To the Graduate Council:

I am submitting herewith a thesis written by Charles Steven Williams entitled "Johnsongrass Competition and Control in Soybeans." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Plant and Soil Science.

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JOHNSONGRASS COMPETITION AND CONTROL IN SOYBEANS

A Thesis

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ABSTRACT

Field studies were conducted at two locations in West Tennessee to determine the competitive effect of johnsongrass [Sorghum halepense (L.)Pers.] on soybeans [Glycine max(L.)Merr.]. The objectives of these studies were to determine: (1) the most critical parameters in predicting the economic threshold of johnsongrass in two common soybean cropping systems in the Midsouth, (2) the critical johnsongrass-free requirement of soybeans, (3) the critical duration of johnsongrass in soybeans, (4) the optimum time for application of sethoxydim [[2-[-1-(ethoxyimino) butyl-]-5-[2-(ethylthio) propyl]-3-hydroxy-2-cyclohexen-1-one]] at 1.12 kg/ha plus oil concentrate at 1 percent v/v to johnsongrass, and (5) the degree of competition for available soil water between johnsongrass and soybeans.

All experiments were conducted as randomized complete block designs with a minimum of four replications. The threshold studies consisted of either eight rows or three rows by 9.1 m long for the .25 m and 1.0 m row spacings, respectively. The competition study consisted of three rows one m wide by 7.6 m long. Critical population and measurements were taken from the center row of each plot or its equivalent.

Johnsongrass dry matter and the number of johnsongrass culms produced per hectare were more highly correlated with soybean yield reduction than the number of johnsongrass plants per hectare. The number of johnsongrass plants per hectare was determined to be the

most practical means of predicting soybean yield reduction. Regression analysis indicated that each johnsongrass plant reduced soybean yields 30 to 45 g in the two row spacings.

The critical johnsongrass free requirement of soybeans was determined to be four weeks after planting. If soybeans were not kept free of johnsongrass for at least four weeks, johnsongrass would be able to reestablish and reduce soybean yields.

The critical duration of johnsongrass was determined to be seven weeks after planting for mechanical removal and five weeks after planting for chemical control with sethoxydim. The critical duration of johnsongrass in soybeans spans a wider range depending on control measures employed, since mechanical removal is a physical process occurring within a short period of time while the chemical control is a physiological process occurring over a period of several hours to several days depending upon johnsongrass stage of growth and environmental conditions.

Optimum johnsongrass control was obtained when sethoxydim was applied to johnsongrass at a height range of 25 to 50 cm.

Soybean yield per cm of available soil water was highest where johnsongrass was controlled season-long or by applying sethoxydim at four weeks after planting. This observation indicates that when water is critically limiting, soybeans are better able to utilize available soil water when johnsongrass is not present.

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CHAPTER I

INTRODUCTION

Holm (58) has reported that johnsongrass [Sorghum halepense(L.) Pers.] is one of the 10 worst weeds in the world and occurs in all major warm regions. Johnsongrass is one of the 10 worst weeds in soybeans [Glycine max(L.)Merr.] in all Southern states and the second worst weed in soybeans in Tennessee (102). The shift from the labor intensive cotton [Gossypium hirsutum L.] crop to soybeans had led to increased infestations of johnsongrass, since soybeans do not receive the high degree of cultivation and hand weeding once given to cotton. Without the high level of management, johnsongrass is able to spread rapidly due to its prolific nature. Stamper (112) found that each johnsongrass panicle contained approximately 700 seed, which led to the presence of 2 to 12 million viable seed/ha. He also observed johnsongrass shizome production of 33 MT/ha.

Each year more soybeans are being planted in some type of reduced tillage system. These planting systems often eliminate the possibility to control johnsongrass by cultivation and in the case of no-tillage, it has eliminated the degree of rhizome johnsongrass control provided by several preplant incorporated herbicides. Research conducted by Jeffery et al. (62) indicated that no single herbicide or tillage treatment consistently provided adequate control of both seedling and rhizome johnsongrass, but various combinations of sequential treatments were effective. They reported a possible 161 to 276 kg/ha increase in soybean yield for every 10 percent of johnsongrass control obtained.

At present, few farmers are able to control johnsongrass to a satisfactory level without the incorporation of some type of post-emergence johnsongrass control program. This is especially true for the soybean cropping system which eliminates the possibility of controlling johnsongrass through cultivation.

Soybean producers are continually confronted with the question of how to efficiently utilize new and innovative johnsongrass control measures. Personnel involved in crop pest management rely upon the population of the pest in question (insect, weed, nematode, etc.) exceeding a predetermined threshold level. Establishment of economic thresholds for weed pests has not been as extensive as other areas of crop pest management and is lacking for many weed species, especially johnsongrass. Implementation of control measures must be based not only on the number of plants but on the stage of growth of both the crop and the weed species as well as the cost of control. Thus the objectives of these studies were to determine: (1) the most critical parameters in predicting the economic threshold of johnsongrass in two common soybean cropping systems in the Midsouth, (2) the critical johnsongrass-free requirement of soybeans, (3) the critical duration of johnsongrass in soybeans, and (4) the optimum time of sethoxydim [[2-[-1-(ethoxyimino) butyl]-5-[2-(ethylthio) propyl]-3-hydroxy-2-cyclohexen-1-one]] application to johnsongrass, and (5) the degree of competition for soil moisture between johnsongrass and soybeans.

CHAPTER II

LITERATURE REVIEW

Johnsongrass

Johnsongrass is native to the Mediterranean region of the world (75). It is generally agreed that johnsongrass was introduced into the United States early in the nineteenth century (75). After its introduction into the United States, johnsongrass was commonly referred to as guinea grass, Samoa grass Cuba grass, Egyptian grass, Means grass, evergreen millet, and bankruptcy grass (75). The first written use of the name johnsongrass was made in 1874 by John Harralson of Selma, Alabama, in a letter to George Vasey of the U.S.D.A. in Washington, D.C. Harralson requested an identification and analysis of the grass sample he sent to Vasey and reported that it was known locally as Johnson grass. The name was derived from that of William Johnson, who had presumably introduced it into Alabama. Vasey acknowledged that the grass sample was Sorghum halepense. Vasey later published the letters in the Monthly Report of U.S.D.A. and Farmers Book of Grasses. The attention these publications received resulted in the use of the common name johnsongrass (75).

Johnsongrass is a member of the Gramineae family, one of the largest families of flowering plants, and is in the subfamily, Panicoideae, which comprises the majority of the grasses of the tropical-subtropical regions of the world. This subfamily is divided into two large tribes,

Paniceae and Andropogoneae in which johnsongrass is a member of the latter tribe (47).

Members of the genus Sorghum have spikelets in pairs, one sessile and fertile, the other pedicellate, sterile but well developed, usually staminate, and the terminal sessile spikelet has two pedicellate spikelets (57).

Johnsongrass is an erect, warm-season perennial which has been reported to grow to a height of 190 to 320 cm (9, 38, 54, 77, 88). The culms arise from seeds and extensively creeping scaly rhizomes (54, 57, 77, 88). Leaf sheaths are entirely smooth, green or tinged maroon, and slightly flattened with smooth green collars (14). The ligule is membraneous, 3-4 mm long at maturity, and ciliate along the apical margin (14). Leaf blades are alternate and simple, smooth on the lower surface, and hairy basally on the upper surface with scabrous margins. The midvein is thick, white, and rolled in the bud. The leaf blades are commonly 15 to 51 cm long and about one to four cm wide (5, 11). The inflorescense is a large, purplish, hairy panicle 10 to 35 cm long (5, 11, 88). The seeds are 4.0 to 5.5 mm long, oval, reddish-brown, and bear a conspicuous awn which is easily broken off (5, 11).

Johnsongrass can propagate from both seed and rhizomes. The seeds have been found to be highly dormant requiring a cold treatment before achieving germination (116). The seed dormancy is largely imposed by the mechanical restriction afforded by the seed coat (116). Hull (61) did not detect dormancy in rhizomes harvested at any time during the year. Rhizome bud germination is suppressed at 15°C with optimum bud germination and shoot growth occurring at approximately

30°C (61). The rhizome buds are strongly influenced by apical dominance and emerged shoots partially suppress germination of adjacent rhizome buds (10,61). McWhorter (76) found that rhizome buds exposed to temperatures of 50 to 60°C were killed within one to three days and that rhizomes usually survived temperatures of -3 to -5°C for only a few hours.

McWhorter et al. (86) reported that root and rhizome development were enhanced with increasing light intensity reaching optimum growth at 32°C. Horowitz (59) found rhizomes to constitute more than 90 percent of the total subterranean weight with 60 percent of the weight being located in the first 15 cm of the soil profile. McWhorter (76) reported that near 80 percent of the johnsongrass rhizomes produced in a clay soil were in the top 7.5 cm, but 80 percent of the rhizomes in a sandy loam occupied the top 12.5 cm of the soil profile.

McWhorter (70) found johnsongrass to have three sets of rhizomes--primary, secondary, and tertiary. The primary rhizome produces the initial growth in the spring, dissipating in two to three weeks after growth begins. As the primary rhizomes begin to decay, the young plants initiate growth of the secondary rhizomes which continues throughout late summer. At this time, production of secondary rhizomes ceases and the mature johnsongrass plants begin growth of tertiary rhizomes which are not as large or as vigorous as secondary rhizomes and are usually more rounded. Growth of the tertiary rhizomes continues until frost. The tertiary rhizomes remain dormant throughout the winter, becoming the primary rhizomes the next year. Secondary rhizomes do not usually over-winter but gradually decompose. McWhorter

(70, 72) found that seedling johnsongrass initiated a rhizome approximately 18 to 21 days after growth began. This is in contrast to researchers in Indiana (101), Kansas (2), and California (63), who found that seedlings developed rhizomes at 50 days, 28 to 35 days, and 21 to 42 days after germination, respectively. McWhorter (70, 72) observed the growth habit of johnsongrass plants started from seed to be very similar to that of plants started from rhizomes. The only major exception was the absence of a primary rhizome system for seedling johnsongrass.

Rhizome growth has been found to be relatively slow in relation to foliar growth until the bloom stage, at which time rhizome growth increases as foliar growth decreases (2, 70, 72, 101, 119). Individual johnsongrass plants have been found to produce up to one m of rhizomes per day during optimum growth periods and to produce 64 m of rhizomes and 676 g of seed in one growing season (70, 72, 119).

McWhorter (79) found glucose, fructose, and sucrose to be the predominant sugars in the leaves, culms, and rhizomes of johnsongrass. Glucose is an easily metabolized sugar and sucrose is the major storage sugar (70, 79). Soon after growth begins in the early spring, the quantities of these sugars drop to very low levels in the rhizomes and reach a maximum when plants begin flowering. In the leaves, these carbohydrates are at maximum levels within 30 days after plant emergence. Glucose is present only in trace amounts in leaves during the initial flowering period while fructose and sucrose are at maximum levels (79).

Johnsongrass has developed into several morphologically distinct vegetative types (22, 23, 74, 121). Johnsongrass ecotypes grew differently depending upon the environments in which they developed. In studying the growth and development of 55 morphologically distinct vegetative types of johnsongrass, McWhorter (79) found mature leaf-blades of the different johnsongrass ecotypes varied in length from 31 to 59 cm and in width from 1.7 to 3.4 cm, and plant height and culm density varied two- to four-fold for different ecotypes. Floret production varied from 87 to 353 sessile spikelets for representative panicles and the arrangement of branchlets within panicles varied as did the size of various spikelet components of the different ecotypes. Ecotypes selected from the North have been found to flower earlier and produce a smaller plant than selections obtained from the South (22, 23, 121).

Black (11) has reported that johnsongrass is a photosynthetically efficient plant. Characteristics of photosynthetically efficient plants are: (a) increased uptake of CO_2 as light intensity increases to nearly full sunlight, (b) optimum uptake of CO_2 at temperatures from 30 to 40°C, (c) inability of oxygen to inhibit photosynthesis, (d) absence of photorespiration, (e) a low photosynthetic CO_2 compensation concentration, and (f) the C_4-dicarboxylic acid pathway of CO_2 fixation. Assimilation of CO_2 by johnsongrass has been found to be by the C_4-pathway fixation CO_2 via phosphoenolpyruvate to produce oxaloacelate and inorganic phosphate. The oxaloacelate is then converted to malate and aspartate (12, 17). Plants which fix CO_2 by the C_4-pathway also

have a characteristic leaf anatomy (95, 110). In the leaves of C_4 plants, vascular bundles are surrounded by a layer of chloroplast containing parenchyma cells known as bundlesheath cells in addition to the chloroplast containing mesophyll cells (95). The bundle sheath cells contain the enzymes of the C_4-pathway while the mesophyll cells contain the enzymes characteristic of the C_3 pathway. Bundle sheath cells lack intercellular spaces between cells and between bundle sheath cells and the enclosed vascular bundles. The bundle sheath extends over the ends of the vascular bundles thus making it necessary for all substances moving between leaf mesophyll cells and vascular bundles to pass through the bundle sheath cells (95).

Johnsongrass Competition in Soybeans

Very little research has been conducted to determine the competitiveness of johnsongrass in soybeans. McWhorter and Hartwig (84) reported that johnsongrass reduced yields of six soybean varieties from 23 to 43 percent. They concluded that long season soybeans were more competitive with johnsongrass, thus producing higher yields than short season soybeans (85). Buntley (19) found that 29 mature johnsongrass plants/18m of row reduced soybean yields by 48 percent.

Caviness and Taylor (26) conducted a study to determine the critical duration of johnsongrass in soybeans when johnsongrass was controlled by hand-hoeing. They found soybeans receiving two hand-hoeings during the growing season, i.e., one hand-hoeing at four weeks after planting of soybeans and the second hand-hoeing three weeks later, to have yields equal to that of the weed free check. Therefore,

johnsongrass was not able to produce its competitive effects in soybeans when removed early in the growing season. Other researchers (20, 64) have also observed the importance of early weed control.

The competition that exists between plants such as johnsongrass and soybeans has been noted to always occur where two or more plants make demands for environmental factors in excess of supply (120). The major environmental factors that plants compete for are nutrients, water, light, and carbon dioxide. Donald (34) reported that the interaction of competition for two environmental factors, i.e., light and water, allows the aggressive or most competitive plant species to acquire a continuously increasing share of each factor. He stated that not only is there a progressively decreasing share of the environment available to the suppressed species, but also a decreasing capacity by the suppressed species to make use of the environment available to it.

Black (13) stated that competition among plants may depend on many characteristics such as morphology, their capacity to extract nutrients or moisture from the soil, differential responses to temperature, or a variety of other factors. He proposed that the competitive ability of plants depends on the net capacity of a plant to assimilate carbon dioxide and use the photosynthate, to extend its foliage, or increase its size. Black considered johnsongrass a very competitive weed since it fixed carbon dioxide at very high rates coupled with the production of spreading rhizomes and many easily disseminated seeds. He further stated that CO_2 efficient plants such as johnsongrass are able to fix CO_2 at higher temperatures and light

intensities and better utilize water than plants such as soybeans.

The ability of johnsongrass to capture light and thus shade soybeans is another characteristic of johnsongrass that adds to its competitive nature. Bush and Staniforth (24) found that the shading effects at the side of soybean rows produced greater soybean yield reductions than those resulting from top shading, which developed later in the season when weeds grew taller. They suggested that shading effects may be less serious, as measured by soybean yields, when soil moisture is moderately to severely limited during the mid-summer.

Horowitz (60) found that johnsongrass not only competes with plants for nutrients, but his study dealing with crops other than soybeans suggests that the competitive effects of johnsongrass may be due to biologically active substances produced by johnsongrass.

Not only does johnsongrass suppress soybean yields due to its strong competitive nature, it further reduces yields by reducing harvesting efficiency. Nave and Wax (94) found giant foxtail (Setaria faberri Herrm.), which has very similar foliar growth to that of johnsongrass, to increase threshing losses four-fold when compared to weed free plots.

Johnsongrass Control in Soybeans

There are several approaches for control of rhizome johnsongrass in soybeans. The least expensive method of johnsongrass control in soybeans is prevention--avoiding the problem. Using clean seed; cleaning combines; controlling the movement of hay, cattle, and machinery from infested to clean fields; and preventing johnsongrass from going

to seed in fence rows, roadsides, and other waste areas are all important. Control in infested fields usually involves an integrated system employing crop rotation, tillage, and chemical control practices (1, 25, 31, 46, 52, 56, 66, 98, 103, 123).

Cultural Control

Crop rotations. Crop rotations can be utilized to obtain control of johnsongrass in a subsequent soybean crop. A small grain crop followed by a summer fallow program utilizing tillage and/or herbicides can provide almost complete control of rhizome johnsongrass within one year (62). Similarly, where corn is harvested for silage, there is adequate time for regrowth of johnsongrass and adequate time for application of foliar herbicides and/or use tillage before johnsongrass goes dormant (100).

Tillage. Burt and Willard (21) found that plowing in the summer or fall followed by tillage to control regrowth to be effective in reducing the stand of johnsongrass plants from rhizomes the following year. When these cultural practices were conducted earlier in the fall, more effective johnsongrass control was obtained. The major disadvantage of this practice is that the land must be fallowed during the tillage period if optimum control is to be obtained (21).

Breaking or chiseling of the soil in late fall to expose the johnsongrass rhizomes to freezing temperatures effectively reduces johnsongrass rhizome populations (6). This method is effective since

johnsongrass rhizomes are not cold-hardy and cannot withstand temperatures of -3 to -5°C for extended periods of time (76).

McWhorter and Hartwig (83) reported that soybeans planted following 6 to 10 diskings at four to six-day intervals yielded more than soybeans grown in the conventional manner and as much as soybeans grown where johnsongrass was controlled with a preplant herbicide. They also found that 10 diskings before planting soybeans on June 5 destroyed 90 percent of the rhizomes. Researchers have found that frequent diskings or cultivations cut the rhizomes into short pieces resulting in dehydration of the rhizome and/or the stimulation of shoot development which exhausts the energy reserves in the rhizomes (10, 83). Beasley (10) indicated that better control could be obtained with additional cultivation. Jeffery et al. (62) reported that plowing, followed by two or three double-diskings on separate dates using a single rate of trifluralin (a,a,a-trifluoro-2,6-dinitro-N,N-dipropyl-p-toluidine), plus timely cultivation resulted in fair to good johnsongrass control the first year, 85 percent control at the end of the second year, and 92 percent control at the end of the third year. Others (1, 6, 52, 66, 98) have also found that cultural methods increase the effectiveness of chemicals used to control johnsongrass.

Hauser and Thompson (52) concluded that cultural control methods, while effective for johnsongrass control under certain conditions, are usually laborious, expensive, and often necessitate the removal of cropland from production during the treatment period. Johnsongrass

control programs including tillage which do not remove the land from production have been developed (62, 96, 100). On some soils these practices also make the soil more vulnerable to erosion.

Chemical Control

Preplant treatment. Dalapon (2,2-dichloropropionic acid) is a systemic herbicide which controls rhizome johnsongrass (39, 40, 65, 104). Hicks (56) found a dalapon application at 4.1 or 8.3 kg/ha to johnsongrass in the fall to significantly reduce rhizomatous johnsongrass populations the following spring. Dalapon applied to succulent, 30 to 46 cm johnsongrass in the early spring, followed by plowing one week after application and planting of soybeans three weeks after application, provided excellent rhizome johnsongrass control. Nation (93) observed excellent early-season johnsongrass control when 4.1 or 8.3 kg/ha of dalapon were applied to 20 to 41 cm johnsongrass. He noted that reinfestation of the johnsongrass later in the season could reach 50 percent of the original infestation when plots were not hand-hoed.

Hamilton and Tucker (48) found that various johnsongrass strains differed in their response to dalapon. Although the variable response of strains to dalapon may account for the survival of some "resistant" plants, the improper timing and application of dalapon are the most common causes of unsatisfactory johnsongrass control.

Dalapon applied at a rate of 6.7 to 9.0 kg/ha plus surfactant in 187 to 280 L/ha of water is currently recommended as a preplant

herbicide for the control of 35 to 50 cm johnsongrass. A thorough disking three to five days after dalapon application will improve control and help dissipate the dalapon in the soil. Soybeans may be planted one week after disking or 10 days after dalapon application (6).

Glyphosate [N-(phosphonomethyl) glycine] may also be used preplant for johnsongrass control. It is a nonselective systemic herbicide which provides excellent control of rhizome johnsongrass (7, 25, 28, 29, 33, 97). Baird et al. (7) observed the capacity of glyphosate to translocate readily and thereby kill perennial weeds having vegetative propagules. Glyphosate (2.0 kg/ha) provided 98 to 100 percent johnsongrass control five to seven weeks after application (7). Connell and Derting (28) found that a preplant application of glyphosate (2.2 kg/ha) gave 100 percent control at four weeks after application and also found this treatment to be superior to dalapon. Parochetti et al. (103) reported that glyphosate (1.12 to 2.24 kg/ha) provided good control of johnsongrass with optimum control being achieved when applied to johnsongrass in the boot to full-head stage of growth. Overton et al. (97) found that a preplant application of glyphosate (0.56 kg/ha) controlled 80 percent of the rhizomatous johnsongrass regardless of the stage of growth. Derting et al. (33) also observed johnsongrass to be highly responsive to glyphosate at all stages of growth.

As a preplant foliar applied herbicide, glyphosate is recommended at a rate of 2.24 to 3.36 kg/ha in 187 to 280 L/ha of water. Application should be made after johnsongrass has reached a height of at least

46 cm. A thorough disking seven days after application will improve control and the crop can be planted in the usual manner (6).

Preplant incorporated control. Trifluralin is a preplant incorporated herbicide used to control both seedling and rhizome johnsongrass (67, 99, 113). Standifer and Thomas (113) found trifluralin (0.56 kg/ha) to inhibit the growth of shoots developing from the primary rhizome. Stubby nodal roots grew from shoot nodes, but the nodes did not develop lateral roots and were apparently nonfunctional. Kleifield (67) reported that trifluralin (1.2 kg/ha) reduced johnsongrass infestations by controlling seedling johnsongrass infestations and by the probable inhibition of johnsongrass roots, thus reducing rhizome development.

Millhollon et al. (87) found the control of johnsongrass rhizomes by trifluralin to be influenced by length of rhizomes, depth of rhizomes in relation to the zone of treated soil, and application rate. When 2.5 cm rhizomes were planted 3.8 cm deep, trifluralin at rates of 1.7 and 3.4 kg/ha provided 95 to 100 percent control while 15 cm rhizomes planted at the same depth were controlled only 54 and 81 percent for the low and high rates, respectively. More rhizomes were killed when the depth of incorporation of trifluralin was 7.5 cm rather than 15 cm, indicating that the concentration around the rhizome is more important than depth of incorporation, Mullins et al. (91) observed the dilution problem where trifluralin (1.7 kg/ha) was incorporated to a depth of 15 to 20 cm which resulted in less johnsongrass control and lower soybean yields. Millhollon et al. (87) observed that

trifluralin was toxic to roots growing from rhizomes and ultimately stunted the roots and eventually caused the death of johnsongrass shoots.

McWhorter (78) found that trifluralin applied at 1.12 to 2.24 kg/ha for two successive years effectively controlled rhizome johnsongrass without soybean injury and with greatly increased soybean yields. Overton et al. (99) reported 79 percent control of johnsongrass at the end of a two-year period following annual applications of twice the normal use rate of trifluralin, i.e., 1.68 kg/ha. Ross (108) has found that the control of johnsongrass in soybeans has improved to the point that farmers in Indiana need not lose one crop in four to summer fallow programs in order to control established johnsongrass rhizome stands. He attributes the control of rhizome johnsongrass to the use of the "double-rate" of trifluralin.

Acceptable control of rhizome johnsongrass can be obtained when a "double-rate" of trifluralin is applied for two years. A chisel plow or similar implement should be used to bring rhizomes to the top of the soil followed with a disk before application to cut rhizomes into small (5 to 7.5 cm) pieces. Trifluralin should then be thoroughly incorporated with a disk set to cut 10 to 15 cm deep and operated in two different directions at 6.4 to 9.7 km/hr. Some johnsongrass plants will escape. Timely cultivations are necessary to obtain control of these plants. Other dinitroaniline herbicides such as pendimethalin [N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitro-benxenamine], fluchloralin [N-(2-chloroethyl)-2,6-dinitro-N-propyl-4-(trifluromethyl) aniline], and

profluralin [N-(cyclopropylmethyl)-a,a,a-trifluro-2,6-dinitro-N-propyl-p-toluidine] may provide similar rhizome johnsongrass control or suppression (62).

Postemergence control. The use of selective application equipment for the postemergence control of johnsongrass in soybeans did not receive much attention until the introduction of glyphosate. Since this time, selective application equipment such as the recirculating sprayer and the rope-wick applicator have received much enthusiastic interest on the part of weed scientists and farmers. The use of selective application equipment in conjunction with glyphosate has led to the increased control of johnsongrass in soybeans.

The recirculating sprayer was designed to apply herbicides to weeds taller than the crop. The herbicide solution is usually applied through solid stream nozzles above and at right angles to the rows, so that a trap collects the herbicide spray not deposited on weeds. The trapped solution is filtered and returned to the original spray tank by gravity flow (23). There are recirculating sprayers marketed which deviate from this basic design.

Derting (32) reported that individual johnsongrass plants having two to three stems growing above the soybeans were controlled much better than when only foliage was above the soybeans. He concluded that better control may have been due to a larger exposed foliage surface, greater liquid retention in the "trap" formed by the sheath, or that the application was made at a more susceptible growth stage.

McWhorter (80) reported that glyphosate (1.12 kg/ha) applied with the recirculating sprayer provided 78 to 85 percent control of johnsongrass, and this resulted in increased soybean yields. Other researchers have observed good to excellent johnsongrass control in soybeans when glyphosate was applied to johnsongrass with the recirculating sprayer (32, 38, 92).

McWhorter (81) lists advantages of the recirculating sprayer as: (a) spray can be applied at sufficient volume to thoroughly wet weeds growing above the crop, (b) the recirculating sprayer can be operated at higher speeds than other selective applicators, and (c) the recirculating sprayer will provide a higher level of weed control with fewer trips through the field than with the other methods of selective application. The major disadvantages are: (a) expensive and more complicated when compared to other application techniques, (b) there is some ricochet of the herbicide solution from weeds onto the crop, (c) some drift of fine spray particles onto the crop, (d) the high level of surfactant in Roundup[1] (the commercial product containing glyphosate) produces foam which can be troublesome, and (e) dirt and debris accumulating in the spray trap eventually enter the herbicide solution which impedes the flow of herbicide solution through strainers and nozzles (81).

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[1]Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the authors nor does it imply its approval to the exclusion of other products that may also be suitable.

It is recommended that 3.8 L of glyphosate per 38 to 76 L of water be applied with the recirculating sprayer. It is suggested to use low pressure, avoid windy days for application, travel about 4.8 km/hr, and to use a defoaming agent in the spray tank (6).

The rope-wick applicator was developed to apply non-selective systemic herbicides (such as glyphosate) above the canopy of row-crops. The loosely woven nylon rope (wick) conveys the herbicide solution to weeds that physically contact the rope as the tractor moves through the field. Herbicide on the wick is replenished by capillary movement of herbicide solution from the reservoir (30).

Dale (30) reported that glyphosate applied above the soybean canopy by the rope-wick applicator controlled johnsongrass in soybeans as effectively as glyphosate applied with a recirculating sprayer and resulted in a 51 percent increase in soybean yield compared to an 18 percent increase in soybean yield from plots treated with the recirculating sprayer. The increase in soybean yield was attributed to the greater precision in application of the glyphosate with the rope-wick applicator. Wiese and Lavake (122) observed a variation in johnsongrass control in soybeans from 68 to 88 percent depending on the dilution of glyphosate with water and the speed of application. The best control of johnsongrass was obtained with a 1:2 mixture of glyphosate: water and applied at 4.8 km/hr. Dale (31) reported 93 to 95 percent control of johnsongrass in soybeans when glyphosate was applied with the rope-wick applicator preplant and reapplied seven weeks after planting soybeans to control escaped johnsongrass.

McWhorter (81) considers the major advantage of the rope-wick applicator as: (a) relatively inexpensive and easy to construct compared to other selective applicators, (b) no moving parts, (c) lightweight, (d) applies less herbicide per hectare than other selective application equipment, and (e) no splash or drift problems. The major disadvantages are: (a) slow wick action of some ropes often results in ineffective control, especially in heavy weed populations, (b) must travel at a slow speed, (c) only one side of the weed can be treated, often necessitating multiple trips through the field, and (d) drip of herbicide on the crop can be a problem depending on the type grommet and rope used in construction.

A ratio of 3.8 L of Roundup to 7.6 to 11.4 L of water is recommended (6). Johnsongrass should be at least 25 cm above soybean plants before applying glyphosate with the rope-wick applicator. Ground speeds of 4.0 km/hr or less are recommended with application in two directions if johnsongrass clumps are large (6).

The major disadvantage of the selective application equipment is the necessity for the johnsongrass to be taller than the soybeans before application of glyphosate can be made. By this time, johnsongrass will have competed with soybeans to the point that soybean yields are reduced (15, 80).

Spot treatment. "Spot spraying" or "spot treatment" implies the application of herbicide spray to a restricted area, usually less than 1 m in diameter. Literature on the effects of spot sprays for

johnsongrass control in soybeans is relatively scarce. Frans (41) reported an 86 percent reduction in rhizome johnsongrass clumps after three years of a control program which included two spot applications per year of delapon at a concentration of 12 g/L of water. McWhorter (82) found that a single spot treatment of glyphosate at 6 or 12 g/L of water provided excellent to complete seasonal control of johnsongrass. In addition, spot treatments of glyphosate in soybeans that resulted in 5, 10, and 20 percent soybean stand reductions resulted in soybean yield reduction of 9, 17, and 28 percent, respectively. Consequently, the utility of spot treatments is somewhat limited to sparse populations of johnsongrass and are used to supplement other control measures.

Mefluidide. Mefluidide [[N-[2,4-dimethyl-5-(trifluoromethyl) sulfonyl] amio] phenyl] acetamide]] has been found to selectively control johnsongrass in soybeans as an over-the-top postemergence spray (44, 45, 49, 53, 107, 115). Gates and Prochaska (44) found that a single broadcast rate of mefluidide (128 kg/ha) applied when soybeans were in the V3 to V7 stage of growth and johnsongrass was less than 38 cm tall, allowed various levels of johnsongrass regrowth depending on how quickly the soybeans formed a canopy. A second application of mefluidide (.14 or .28 kg/ha) four weeks later contributed to higher levels of control at harvest. Hargroder et al. (49) observed 81 to 87 percent control of johnsongrass when mefluidide (.28 to .56 kg/ha) was applied to johnsongrass up to 38 cm tall. A second application of mefluidide (.14 to .28 kg/ha) to johnsongrass regrowth provided excellent control. Glenn and Rieck (45) reported that an application of mefluidide to johnsongrass

45 cm tall significantly increased soybean yields over the yields obtained when the application was made to 30 or 75 cm johnsongrass. Swisher and Kapusta (115) stated that mefluidide applied as a single application or split application during drought-stress growing conditions resulted in less than a 23 percent johnsongrass stand reduction. Hayes and Williams (53) observed fair to very good johnsongrass control from an application of mefluidide (.28 kg/ha) to actively growing johnsongrass at least 38 cm tall followed by a second application to any regrowth. Following application, soybeans were stunted and delayed in maturity in some instances. Other researchers (45, 107) have observed soybean injury when applying mefluidide at rates greater than label recommendations.

It is currently suggested to apply mefluidide at a rate of .28 kg/ha to actively growing johnsongrass less than 38 cm tall. Soybeans should be actively growing and past the V3 stage of growth. An optional second application of mefluidide (.28 kg/ha) is suggested three to four weeks after the first application if new growth or regrowth of johnsongrass occurs. The second application must be made no later than 60 days prior to harvest (4).

Sethoxydim. Sethoxydim is a postemergence grass herbicide discovered in the laboratories of Nippon Soda and is currently being developed by BASF Wynandotte Corporation in the United States (3). Sethoxydim has been found to selectively control annual and perennial grasses in broadleaf crops at rates ranging from .14 to 1.12 kg/ha (27, 53, 90, 105, 106). McAvoy (69) reported that the addition of oil

concentrate increased the activity of sethoxydim and compensated for approximately .28 kg/ha sethoxydim.

Sethoxydim has been found to translocate both basipetally and acropetally resulting in the death of the meristamatic tissue in the shoot, roots, and rhizomes (69).

Rosser and Witt (109) applied sethoxydim to johnsongrass at rates of .33, .56, and 1.12 kg/ha on two dates, i,e,, the first date at the early boot to boot stage and the second date at the late boot to early seed fill stage, in order to determine rhizome control. Sethoxydim at all rates applied at the first date gave control ranging from 85 to 95 percent while 81 percent control was the best obtained from the second date. Single node rhizome segments (2.5 cm) were removed from field plots and planted in the greenhouse six weeks after treatment application in order to determine regrowth from the rhizomes. Sethoxydim provided 88 to 100 percent reduction in regrowth from rhizomes at the rate of 1.12 kg/ha at both application dates.

Bridges et al. (16) reported effective rhizome control by the single application of sethoxydim at 1.12 kg/ha or by an initial application of sethoxydim at .45 kg/ha followed by .37 kg/ha three weeks later.

Banks (8) applied sethoxydim to johnsongrass at three stages of growth (15, 41, and 91 cm tall). Sethoxydim applied to johnsongrass 15 cm tall resulted in less than 75 percent control. Sethoxydim applied to johnsongrass 91 cm tall provided better control than when applied to the johnsongrass at either 15 or 41 cm tall. Hayes and Williams (53) observed excellent johnsongrass control with 0.45 to 1.12 kg/ha

sethoxydim plus 0.5 to 1 percent v/v oil concentrate when applied to actively growing johnsongrass at least 30 cm tall with 45 to 60 cm being the optimum height range.

CHAPTER III

MATERIALS AND METHODS

Johnsongrass Threshold in Soybeans

The experiments were conducted at the West Tennessee Experiment Station at Jackson, Tennessee on a Collins silt loam (coarse-silty, acid, thermic Aquic Udifluvent) having a pH of 6.9 with 1 percent organic matter.

Treatments were arranged in a randomized complete block design and replicated seven times in the .25 m row spacing and five times in the 1.0 m spacing. Individual plots consisted of eight rows or three rows by 9.1 meters long in the .25 m and 1.0 m row spacings, respectively. Each experiment consisted of eight treatments (Table 1).

Prior to planting, seedbeds were prepared by moldboard plowing in the spring. Fertilizer was applied at a rate of 45 kg/ha of P_2O_5 and 45 kg/ha of K_2O. Trifluralin (.56 kg/ha) was applied preplant incorporated to control annual grasses and some annual broadleaf weeds. The seedbeds were smoothed and finished with a seedbed conditioner and 'Forrest' soybeans were planted at a rate of 67 kg/ha on May 15 and 19, 1980, for the 1.0 m and .25 m row spacings, respectively.

Johnsongrass plants having secondary rhizomes were transplanted by hand on June 10 and 11 in the center row of each plot at equal distances from each other and the ends of the row. On June 17, johnsongrass transplants that had died due to dry soil conditions were replaced

with johnsongrass transplants similar to those plants initially transplanted.

Table 1. Johnsongrass populations used in the threshold studies.

Treatment Number	Johnsongrass Plants/9.1 m	Johnsongrass Plants/ha
1	0	0
2	1	1000
3	2	2000
4	4	4000
5	8	8000
6	12	12000
7	16	16000
8	30	32000

Plots were maintained free of weeds, except the established johnsongrass populations, by hand-hoeing and with the use of bentazon [3-isopropyl-1H-2,1,3-benzothiadiazin-4(3H)-one 2,2-dioxide] (.84 kg/ha) for the control of cockleburs (Xanthium pensylvanicum Wallr.).

On October 21 the number of johnsongrass culms/plot was determined for each treatment and then johnsongrass plants were cut at soil surface, oven-dried at 65°C, and dry weights determined.

Soybean yield was determined on October 21 by harvesting the center row from each plot having a 1.0 m row spacing and the four center rows from each plot having a .25 m spacing. Soybean yields were reported as No. 2 yellow soybeans at 13 percent moisture.

Johnsongrass Competition in Soybeans

The Johnsongrass competition study was conducted in 1980 at the Milan Experiment Station near Milan, Tennessee. Individual plots consisted of three rows, 102 cm by 7.6 m long. Each treatment was replicated four times in a randomized complete block design.

The study was established on Loring silt loam (fine-silty mixed, thermic Typic Fragiudalfs) having a pH of 6.5. Fertilizer was applied at a rate of 45 kg/ha P_2O_5 and 45 kg/ha K_2O at Milan. The soil was prepared for planting by moldboard plowing in the spring followed by disking. The seedbed was smoothed and finished with a seedbed conditioner and 'Bedford' soybeans were planted at a rate of 45 kg/ha on May 26.

The experiment consisted of 20 treatments. The treatment schemes suggested by Buchanan (18) and used in this experiment are shown in Figures 1 and 2. Treatments 1 and 14 are the weedy check and weed free check, respectively. Treatments 2 through 7 were initiated in order to determine the critical johnsongrass free requirement of soybeans. Treatments 8 through 13 were initiated to determine the critical duration of johnsongrass competition in soybeans, and treatments 15 through 20 were conducted to determine the critical duration of johnsongrass in soybeans when johnsongrass is controlled with sethoxydim and to determine the optimum time of application of sethoxydim for johnsongrass control. Sethoxydim was applied at a rate of 1.12 kg/ha with 1 percent (v/v) oil concentrate. The herbicide was applied as an over-the-top aqueous spray in a volume of 187 L/ha.

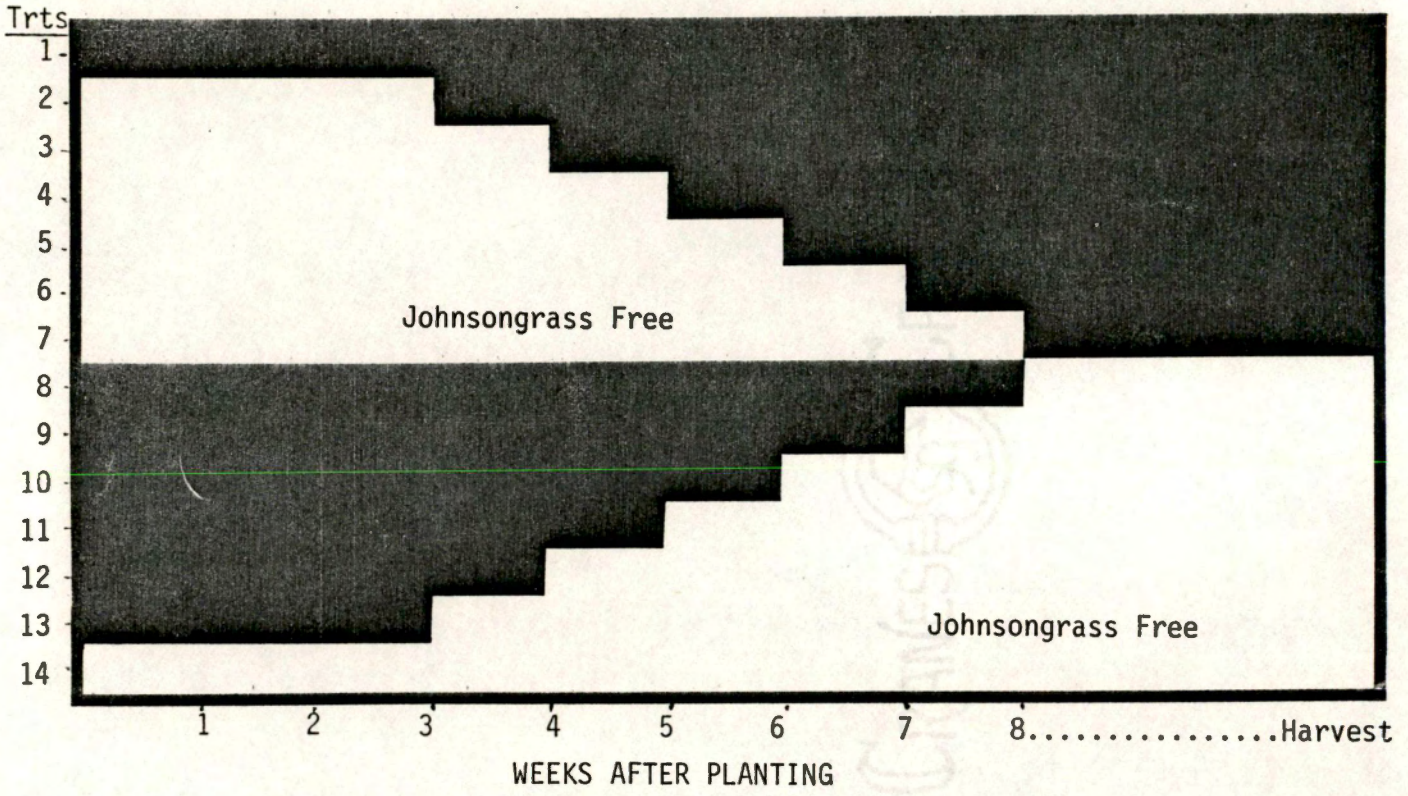


Figure 1. Treatments used in the johnsongrass competition study to determine the critical johnsongrass free requirement of soybeans and the critical duration of johnsongrass in soybeans.

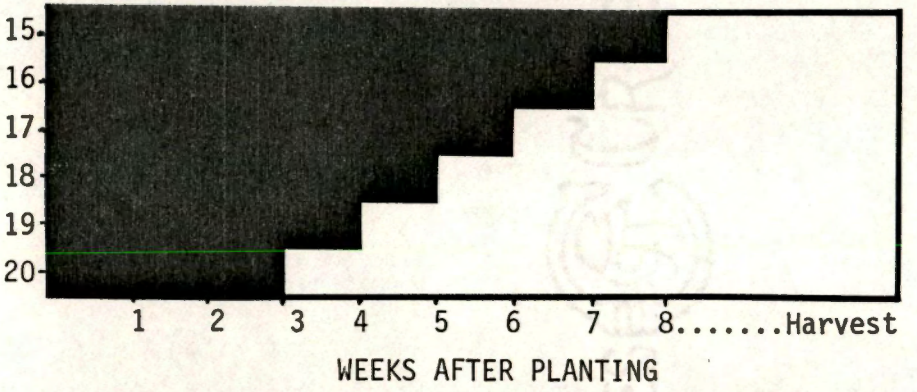


Figure 2. Treatments used in the johnsongrass competition study to determine the optimum time for application of sethoxydim to johnsongrass. (Applications were made at weekly intervals from three to eight weeks after planting.)

Mechanical removal of johnsongrass at the designated weekly intervals was accomplished and subsequently maintained by hand-hoeing. Plots were kept free of all weeds except johnsongrass by hand-hoeing and with over-the-top broadcast applications of bentazon (.84 kg/ha).

Before initiating treatments 8 through 13 at the designated weekly intervals, the number of johnsongrass plants per a 1 m^2 section of the plot was recorded. After recording the number of johnsongrass plants, the plants were removed at the soil surface, oven dried at 65 $^{\circ}$C and dry weights determined. The johnsongrass plants were ground to pass through a 20 mesh screen and nutrient analysis determined and expressed on a percentage of dry weight basis. Nitrogen analysis was conducted on the Technicon autoanalyzer from a 0.2 gm sample by a total nitrogen (NH_4^+) procedure described by Thomas et al. (117). Phosphorus, potassium, magnesium, and calcium analyses were conducted on the autoanalyzer from a 0.5 gm sample after a wet digestion procedure described by Blanchar et al. (14).

Johnsongrass and soybean height was determined and recorded from three weeks after planting to 14 weeks after planting. Johnsongrass control was visually estimated throughout the season on the basis of 0 = no control to 100 percent = complete control by mechanical removal or death of johnsongrass (42).

The upper 90 cm of the soil profile was sampled on August 7 and soil water content determined using the procedure described by Gardner (43). The number of johnsongrass plants and culms was determined from the 7.6 m^2 center row section in each plot when

soybeans had reached the R6 stage of growth. Soybean and johnsongrass plant dry weight was determined by cutting the plants at the soil surface from a 1 m^2 or 7.6 m^2 center row section, respectively, and oven drying at 65°C. Soybean yields were obtained by hand harvesting the center row of each plot on October 31. Soybean yields are reported as No. 2 yellow soybeans at 13 percent moisture.

Rainfall data at both locations were recorded throughout the growing season and are presented in the Appendix.

CHAPTER IV

RESULTS AND DISCUSSION

Johnsongrass Threshold in Soybeans

The influence of various parameters affecting soybean yield is illustrated in Figures 3 to 6. With an increasing amount of johnsongrass dry weight and number of culms/ha, a trend in yield reduction was observed (Figures 3, 4, 5, and 6). Significant soybean yield reduction occurred with the equivalent of 32,000 johnsongrass plants/ha in the 1 m row spacing study (Figures 4 and 6).

Correlation coefficients indicated that johnsongrass dry weight/ha and the number of johnsongrass culms/ha were more highly correlated with soybean yield than the number of johnsongrass plants/ha (Tables 2 and 3). This was probably due to the inconsistency in size of johnsongrass plants due to adverse weather conditions. The number of johnsongrass plants/ha was not as highly correlated with johnsongrass dry weight as the number of johnsongrass culms/ha (Tables 2 and 3). This indicates that predicting soybean yield reduction based on the number of johnsongrass plants/ha would be difficult since one must also predict how much the johnsongrass will grow. Schweizer (111) observed this difficulty in predicting yield reduction based on the number of weeds/30 m of row in sugar beets (Beta vulgaris L.). He concluded that weeds under stress, in this case caused by herbicides, were not able to grow competitively with the crop and consequently reduce crop yield.

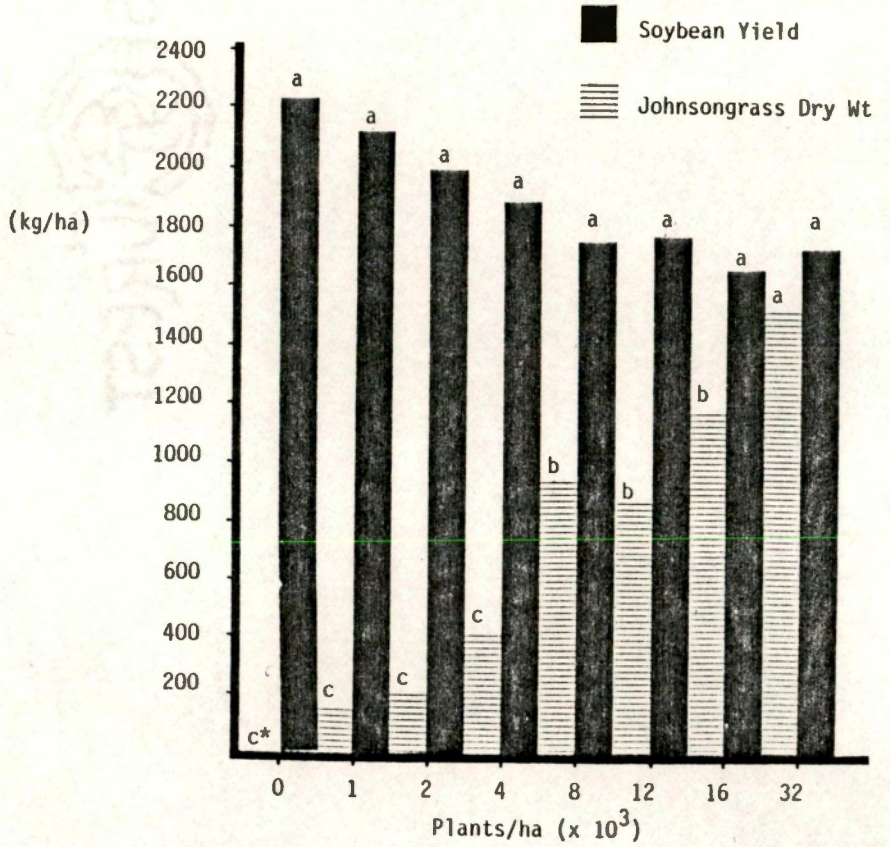


Figure 3. The effect of increasing johnsongrass plant number and dry weight on soybean yields in the .25 m row spacing study.

*Values within like bars followed by the same letter are not significantly different at the 5 percent level, according to Duncan's multiple Range Test.

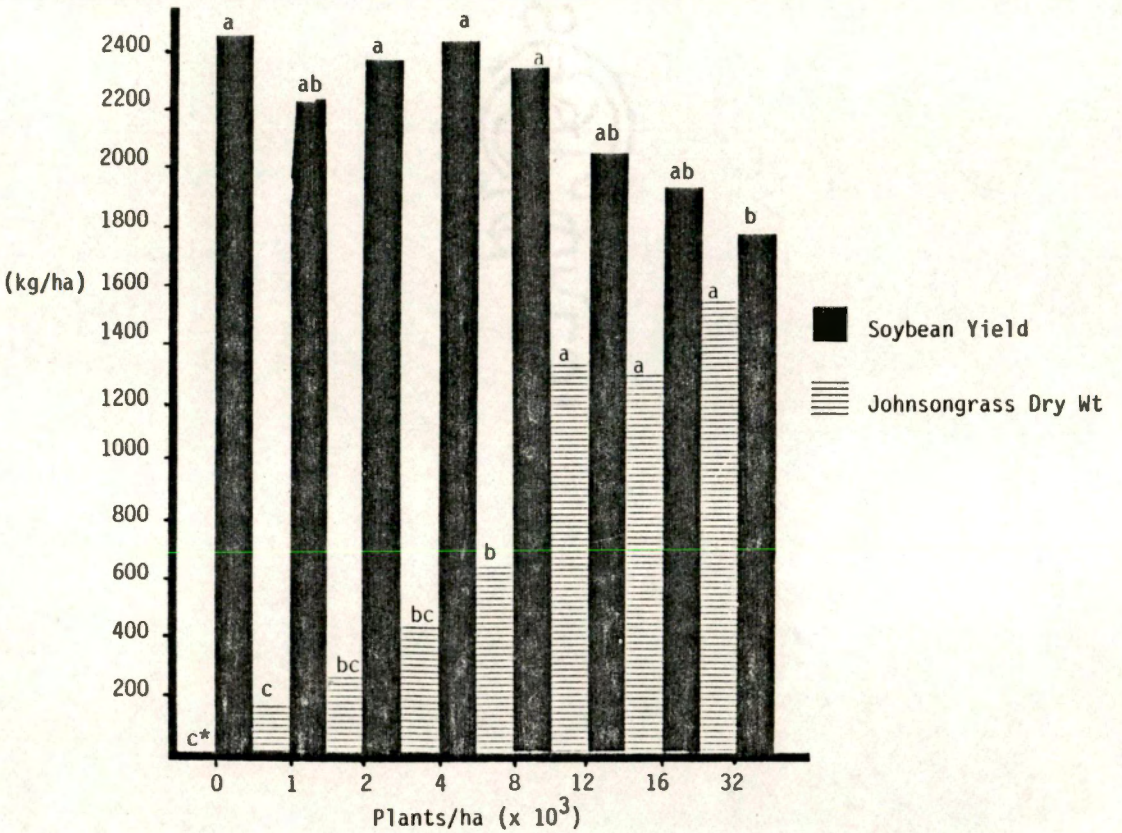


Figure 4. The effect of increasing johnsongrass plant number and dry weight on soybean yield in the 1.0 m row spacing study.

*Values within like bars followed by the same letter are not significantly different at the 5 percent level, according to Duncan's Multiple Range Test.

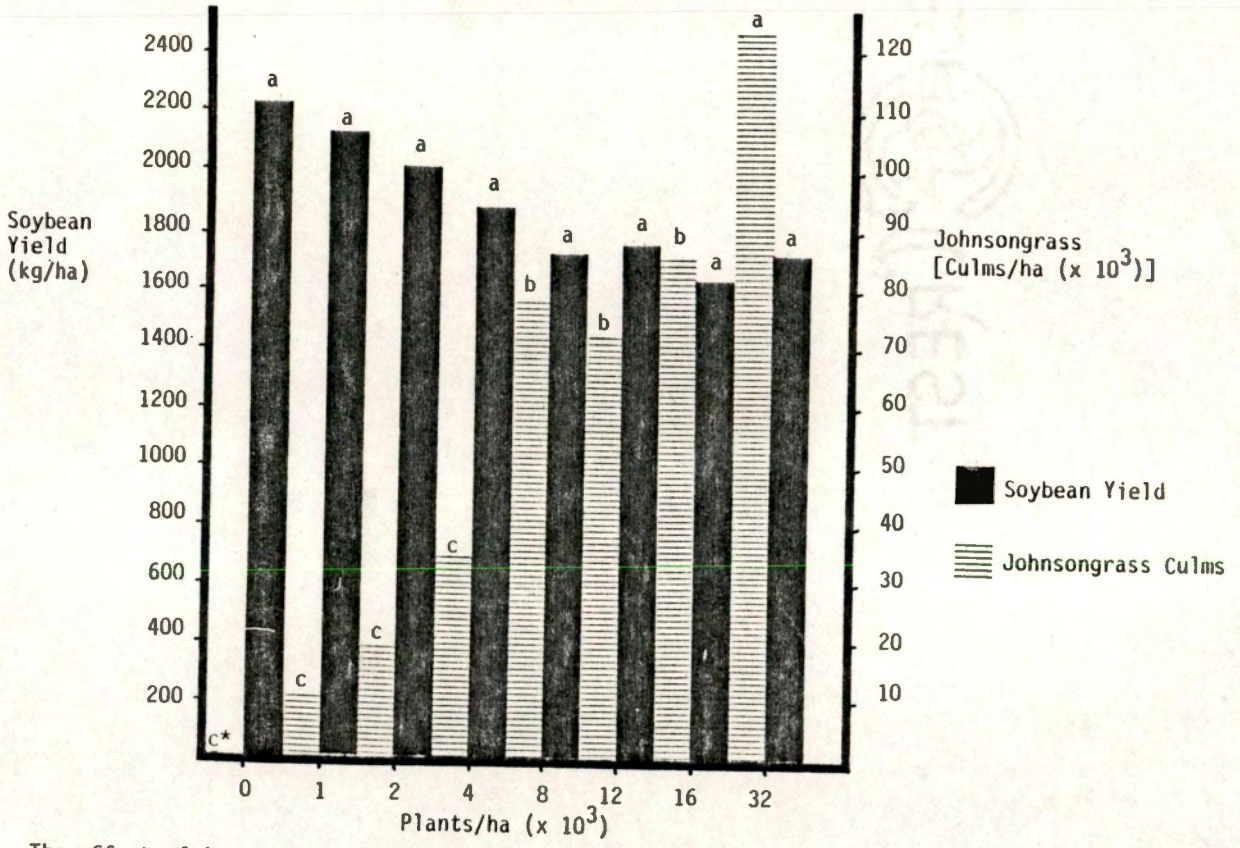


Figure 5. The effect of increasing johnsongrass plant number and the number of culms on soybean yields in the .25 m row spacing study.

*Values within like bars followed by the same letter are not significantly different at the 5 percent level, according to Duncan's Multiple Range Test.

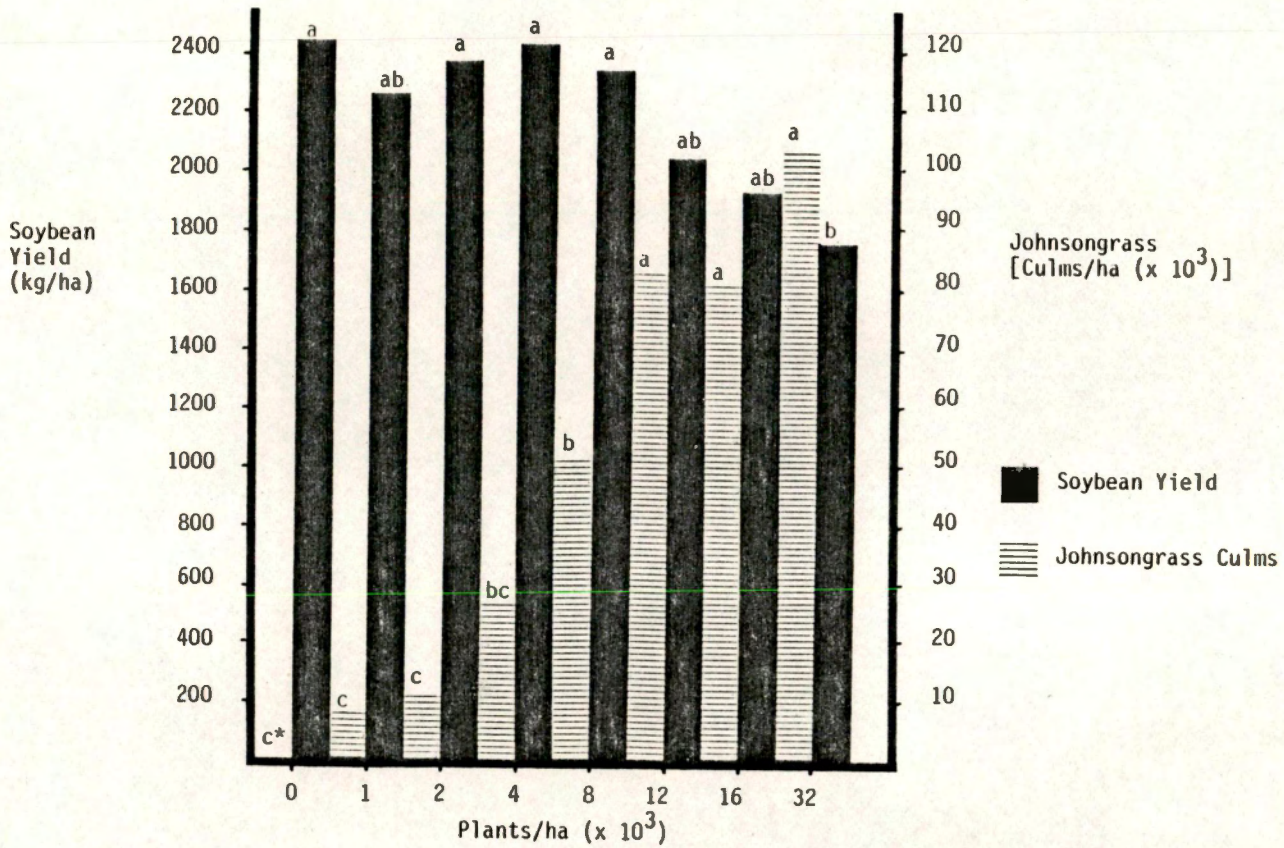


Figure 6. The effect of increasing johnsongrass dry weight and the number of culms on soybean yields in the 1.0 m row spacing study.

*Values with like bars and followed by the same letter are not significantly different at the 5 percent level, according to Duncan's Multiple Range Test.

Table 2. Matrix of correlation coefficients between johnsongrass plants (plant/ha), johnsongrass culms (culms/ha), johnsongrass dry weight (kg/ha), and soybean yield (kg/ha) when grown in rows spaced .25 m apart.

Character	Johnsongrass Culms	Johnsongrass Dry Weight	Soybean Yield
Johnsongrass plants	.78*	.77*	-.30**
Johnsongrass culms		.97*	-.60*
Johnsongrass dry weight			-.58*

*Values significant at the 0.01 probability level.

**Values significant at the 0.05 probability level.

Table 3. Matrix of correlation coefficients between number of johnsongrass plants (plants/ha), johnsongrass culms (culms/ha), johnsongrass dry weight (kg/ha), and soybean yield (kg/ha) when grown in rows spaced 1.0 m apart.

Character	Johnsongrass Culms	Johnsongrass Dry Weight	Soybean Yield
Johnsongrass plants	.83*	.77*	-.48**
Johnsongrass culms		.94*	-.62*
Johnsongrass dry weight			-.73*

*Values significant at the 0.01 probability level.

**Values significant at the 0.05 probability level.

Although johnsongrass dry weight and the number of johnsongrass culms/ha were better indicators of soybean yield reduction than the number of johnsongrass plants/ha, the former parameters can only be determined after the johnsongrass has exerted its competitive influence.

A simple and early method of determining the possible yield reduction in soybeans is necessary to benefit farmers and personnel involved with integrated pest management. Therefore, determining the number of johnsongrass plants/ha would be the most appropriate method of predicting the economic threshold in soybeans.

The initial number of johnsongrass plants present early in the season was correlated with soybean yield (Figures 7 and 8). Regression analysis revealed that the most practical prediction equations over the range of johnsongrass populations for .25 and 1 m row spacings, respectively, are as follows:

$$\hat{Y} = 2033 - .03x$$

and

$$\hat{Y} = 2405 - .045x$$

where $\hat{Y}$ = the estimated soybean yield (kg/ha and x represents the number of johnsongrass plants (plants/ha). These equations provide a basis for projecting the yield reduction due to johnsongrass early in the season.

Further research is necessary in order to determine the economic threshold of johnsongrass in soybeans. This information will be helpful in determining the growth and competitive influence of

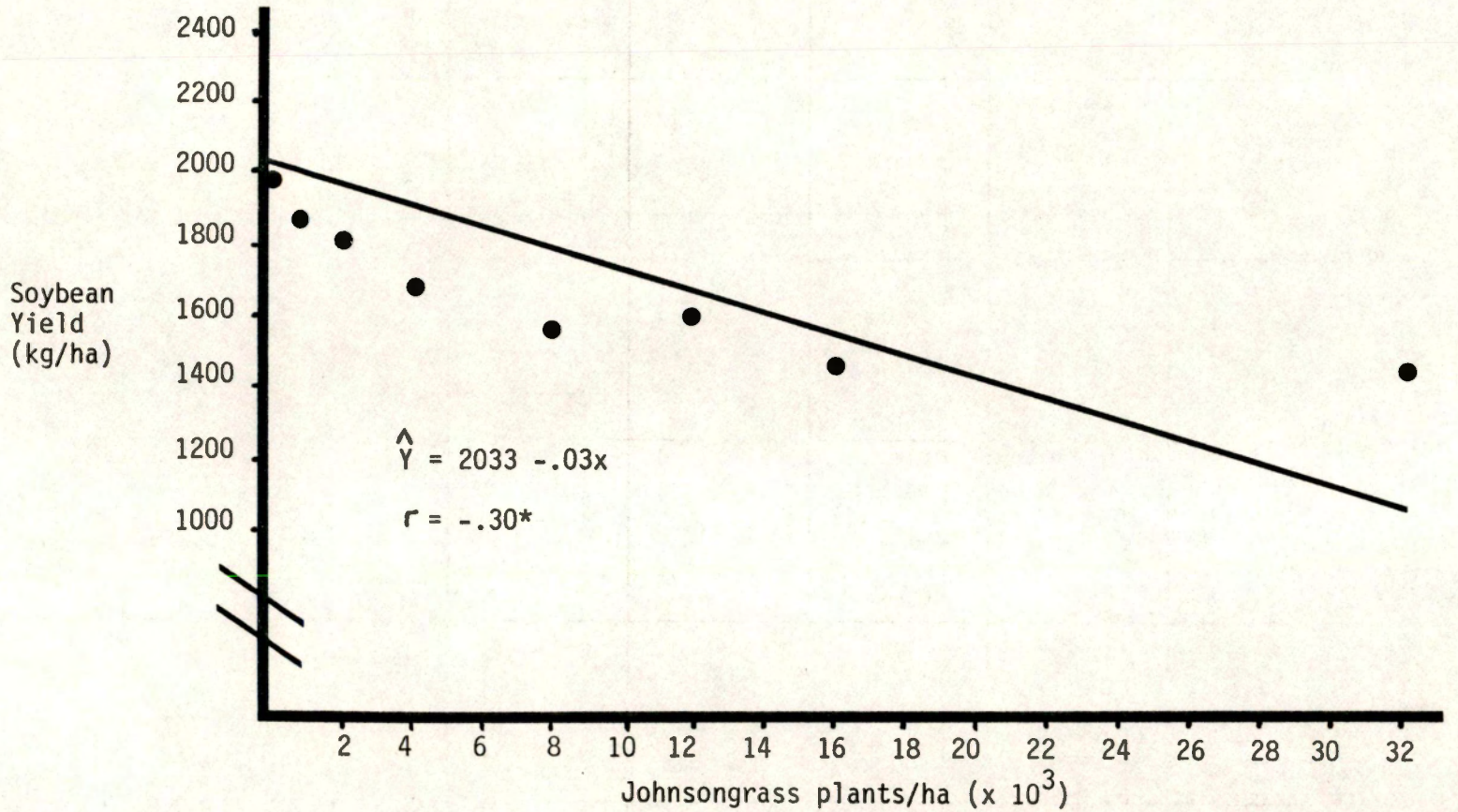


Figure 7. Soybean yield as affected by johnsongrass plant density in the .25 m row spacing study.

*Value significant at the 0.05 probability level.

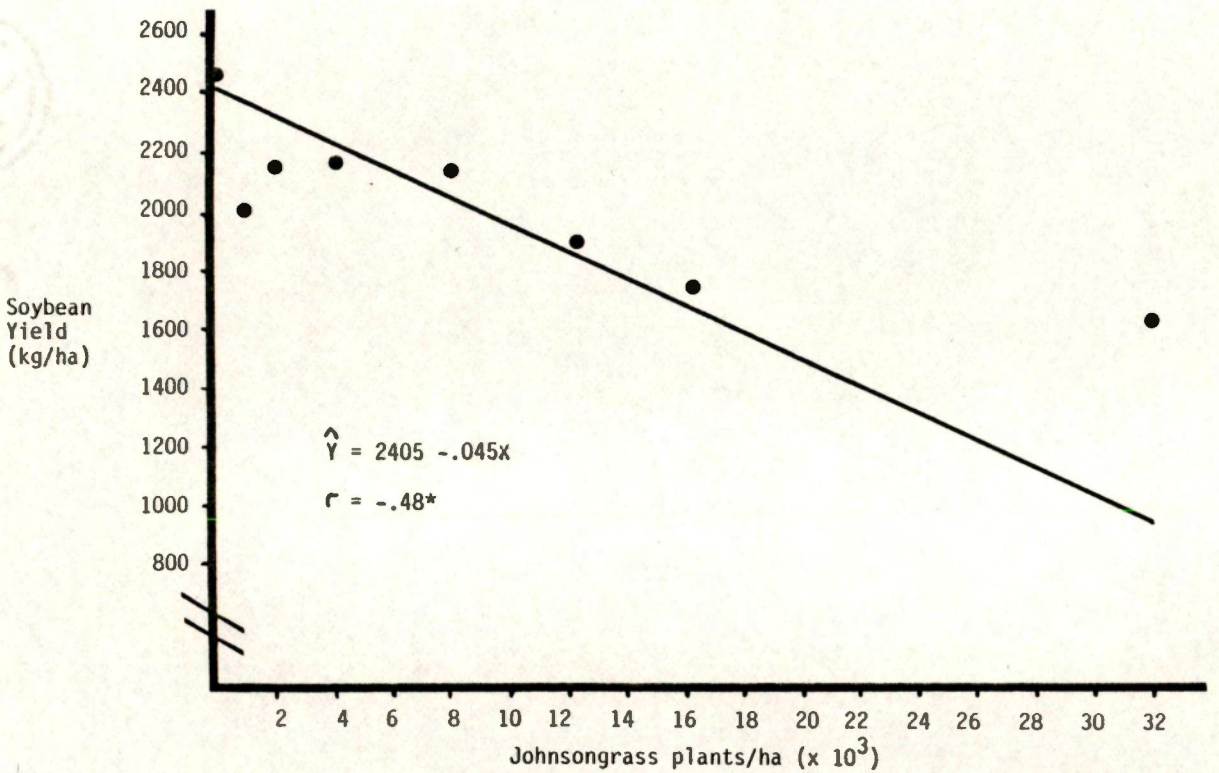


Figure 8. Soybean yield as affected by johnsongrass plant density in the 1.0 m row spacing study.

*Value significant at the 0.05 probability level.

johnsongrass in soybeans and to make accurate predictions such that appropriate management strategies can be employed by farmers.

Critical Johnsongrass-free Requirement of Soybeans

Excellent johnsongrass control was obtained when soybeans were maintained free of johnsongrass for as long as six weeks after planting (Figure 9). Soybeans maintained free of johnsongrass for five weeks after planting resulted in good weed control at the end of the season (Figure 9). Approximately 15 and 64 percent end of season johnsongrass control was obtained in soybeans maintained free of johnsongrass for three or four weeks after planting, respectively (Figure 9). Johnsongrass control ratings for these two treatments were low since johnsongrass was able to reestablish and attain much growth by the end of the season. When plots were maintained johnsongrass-free for as long as five weeks after planting, soybeans had attained a height of 25 cm and were consequently very competitive with newly emerging johnsongrass. Not only did soybeans have a competitive advantage with the johnsongrass due to the height differential, the weekly mechanical removal of johnsongrass was exhausting the energy source reserves in the rhizomes, thereby producing fewer and weaker plants. Johnsongrass control ratings indicate that end of season johnsongrass control is improved when the mechanical removal of johnsongrass is prolonged.

Generally, there was an inverse relationship between soybean and johnsongrass plant dry weights harvested at the R6 stage of soybean growth (Figure 10). The weedy check contained 3.3 times as much johnsongrass dry weight as compared to plots maintained johnsongrass-

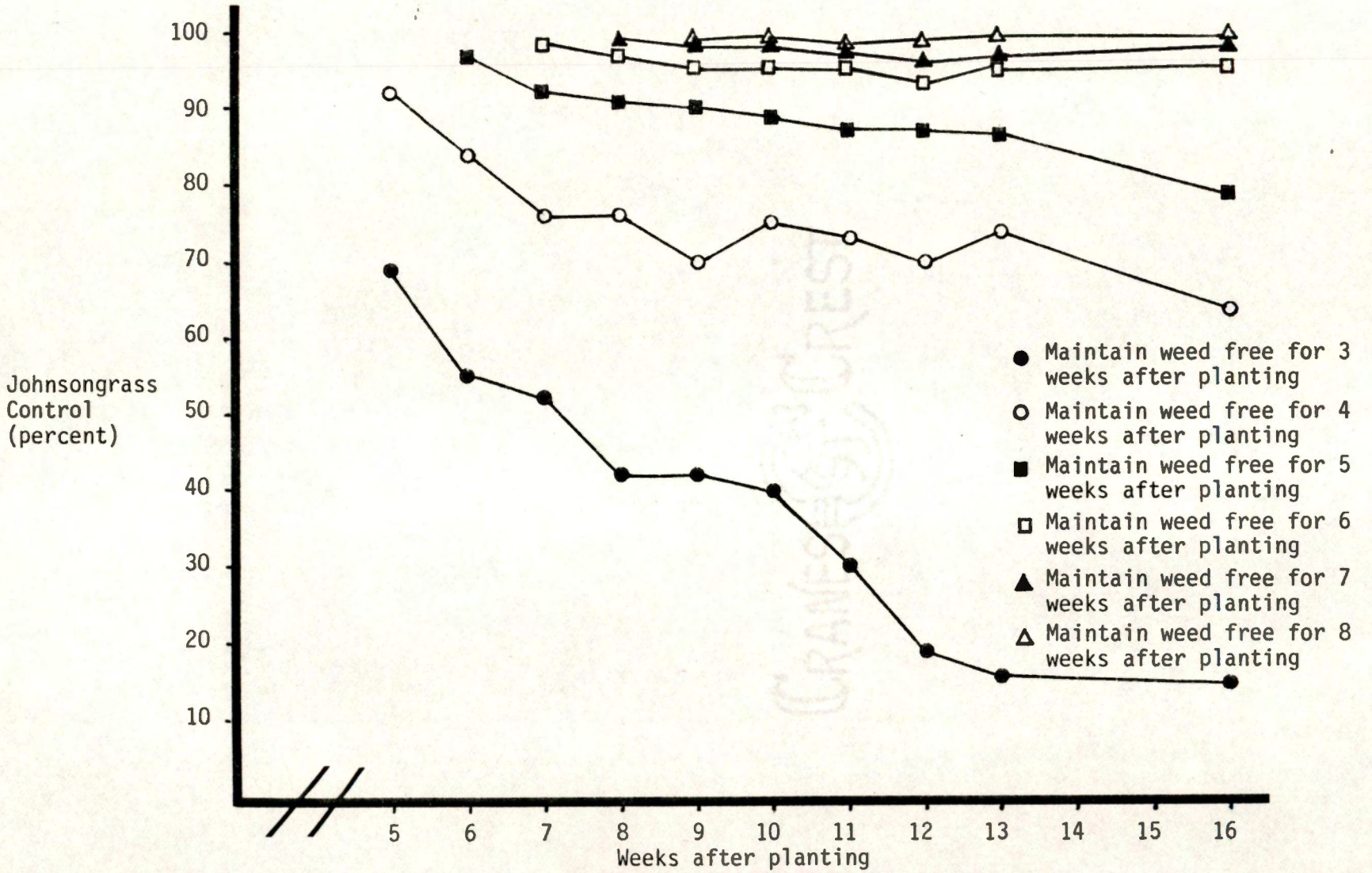


Figure 9. Johnsongrass control provided through the growing season when soybeans were kept johnsongrass-free for the respective number of weeks after planting.

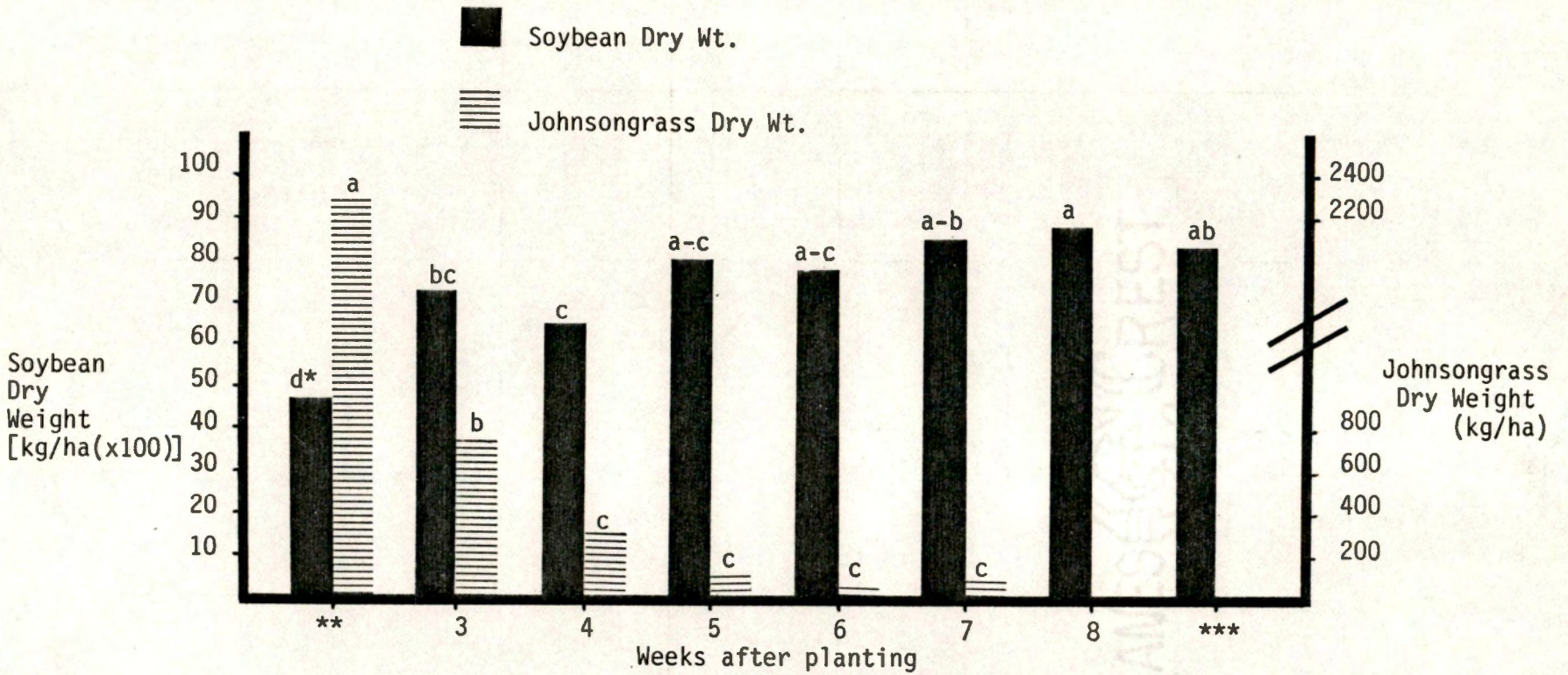


Figure 10. The influence of keeping soybeans johnsongrass-free for the respective number of weeks after planting on soybean and johnsongrass plant dry weight.

*Values within the same plant dry weight followed by the same letter are not significantly different at the 5 per cent level, according to Duncan's Multiple Range Test.

**Weedy check.

***Weed free check.

free for three weeks after planting and 60 times as much as plots maintained johnsongrass-free for seven weeks after planting (Figure 10). Soybean dry weights in the weedy check and in plots maintained johnsongrass-free for three weeks after planting contained a significantly greater amount of johnsongrass dry weight than soybeans maintained johnsongrass-free for four weeks after planting. Soybean dry weight in plots maintained johnsongrass-free for three weeks after planting was not significantly less than soybean dry weight in the weed-free check (Figure 10). The addition of the johnsongrass dry weight to the soybean dry weight in treatments having significantly less soybean dry weight did not increase the total biomass weight to that of the weed-free check (Table 4). This is in contrast to the findings of researchers studying the competition between soybeans and other weeds (68, 69).

A significant reduction in soybean seed yield occurred when soybeans were maintained johnsongrass-free for only three weeks after planting (Figure 11). The critical johnsongrass-free requirement of soybeans as determined by soybean seed yield was four weeks (Figure 11).

Critical Duration of Johnsongrass in Soybeans

An exponential increase in dry weight of johnsongrass occurred from three weeks after planting through eight weeks after planting (Figure 12). From eight weeks after planting to 16 weeks after planting a slight decrease in johnsongrass dry weight was observed (Figure 12). This was probably due to the natural defoliation of

Table 4. The production of dry matter from soybeans and johnsongrass grown in competition.

Treatments	Soybean Dry Weight	Johnsongrass Dry Weight kg/ha	Total Biomass
Weedy check	4800	2229	7029b*
Weed free check	8200	-	8200a
Maintain weed free for 3 weeks after planting	7300	673	7973a
Maintain weed free for 4 weeks after planting	6500	307	6807b
Maintain weed free for 5 weeks after planting	8000	120	8120a
Maintain weed free for 6 weeks after planting	7800	23	7823a
Maintain weed free for 7 weeks after planting	8500	37	8537a
Maintain weed free for 8 weeks after planting	8900	-	8900a

*Values followed by the same letter are not different, according to Duncan's Multiple Range Test.

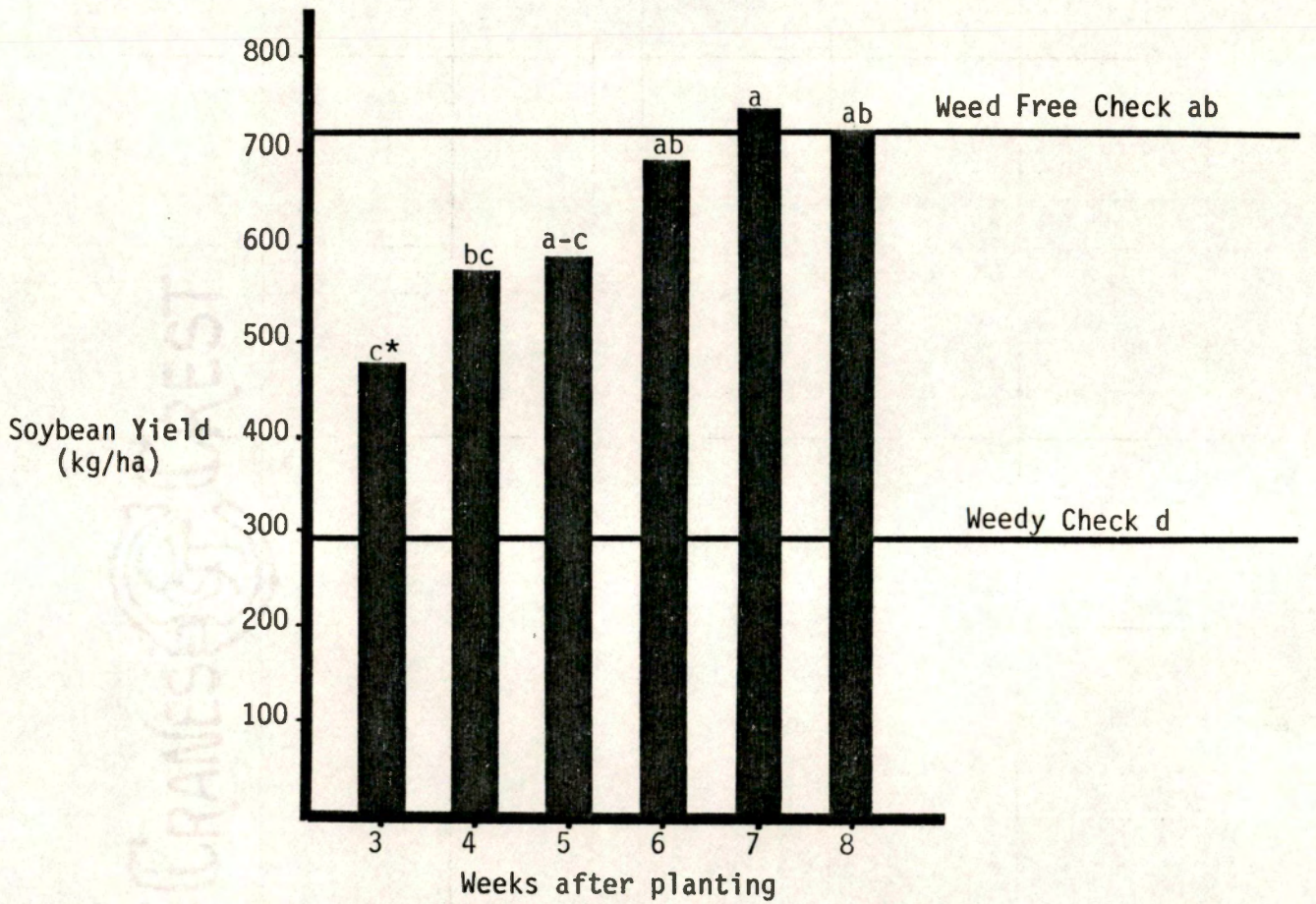


Figure 11. The influence of keeping soybeans johnsongrass-free for the respective number of weeks on soybean yield.

*Values followed by the same letter are not significantly different at the 5 per cent level, according to Duncan's Multiple Range Test.

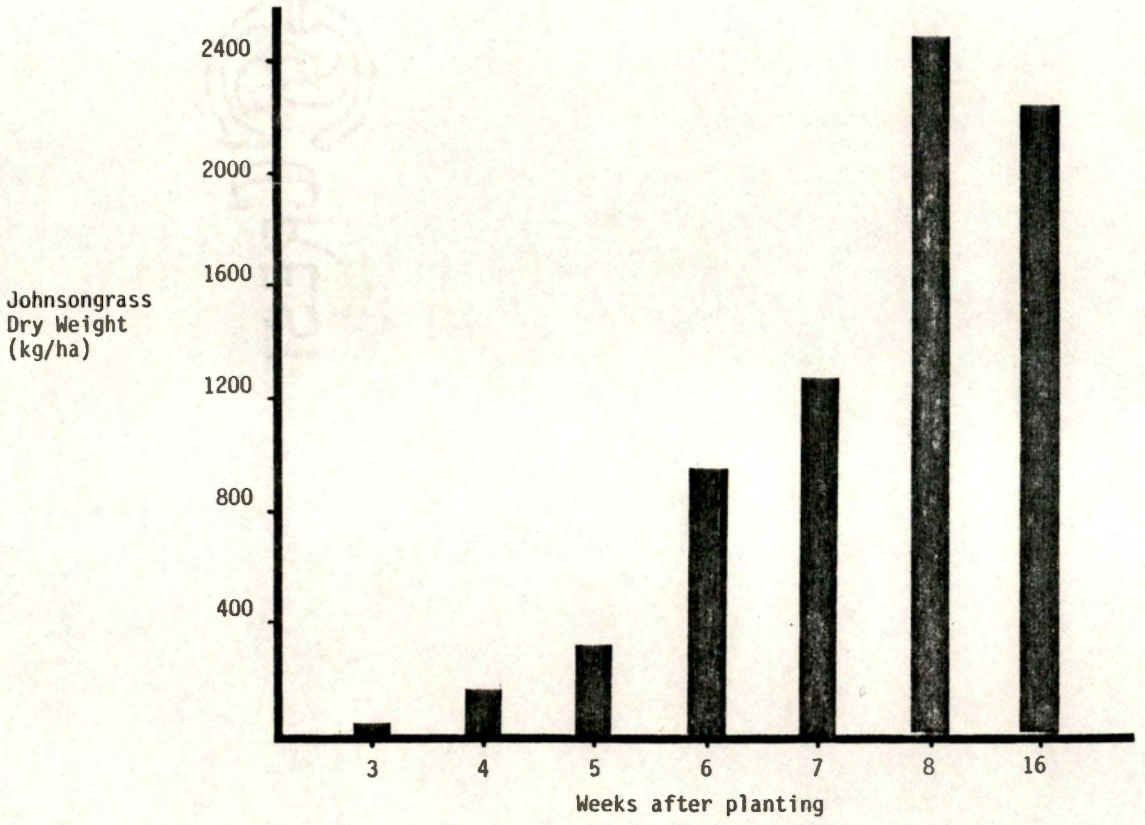


Figure 12. Seasonal growth of johnsongrass growing in competition with soybeans.

johnsongrass as a result of drought conditions and the abscission of seed from the plant.

Johnsongrass height increased exponentially from three weeks after planting through nine weeks after planting (Figure 13). The point of inflection was observed at nine weeks after planting resulting in the plateau phase of growth thereafter (Figure 13). Soybean plants were slightly taller than johnsongrass plants until the period between five and six weeks after planting (Figure 13). By nine weeks after planting, an 80 cm height differential existed between the taller johnsongrass plants and the soybean plants (Figure 13). The johnsongrass plants extended above soybean plants by at least 60 cm from this time through the R6 stage of soybean growth (Figure 13).

Johnsongrass had a competitive advantage over soybeans in that it was able to emerge with the soybeans and almost attain its maximum height and foliar dry weight within eight weeks after planting.

Mineral analysis indicated that johnsongrass contained a higher percent of each mineral at early stages of growth (Table 5). Although the degree of competition between johnsongrass and soybeans cannot be determined for the nutrients analyzed, the analysis does indicate the amount of each nutrient contained in the johnsongrass and consequently, unavailable to the soybeans (Table 6).

Soybean dry weight was significantly reduced when johnsongrass was allowed to grow with soybeans for eight weeks after planting (Figure 14). This would indicate that soybean plants are strong competitors with johnsongrass plants during the first seven weeks

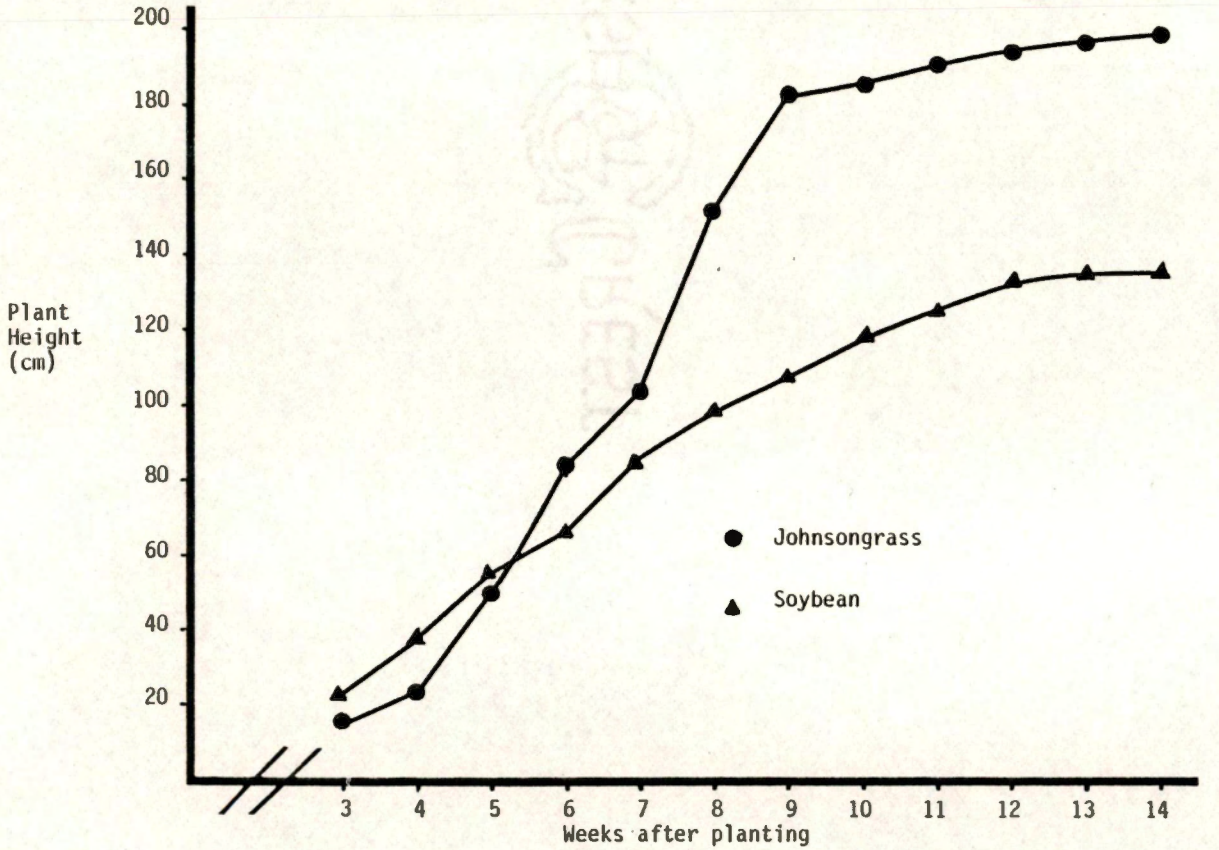


Figure 13. Seasonal growth of johnsongrass and soybean plants growing in competition with each other.

Table 5. Selected nutrients contained in the foliar portion of johnsongrass when allowed to grow with soybeans for the respective number of weeks (percent dry weight).

Number of Weeks	Per Cent Dry Weight				
	N	P	K	Ca	Mg
5	2.42	0.28	4.22	1.81	0.56
6	1.99	0.25	4.60	0.38	0.42
7	1.54	0.24	4.01	0.39	0.43
8	1.07	0.17	3.25	0.41	0.41

Table 6. Selected nutrients contained in foliar portion of johnsongrass when allowed to grow with soybeans for the respective number of weeks (kg/ha).

Number of Weeks	Kg/Ha				
	N	P	K	Ca	Mg
5	7.65	0.87	13.37	5.72	1.77
6	19.53	2.41	45.16	3.75	4.10
7	20.12	3.09	52.44	5.11	5.68
8	26.82	4.19	81.53	10.16	10.31

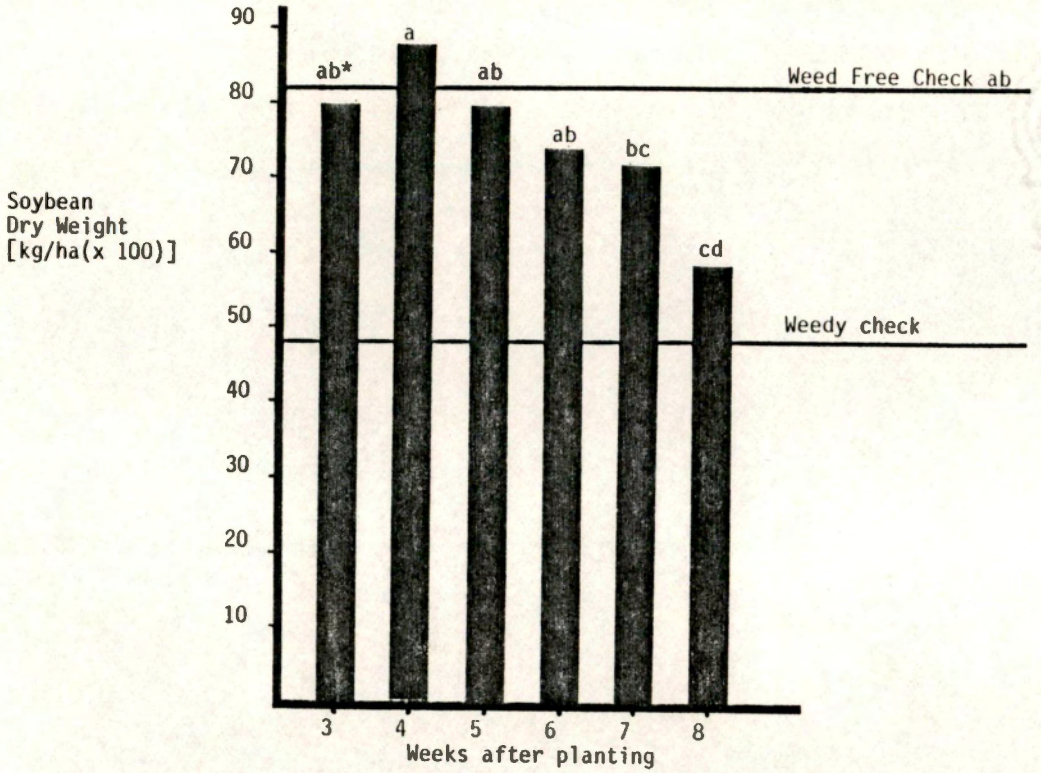


Figure 14. The influence of allowing johnsongrass to grow with soybeans for the respective number of weeks on soybean plant dry weight.

*Values followed by the same letter are not significantly different at the 5 percent level, according to Duncan's Multiple Range Test.

after planting or if soybean plants are weak competitors with johnsongrass plants during this time period, the mechanical removal of johnsongrass from seven weeks after planting to harvest allows the soybean plants to compensate for reduced early growth resulting in soybean dry weights equal to that of the weed free check.

Soybean seed yield was reduced when johnsongrass was allowed to grow with soybeans for eight weeks after planting (Figure 15). The critical duration of johnsongrass in soybeans as determined through seed yield was determined to be seven weeks after planting.

Critical Timing of Sethoxydim Application for Johnsongrass Control in Soybeans

Optimum johnsongrass control was achieved when sethoxydim was applied to johnsongrass at four or five weeks after planting (Figure 16). Sethoxydim applied at three weeks after planting gave excellent early season johnsongrass control, but either johnsongrass regrowth or the emergence of johnsongrass after sethoxydim application led to a slight decrease in johnsongrass control (Figure 16). Sethoxydim application at five weeks after planting gave very good johnsongrass control one and two weeks later, although johnsongrass control continued to decrease from this time due to johnsongrass regrowth (Figure 16). Sethoxydim applied to johnsongrass at seven and eight weeks after application resulted in moderate johnsongrass control four to five weeks after application (Figure 16). Sethoxydim application at eight weeks after planting was found to give better johnsongrass control by the end of the season than either of the two previous applications

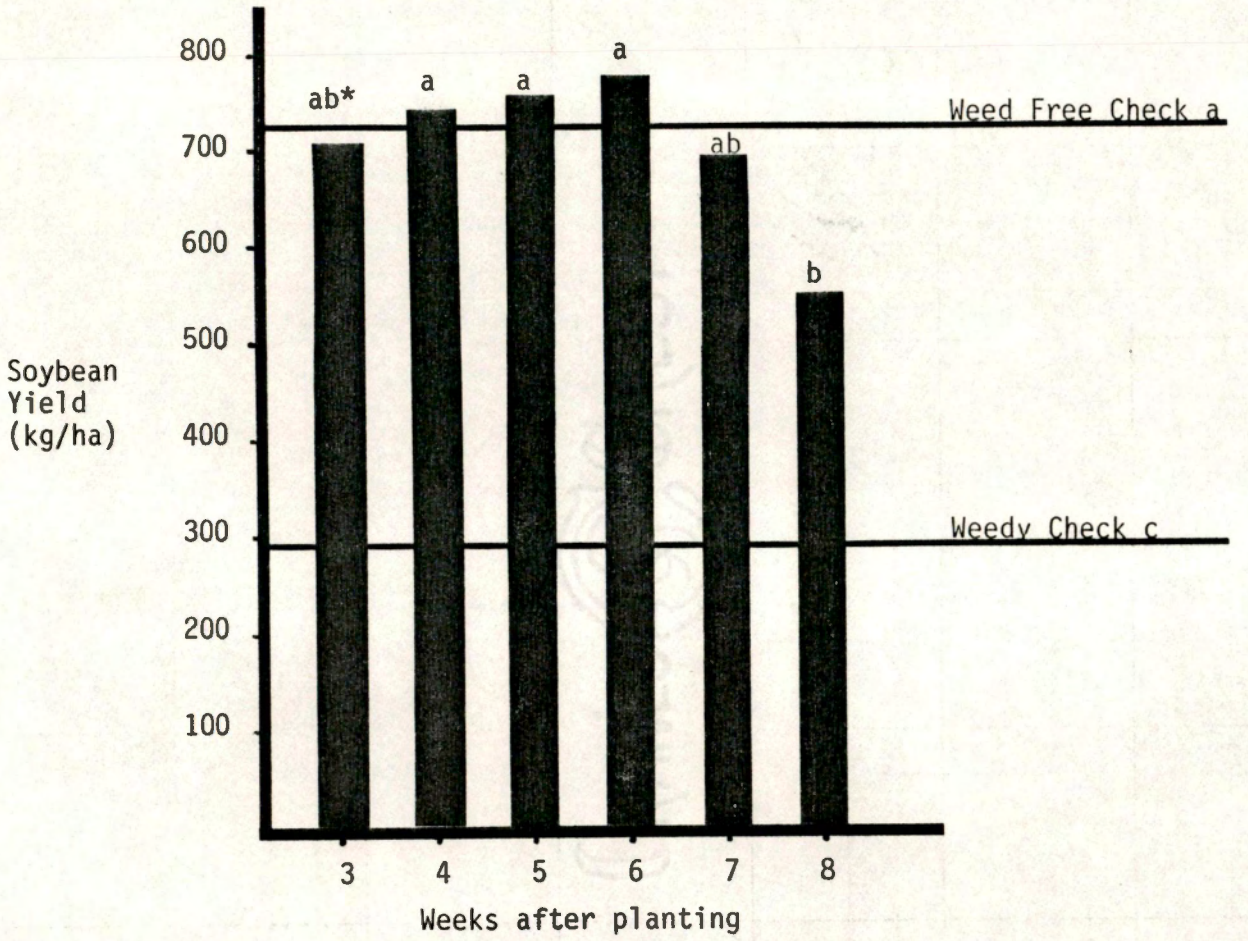


Figure 15. The influence of allowing johnsongrass to grow with soybeans for the respective number of weeks on soybean yield.

*Values followed by the same letter are not significantly different at the 5 percent level, according to Duncan's Multiple Range Test.

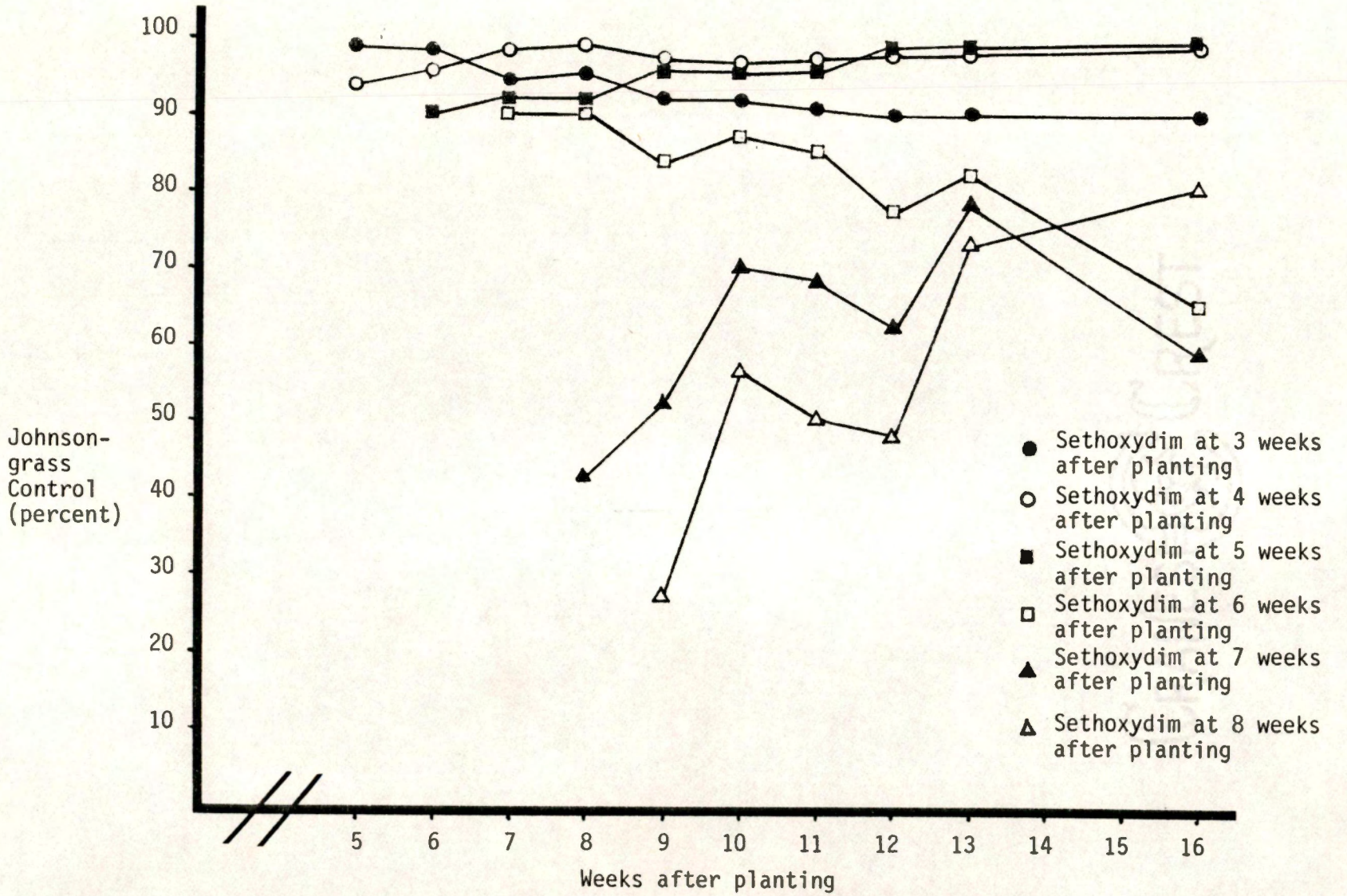


Figure 16. Johnsongrass control through the growing season when sethoxydim was applied at the respective week after planting.

(Figure 16). This was probably due to changing environmental conditions that enhanced the activity of the later application and/or the johnsongrass stage of growth.

Optimum johnsongrass control was obtained when sethoxydim was applied to johnsongrass at a height range of 25 to 50 cm, which corresponded to applications at four or five weeks after planting (Figure 17). The increased johnsongrass control at this height range over the earlier sethoxydim application was probably due to the increased size of soybeans and therefore competitiveness of the soybeans, which would result in less johnsongrass emergence after sethoxydim application. The results indicate that johnsongrass is more sensitive to sethoxydim when it is less than 50 cm tall.

There was a significant increase in johnsongrass dry weight when sethoxydim was applied later than five weeks after planting (Figure 18). This increase in johnsongrass dry weight was most likely due to an incomplete kill of the johnsongrass, the regrowth from the plant and rhizomes, or the possibility that some dead johnsongrass plants from each plot were harvested. Along with a significant increase in johnsongrass plant dry weight was a significant decrease in soybean plant dry weight (Figure 18). The decrease in soybean dry weight when sethoxydim was applied to johnsongrass later than five weeks after planting is presumably due to the increased length of time in which johnsongrass is allowed to compete with soybeans before application and to the inadequate control of johnsongrass after application thereby allowing for continued competition.

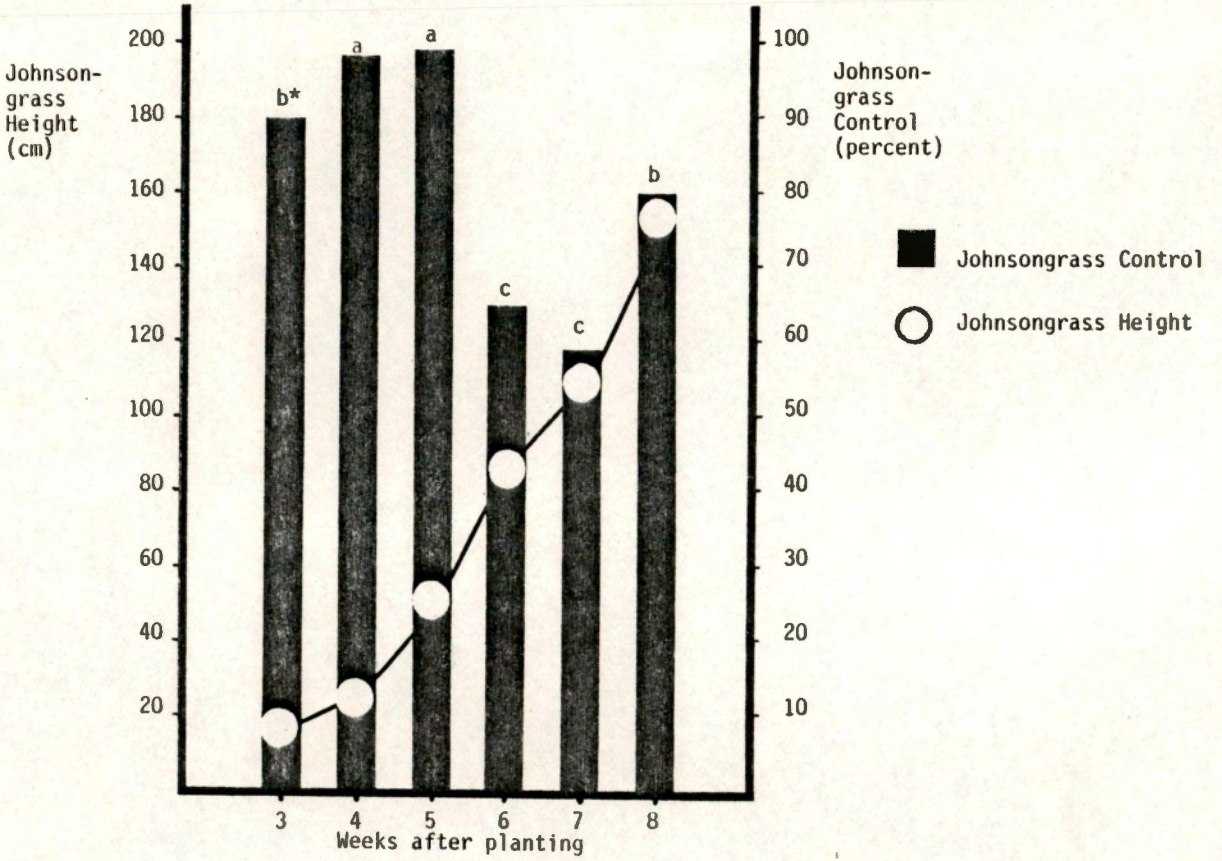


Figure 17. Johnsongrass control at the R6 stage of soybean growth provided by sethoxydim and johnsongrass height at the time of sethoxydim application.

*Values followed by the same letter are not significantly different at the 5 percent level, according to Duncan's Multiple Range Test.

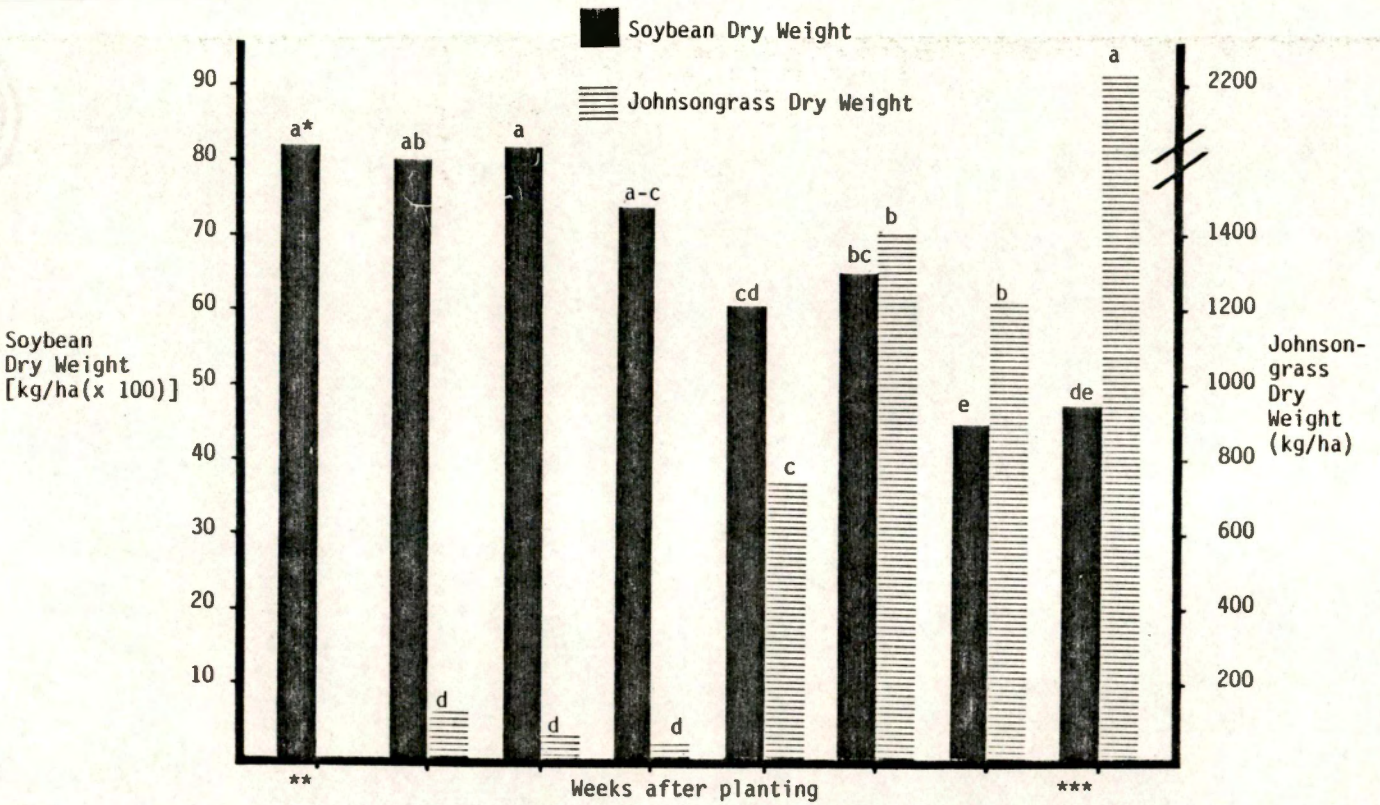


Figure 18. The influence of time of sethoxydim application on soybean and johnsongrass plant dry weight.

*Values within the same plant dry weight followed by the same letter are not significantly different at the 5 percent level, according to Duncan's Multiple Range Test.

**Weedy check ***Weed free check.

Sethoxydim applied later than five weeks after planting resulted in decreased soybean seed yield (Figure 19). The critical timing of sethoxydim application for johnsongrass control in soybeans is five weeks after planting. This is about two weeks earlier than when johnsongrass is controlled mechanically because it is a physiological process compared to a physical removal.

Competition of Johnsongrass and Soybeans for Available Soil Water

Treatments having different levels of johnsongrass infestation were found to have the same soil water deficit (Table 7). The soil water deficit indicated that there was a limited amount of soil water available to the two plant species. Rainfall of less than 2.54 cm fell between the day soil samples were taken and the R6 soybean stage of growth (Appendix, Table 9). The soybean seed yields were found to increase as johnsongrass control increased, indicating that there was a greater utilization of the limited available soil water when johnsongrass was controlled.

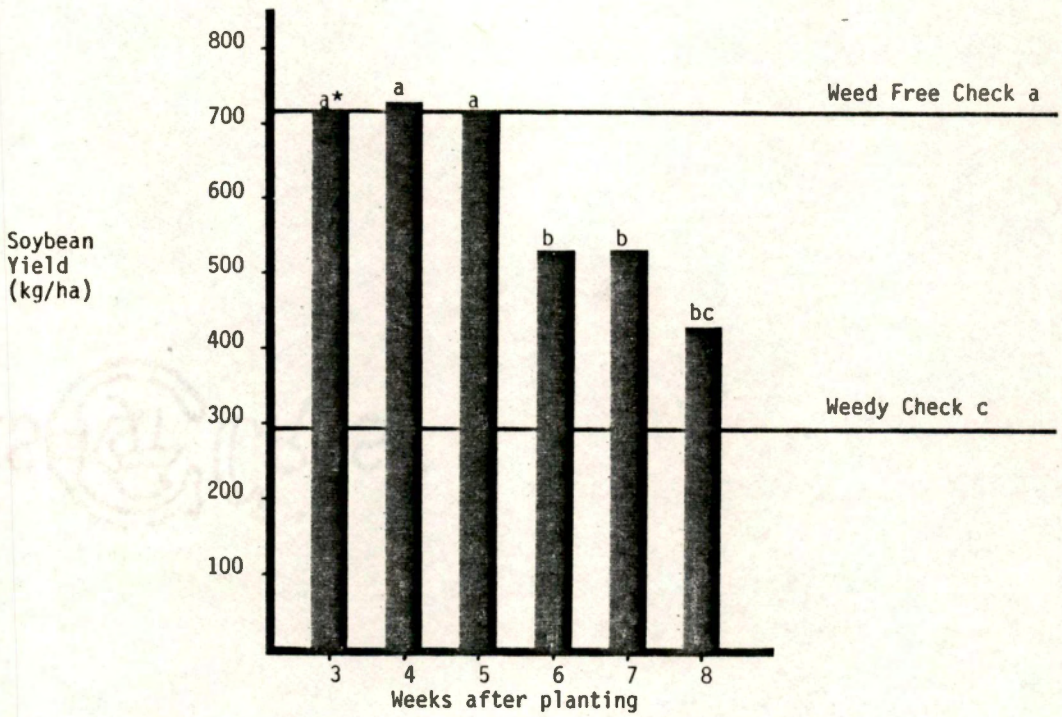


Figure 19. The influence of time of sethoxydim application on soybean yield.

*Values followed by the same letter are not significantly different at the 5 percent level, according to Duncan's Multiple Range Test.

Table 7. Competition of johnsongrass and soybeans for available soil water.

	Soil H_2O Deficit (cm)	Johnsongrass Control (Percent)	Soybean Yield (kg/ha)
Sethoxydim	16a*	99a	725a
Maintain w.f. for 4 weeks	16a	64b	571b
W.f. check	17a	100a	719a
Weedy check	18a	0c	296c

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

CHAPTER V

SUMMARY AND CONCLUSIONS

The results from the threshold studies indicate that johnsongrass dry weight accumulation and the number of johnsongrass culms per hectare are better indicators of soybean yield reduction than the number of johnsongrass plants per hectare. This is due to the inconsistency in growth of johnsongrass plants. While the former parameters are better indicators of soybean yield reduction, they cannot be determined early in the season and consequently soybean yields may be reduced. The number of johnsongrass plants per hectare was determined to be the most practical method of predicting soybean yield reduction. Prediction equations over the range of johnsongrass populations for .25 and 1 m row spacings, respectively, were as follows:

$$Y = 2033 - .03x$$

and

$$Y = 2405 - .045x$$

where Y = estimated soybean yield (kg/ha) and x represents the number of johnsongrass plants per hectare. These equations provide farmers and personnel involved with integrated pest management a basis for predicting soybean yield reduction while proper measures can still be employed if necessary.

The critical johnsongrass-free requirement of soybeans was determined to be four weeks after planting when johnsongrass was

mechanically controlled. Soybeans kept free of johnsongrass for less than four weeks had reduced soybean yields since johnsongrass was able to reestablish and exert its competitive effects after this time.

The critical duration of johnsongrass in soybeans was determined to be seven weeks for mechanical removal of johnsongrass and five weeks for control with sethoxydim. The range of two weeks between the control methods is a result of the incomplete kill of johnsongrass when controlled with sethoxydim resulting in a continuation of the competitive effect of johnsongrass. The mechanical removal of johnsongrass is a physical process occurring in a short period of time while chemical control is a physiological process requiring hours or even days for complete control to be obtained.

Optimum johnsongrass control was obtained when sethoxydim was applied to johnsongrass at a height range of 25 to 50 cm. This height range corresponds to applications made at four and five weeks after planting. Earlier applications provided excellent control early in the season, but the johnsongrass emergence after application resulted in decreased control. This implies that it was necessary to allow soybeans to reach a stage of growth in which they can be more competitive. Application of sethoxydim later than five weeks after planting resulted in insufficient control of johnsongrass and reduced soybean yields. This was probably due to the johnsongrass stage of growth and environmental conditions existing at time of application and throughout the remainder of the growing season.

The soil water deficit was determined to be the same in all plots

sampled, whether there was excellent control of johnsongrass or no control of johnsongrass in soybeans. Soybean yields were reduced 59 percent in plots having no johnsongrass control. The results indicate that when soil moisture becomes critically limiting, there is a greater utilization of water by soybeans where johnsongrass is controlled.

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APPENDIX

APPENDIX

Table 8. Rainfall data 1980, West Tennessee Experiment Station of The University of Tennessee at Jackson.

Day	May	June	July	Aug.	Sept.
1					
2					
3				.08	.30
4					
5					.51
6					
7					
8		1.07			
9					
10					
11					
12				.33	
13	2.18*				
14	.58				
15	.08				
16	.43				
17	.46	1.55			3.33
18	.18				.05
19	T				
20	.18	3.56			
21					1.63
22	.15		1.30		.28
23	.64	1.42	5.08		1.52
24		5.97			1.75
25					1.85
26					.20
27					
28			1.37		.41
29				T	.76
30		9.65			T
31					
Total	4.88	23.0	7.75	.41	12.60

*Rainfall recorded in centimeters.

Table 9. Rainfall data 1980, Milan Experiment Station of The University of Tennessee at Milan.

Day	May	June	July	Aug.	Sept.
1					
2			1.32		
3			1.42	.28	
4					
5				T	
6			T		
7					
8		.97			
9					
10					
11					
12	2.84*				
13					
14					
15				1.52	
16	1.17				
17	.33				4.06
18				1.02	
19		1.40			
20					
21					4.57
22	1.52		1.73		
23		9.14			1.12
24					.38
25	1.22				.64
26					
27					
28					.41
29		5.21			
30					T
31					
Total	7.08	16.72	4.47	2.82	11.18

*Rainfall recorded in centimeters.

VITA

Charles Steven Williams was born in Mineral Wells, Texas, on August 8, 1953. He is the son of Mr. and Mrs. Charles F. Williams and brother of Kenneth Webb, Michael Fenner, and Judy Gail Williams. He received his public school education in the Madison County, Tennessee school system and was graduated from North Side High School in May 1971.

In September 1971, he entered Jackson State Community College in Jackson, Tennessee. In September 1973, he entered The University of Tennessee, Knoxville. From 1974 to 1977 he worked on the family farm, worked with Texgas Liquified Petroleum Cooperative, and worked for a housing contractor.

In December 1977, he was married to the former Linda Ann Manuel. In January 1978, he entered The University of Tennessee, Martin, and in June 1979, he received a Bachelor of Science degree with a major in Agriculture Education. In June 1979, 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 Plant and Soil Science with emphasis in Weed Science in June 1981.