosate Treatments	5	1273.16	42.51**
Error	15	29.94	
Total	23	298.40	
	White Seedling Emergence		
Replications	3	13.05	
Glyphosate Treatments	5	507.86	64.92**
Error	15	7.82	
Total	23	117.21	

**Significant at the .01 level of probability.

Table A-23. Analyses of Variance for Weight and Dry Matter Percentage of 21-Day-Old Corn Seedlings Produced From Seeds of Plants Treated in the Fall With Glyphosate, Knoxville Plant Science Field Laboratory, Knoxville, TN, 1975.

Source of Variation	Degrees of Freedom	Mean Squares	F Values
	Total Fresh Weight		
Replications	3	367.15	
Glyphosate Treatments	5	4987.24	10.83**
Error	15	460.49	
Total	23	1432.39	
	Average Fresh Weight		
Replications	3	3989.27	
Glyphosate Treatments	5	35059.15	3.05*
Error	15	11486.81	
Total	23	15633.29	
	Total Dry Weight		
Replications	3	4.67	
Glyphosate Treatments	5	61.37	23.91**
Error	15	2.57	
Total	23	15.62	
	Average Dry Weight		
Replications	3	70.91	
Glyphosate Treatments	5	460.48	6.29**
Error	15	73.21	
Total	23	157.10	
	Dry Matter Percentage		
Replications	3	.14	
Glyphosate Treatments	5	.33	.54
Error	15	.62	
Total	23	.49	

*Significant at the .05 level of probability.

**Significant at the .01 level of probability.

Table A-24. Analyses of Variance for Weight, Dry Matter Percentage, and Length of 21-Day-Old Corn Seedling Roots Produced From Seeds of Plants Treated in the Fall With Glyphosate, Knoxville Plant Science Field Laboratory, Knoxville, TN, 1975.

Source of Variation	Degrees of Freedom	Mean Squares	F Values
	Average Fresh Weight		
Replications	3	29015.88	
Glyphosate Treatments	5	41716.58	1.40
Error	15	29726.84	
Total	23	32240.57	
	Average Dry Weight		
Replications	3	1033.13	
Glyphosate Treatments	5	331.07	.69
Error	15	478.96	
Total	23	519.09	
	Dry Matter Percentage		
Replications	3	3.14	
Glyphosate Treatments	5	2.14	.93
Error	15	2.29	
Total	23	2.37	
	Primary Root Length		
Replications	3	4.37	
Glyphosate Treatments	5	15.92	1.89
Error	15	8.43	
Total	23	9.53	

Table A-25. Analyses of Variance for Germination, Emergence, and Vigor Reduction of Soybean Seedlings Produced From Seeds of Plants Treated in the Fall With Glyphosate, Knoxville Plant Science Field Laboratory, Knoxville, TN, 1975.

Source of Variation	Degrees of Freedom	Mean Squares	F Values
	Seed Germination		
Replications	3	204.42	
Glyphosate Treatments	6	101.95	1.98
Error	18	51.56	
Total	27	79.74	
	Seedling Emergence at 7 Days		
Replications	3	573.96	
Glyphosate Treatments	6	27.53	.22
Error	18	121.98	
Total	27	151.21	
	Seedling Emergence at 10 Days		
Replications	3	442.74	
Glyphosate Treatments	6	33.88	.28
Error	18	122.42	
Total	27	138.33	
	Seedling Emergence at 21 Days		
Replications	3	360.75	
Glyphosate Treatments	6	45.17	.41
Error	18	109.62	
Total	27	123.20	
	Percent Vigor Reduction		
Replications	3	5.95	
Glyphosate Treatments	6	2.98	.65
Error	18	4.56	
Total	27	4.37	

Table A-26. Analyses of Variance for Weight and Dry Matter Percentage of 21-Day-Old Soybean Seedlings Produced From Seeds of Plants Treated in the Fall With Glyphosate, Knoxville Plant Science Field Laboratory, Knoxville, TN, 1975.

Source of Variation	Degrees of Freedom	Mean Squares	F Values
	Total Fresh Weight		
Replications	3	1918.42	
Glyphosate Treatments	6	76.74	.33
Error	18	236.06	
Total	27	387.58	
	Average Fresh Weight		
Replications	3	9745.56	
Glyphosate Treatments	6	5619.39	2.76*
Error	18	2032.62	
Total	27	3686.67	
	Total Dry Weight		
Replications	3	37.57	
Glyphosate Treatments	6	1.29	.35
Error	18	3.68	
Total	27	6.92	
	Average Dry Weight		
Replications	3	542.32	
Glyphosate Treatments	6	29.74	.54
Error	18	55.52	
Total	27	103.88	
	Dry Matter Percentage		
Replications	3	2.78	
Glyphosate Treatments	6	.42	1.55
Error	18	.27	
Total	27	.58	

*Significant at the .05 level of probability.

Table A-27. Analyses of Variance for Weight, Dry Matter Percentage, and Length of 21-Day-Old Soybean Seedling Roots Produced From Seeds of Plants Treated in the Fall With Glyphosate, Knoxville Plant Science Field Laboratory, Knoxville, TN, 1975.

Source of Variation	Degrees of Freedom	Mean Squares	F Values
	Average Fresh Weight		
Replications	3	20981.00	
Glyphosate Treatments	6	27546.12	3.72*
Error	18	7396.06	
Total	27	13383.29	
	Average Dry Weight		
Replications	3	35.59	
Glyphosate Treatments	6	3.95	.23
Error	18	17.39	
Total	27	16.42	
	Dry Matter Percentage		
Replications	3	.10	
Glyphosate Treatments	6	1.82	21.13**
Error	18	.09	
Total	27	.47	
	Primary Root Length		
Replications	3	27.10	
Glyphosate Treatments	6	5.51	.47
Error	18	11.66	
Total	27	12.01	

*Significant at the .05 level of probability.

**Significant at the .01 level of probability.

Table A-28. Analyses of Variance for Protein and Oil Composition of Corn and Soybean Seed From Plants Treated in the Fall With Glyphosate, Ames Plantation, Grand Junction, TN, 1975.

Source of Variation	Degrees of Freedom	Mean Squares	F Values
	Corn Seed Protein Content		
Replications	3	4.58	
Glyphosate Treatments	4	1.90	2.30
Error	12	.83	
Total	19	1.65	
	Corn Seed Oil Content		
Replications	3	.31	
Glyphosate Treatments	4	.20	1.62
Error	12	.12	
Total	19	.17	
	Soybean Seed Protein Content		
Replications	3	23.92	
Glyphosate Treatments	6	2.76	.38
Error	18	7.32	
Total	27	8.15	
	Soybean Seed Oil Content		
Replications	3	.67	
Glyphosate Treatments	6	.71	1.27
Error	18	.56	
Total	27	.60	

Table A-29. Analyses of Variance for Protein and Oil Composition of Corn and Soybean Seed From Plants Treated in the Fall With Glyphosate, Knoxville Plant Science Field Laboratory, Knoxville, TN, 1975.

Source of Variation	Degrees of Freedom	Mean Squares	F Values
	Corn Seed Protein Content		
Replications	3	2.22	
Glyphosate Treatments	5	.92	.64
Error	15	1.42	
Total	23	1.42	
	Corn Seed Oil Content		
Replications	3	1.01	
Glyphosate Treatments	5	.59	2.54
Error	15	.23	
Total	23	.41	
	Soybean Seed Protein Content		
Replications	3	22.41	
Glyphosate Treatments	6	39.01	1.92
Error	18	20.35	
Total	27	24.73	
	Soybean Seed Oil Content		
Replications	3	36.22	
Glyphosate Treatments	6	9.93	.28
Error	18	35.58	
Total	27	29.95	

VITA

Jewell R. English, Jr., was born in Haywood County, Tennessee, on February 28, 1953. He grew up on his father's farm in that county. He attended Forked Deer Elementary School and Haywood County High School from which he graduated in June 1971. In that same month, he entered Memphis State University and studied there until May of 1972. In January 1973, he entered the University of Tennessee at Martin, and was graduated in December 1974, receiving a Bachelor of Science degree in Agriculture with a major in Plant Science. In January 1975, he entered the Graduate School of the University of Tennessee at Knoxville as a graduate research assistant in the Plant and Soil Science Department. He received the Master of Science degree in December of 1976 with specialization in Weed Science.

He is married to the former Karen Joy King of Brownsville, Tennessee, and they have a daughter, Tanya Denise.