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Johnsongrass competition and control in corn

Kevin McDonald Perry

To the Graduate Council:

I am submitting herewith a thesis written by Kevin McDonald Perry entitled "Johnsongrass competition and control in 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 Jeffery, Major Professor

We have read this thesis and recommend its acceptance:

Elmer L. Ashburn, Robert M. Hayes

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

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

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CW Minkel

The Graduate School

JOHNSONGRASS COMPETITION AND CONTROL IN CORN

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Kevin McDonald Perry

August 1983

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ABSTRACT

Field studies were conducted at two locations in East and Middle Tennessee to determine the competitive effects of johnsongrass [Sorghum halepense (L.) Pers.] on corn (Zea mays L.). The objective of these studies was to determine: (1) the competitive effects of johnsongrass on corn in relation to yield reduction and total biomass produced, (2) the critical johnsongrass-free requirement of corn, (3) the critical duration of johnsongrass competition in corn, (4) the percent johnsongrass control obtained from EPTC (S-ethyl dipropylthiocarbamate) and butylate (S-ethyl diisobutylthiocarbamate) plus the herbicide antidote R-25788 (N,N-diallyl-2,2-dichloroacetamide) and EPTC plus R-25788 and the herbicide extender R-33865 (O,O-dietyl-O-phenolphosphorothioate) and (5) the economic threshold of johnsongrass in corn.

All experiments were conducted as randomized complete block designs with four replications. Individual plots in both the threshold and the competition studies consisted of four rows, spaced 91 cm apart by 6.1 m long. Critical data were obtained from the two center rows.

Spring Hill

The critical johnsongrass-free requirement of corn was determined to be between two and four weeks after planting. A johnsongrass-free period of less than four weeks after planting allows sufficient johnsongrass regrowth resulting in significant yield reductions.

The critical duration of johnsongrass competition in corn was determined to be between four and six weeks after planting. Significant stover yield reductions occurred when johnsongrass was allowed to grow with corn for four or more weeks after planting, while six or more weeks of johnsongrass competition were required to significantly reduce grain yields. Season-long johnsongrass competition in corn reduced grain yields by 50% and stover yields by 67% and resulted in 20% lodging.

EPTC or butylate, plus the herbicide antidote did not provide acceptable johnsongrass control.

Johnsongrass plant populations of 16/6.1 meters of row or higher significantly reduced corn grain yield.

Knoxville

From evaluation of both the corn grain yield and the corn stover yields it was determined that no critical johnsongrass-free requirement existed for corn under these growing conditions.

The critical duration of johnsongrass competition in corn was determined to be between six and eight weeks after planting. Season-long johnsongrass competition in corn resulted in an 18% reduction in grain yields and a 37% reduction in stover yields.

EPTC plus the herbicide antidote and the herbicide extender resulted in good end-of-season johnsongrass control; approximately 80%. Yields from corn treated with the same herbicide were not significantly different from the weed-free check.

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CHAPTER I

INTRODUCTION

Johnsongrass is one of the ten worst weeds in the world (24), one of the most competitive weeds of the southern agricultural regions (47), is the seventh most commonly occurring weed in Tennessee corn and is the most troublesome weed to control in corn grown in Tennessee (61). Johnsongrass eradication is difficult because of prolific seed production; approximately 700 seeds per panicle (65), in combination with the early age at which rhizomes are produced.

It is estimated that approximately 25% of all corn acreage grown in Tennessee is infested with johnsongrass. Corn is the single most important grain and silage crop in Tennessee, with an estimated annual value of 200 million dollars and approximately 323,760 hectares produced annually. Corn yields in 1982 reached a five-year high with an average of 5896 kg/ha. The corn farmer is primarily limited to the use of preplant or preemergence herbicides in the battle to control johnsongrass. Effective postemergence grass herbicide use in corn has not fully reached its potential. A successful management system must incorporate cultural control methods such as crop rotation and cultivation in combination with chemical control methods such as preplant and/or preemergence herbicides.

The increasing cost of pest control and the decreasing profits earned by United States farmers mandates the most efficient and economical use of pesticides. Integrated pest management programs make use of economic thresholds which help determine when or if a pesticide application is warranted. Establishment of economic thresholds for weed species has encountered many obstacles due to the variability of field experiments and the differential competitive abilities of weeds under different environmental conditions. In trying to establish an economic threshold for johnsongrass in soybeans [*Glycine max* (L.) Merr.], Williams (71) determined that johnsongrass dry matter and number of johnsongrass culms produced per hectare were more highly correlated with soybean yield reduction than were the number of johnsongrass plants per hectare. Williams predicted that each johnsongrass plant reduced soybean yield by as much as 30 to 45 grams. The objectives of these studies are to determine: (1) the competitive effects of johnsongrass on corn in relation to yield reduction and total biomass produced, (2) the critical johnsongrass-free requirement of corn, (3) the critical duration of johnsongrass competition in corn, (4) an efficient and practical method of predicting the potential yield reduction in corn due to johnsongrass and (5) the percent johnsongrass control obtained from three thiocarbamate herbicides.

CHAPTER II

LITERATURE REVIEW

Johnsongrass

Johnsongrass, a native of the Mediterranean region, has now become established as a pernicious weed in most of the agricultural areas of the southeast United States. Research to determine the initial introduction of johnsongrass was further restricted by the use of more than 40 common names for this weed. Names used most commonly before 1874 were guinea grass and means grass. The first written use of the name johnsongrass was made in 1974 by John Haralson of Selma, Alabama, in a letter to Goerge Vasey, an employee of the U.S. Department of Agriculture in Washington. The wide attention that this and subsequent letters received resulted in the nationwide acceptance of johnsongrass as the common name for *Sorghum halepense*. William Johnson, a farmer of Marion Junction, Alabama, who initially introduced johnsongrass into Alabama as a forage crop is believed to be the namesake of this weed (43).

Johnsongrass is representative of the true grasses and is a member of the Graminae family, which is considered to be one of the largest of the families of flowering plants, with an estimated 600 genera and 7500 species. The Panicoidae subfamily of which johnsongrass is a member is represented in the United States by 28 genera and 356 species of native grasses. Gould estimates that over one-half of the grasses in the southern United States are panicoid. The subfamily Panicoidae is reduced to two large tribes, the Paniceae and the Andropogoneae. Johnsongrass is a member of the latter (19).

Johnsongrass is a stout, erect, warm season perennial grass that spreads by seeds and from long creeping scaly rhizomes. Culms are erect, 0.5 to 3 m tall, arising from seeds or rhizomes; leaf blades are linear, alternate, smooth or rough on the edges with prominent midribs, 20 to 60 cm long and 10 to 30 mm wide. The ligule is short, 2 to 5 mm long, membranous, truncate and fringed apically; leaf sheath is ribbed and entirely smooth. The inflorescence is an open panicle, large, 15 to 40 cm long, pyrimidal, purplish and awned; spikelets are dissimilar, binate although toward the tip of the inflorescence they may occur ternate. When spikelets are in pairs, the lower is usually sessile and the upper pedicelled, and stamen-bearing; when spikelets are in three's, one is sessile and perfect, and the other two are pedicelled and staminate (23, 24). The lemma of the fertile floret is usually with a geniculate and twisted awn, approximately 7 to 32 mm in length (19). The grain is nearly 3 mm long, oval, reddish brown, glossy and marked with fine lines on the surface (24).

Johnsongrass is a very heavy seed producer, this being its principal means of distribution; however, its superior ability to compete with other plants and its persistence under intense control measures result primarily from the very rigorous, highly adaptable rhizome system. The system as determined by McWhorter (38) was found to consist of three sets of rhizomes; i.e., primary, secondary, and tertiary. Initial growth in the spring arises from the primary rhizomes, which remain functional two to three weeks after growth begins. As the primary rhizomes begin to decay, the formation of the secondary rhizomes begin, which will surface and give rise to new plants throughout the growing season. Tertiary rhizomes which grow out from the base of the plant at flowering time, and usually continue to grow until the advent of cold or dry weather, provide the overwintering mechanism. The tertiary rhizomes remain in a quiescent state throughout the winter, becoming the primary rhizomes the next year.

Sturkie (68) in 1920, reported that rhizome production did not occur until the flower heads were showing, and their subsequent development coincided with seed maturation. However, according to McWhorter (39), a rhizome spur was present eighteen days after emergence of the plants. Substantiating the results of McWhorter (39), Oyer et al. (60) found that after the start of blooming, rhizome production increased rapidly, whereas the rate of leaf growth increase declined throughout the remainder of the season. Anderson et al. (2) reported that the greatest increase in rhizome development occurred from the mature seed stage to the winter rest stage. During this period, rhizomes function primarily as storage organs and carbohydrate buildup is rapid. McWhorter (39) calculated that after reaching full bloom stage a johnsongrass plant was capable of producing a minimum of .23 m and a maximum of more than .91 m of rhizome per day. The maximum rhizome production recorded has been 9979 kg or 185 km/ha, according to Stamper (65). McWhorter (39) recognized that plants which originate from rhizomes grow more rapidly than did plants from seeds, under average conditions. He also reported that the only significant difference between johnsongrass plants arising from rhizomes or seed was the presence of a rhizome during the first 19 to 24 days of growth on the rhizome plants.

McWhorter (44) determined that 80% of johnsongrass rhizomes produced in clay soil were in the top 7.5 cm, although in sandy loam 80% of the rhizomes occurred in the top 12.5 cm. Mikulas (51) furthered this idea and determined that rhizome weight decreased with the increase in depth of soil and that 99% of the rhizomes were located in the top 40 cm. Horowitz (25) noted that rhizomes constituted more than 90% of the total subterranean weight. Hull (26) confirmed the work of Beasley (6) in showing that rhizome buds were strongly influenced by apical dominance and that emerged shoots partially suppressed germination of adjacent buds.

McWhorter et al. (49) observed maximum growth and development after 12 weeks was obtained at 32^{o}C and 19 Klux, while maximum leaf growth and development were obtained at 32^{o}C and 9 Klux. He concluded that the ability of johnsongrass to obtain maximum leaf growth under lower light regimes aids in its competitiveness while growing under such crop plants as corn or soybeans. Ingles and Rodgers (27) noted that a 12-hour photoperiod was optimum for both dry matter accumulation and flowering. Keeley et al. (30) noted that seed germination was highest (95%) at a mean air temperature of 35^{o}C and lowest (42%) at 18^{o}C. Hull (26) stated that the optimum temperature for rhizome bud germination and shoot growth was 30^{o}C, whereas bud germination was suppressed at 15^{o}C. Exposure to temperatures of 50^{o} to 60^{o} killed all rhizome buds within one to three days according to

McWhorter (44). He indicated that rhizome dehydration may offer a practical means of johnsongrass control.

Hull (26) determined that johnsongrass rhizomes were susceptible to cold injury at any time in their life cycle and therefore did not display any degree of cold hardiness. He also reported that johnsongrass rhizomes failed to demonstrate true physiological dormancy. However, johnsongrass seeds as determined by Taylorson et al. (69) do exhibit a type of dormancy. He reported that immediately after seed development seeds were highly dormant and required a period of after-ripening to release this dormancy. An alternating period of two weeks at 10^{o}C followed by a temperature shift to 40^{o}C for two hours was effective in breaking seed dormancy. Seed dormancy as reported by both Holm (24) and Taylorson et al. (69) is largely imposed by the mechanical restriction afforded by the seed coat. Evidence provided by Stamper (65) indicated that as many as 2 to 12 million viable seeds per hectare were present in soil heavily infested with johnsongrass. Egley and Chandler (16) reported that after 5.5 years of burial in the soil, 48% of the johnsongrass seed tested were still viable. Seed longevity in soil and prolific seed production greatly reduces the chances of complete eradication of this weed.

McWhorter (40, 46) conducted experiments in which he evaluated the partitioning of carbohydrates as influenced by growth and development of johnsongrass. He found that glucose, fructose and sucrose were the only sugars detected in leaves, culms or rhizomes. Sucrose was determined to be the major storage carbohydrate. Carbohydrate levels in rhizomes were highest when plants began flowering and lowest 10 to 30 days after emergence. Leaf carbohydrate content was at a maximum within 30 days after plant emergence (46). McWhorter (40) found that the sucrose content decreased until the plants reached late boot to early bloom stage, then increased sharply, while the glucose content steadily increased until the late-boot to early bloom stage and then dropped off slightly. Rapp (62) reported that during the period prior to seed formation, the sucrose was converted to the more mobile reducing sugars. After the seeds were formed, this process was reversed for carbohydrate storage in the rhizomes. Water soluble carbohydrate content in rhizomes was reported (25) to be high in early winter and in early summer and low in early spring and fall. McWhorter et al. (49) found that clipping of johnsongrass top growth and its subsequent regrowth resulted in a 25% reduction in total carbohydrate content of rhizomes. Horowitz (25) suggested that mechanical control of johnsongrass should be most effective when food reserves are lowest.

The existence of morphologically distinct ecotypes of johnsongrass has been verified by many researchers (10, 12, 41, 42, 69). In an experiment involving 55 distinct vegetative types, McWhorter (41) revealed that mature leaf blades varied in length from 31 to 59 cm and in width from 1.7 to 3.4 cm. In another experiment McWhorter (42) reported that the number of vascular bundles in rhizomes of different johnsongrass ecotypes varied from 71 to 154. The number of vascular bundles in culms ranged from 43 to 123, while the average number of vascular bundles in individual leaves varied from 46 to 158 for different ecotypes. Taylorson et al. (69) demonstrated varying degrees of seed dormancy and other differential germination characteristics in 44 distinct ecotypes. Burt (10) found that plants obtained from a more northern latitude consistently flowered earlier than plants from a more southern latitude. In a subsequent experiment, Burt et al. (12) found that johnsongrass plants obtained from a southern climate produced more total fresh weight, higher rhizome production and larger number of stems at 35°C than the plants obtained from a more northern climate.

Johnsongrass Competition in Corn

A minimum amount of research has been done to determine the competitive effects of johnsongrass on corn. However, the competitive effects of johnsongrass on other crop species is well documented (5, 31, 32, 48, 52, 71). Arevalo et al. (5) reported yield losses of 71 to 84% in sugarcane (*Saccharum officinarum* L.), and stated that the economic life of the cane is limited to two years when johnsongrass is allowed to compete for 60 days or more. McWhorter et al. (48) indicated that johnsongrass reduced soybean yields by as much as 42%. An average yield loss of 60% occurred when johnsongrass was allowed to compete with cotton (*Gossypium hirsutum* L.) for the entire growing season (31).

Atkinson's (4) work in New Zealand determined that corn is most sensitive to competition from grassy weeds such as *Paspalum spp.*, *Echinochloa crus-galli* and *Panicum spp.*, during the period of adventitous root formation. He stated that corn suffers the most serious weed competition in the stage from germination until the plants are 75 to 100 mm high. Studies conducted by Bochicchio (8) in Argentina revealed that the critical period for weed competition in corn was between 10 and 20 days after planting.

Competition between plant species occurs when one or more of the essential growth factors are limiting. The essential growth factors most prevalent to corn or johnsongrass are: water, nutrients, carbon dioxide and light. Donald (15) reported that when competition occurs for two or more environmental factors, the effects are more than additive. Under these conditions, the most competitive plant species utilizes a continuously larger portion of each factor, while there is a progressively smaller portion of the niche available to the less competitive species and also a decreasing capacity to utilize the factors available to it.

Black et al. (7) classified both corn and johnsongrass as efficient plants based on their ability to fix CO_2 at high temperatures and light intensity and because both utilize water effectively. He reported that corn requires 349 g of H_2O to produce 1 g of dry matter as compared to *Sorghum spp*. which requires 304 g of H_2O to produce 1 g of dry matter. Black proposed that the single greatest factor that contributes to a plant's competitiveness is the net capacity to assimilate CO_2 and use the photosynthate, to extend its foliage, or increase its size.

Sarpe (63) reported that season-long competition of johnsongrass in Romania resulted in a 98% reduction of grain yield in corn. In field trials in 1977, grain yields of corn were reduced by approximately 50% in heavily infested johnsongrass areas (14). Czimber et al. (14) work conducted in Hungary concluded that there was a significant negative correlation (r = -0.89) between johnsongrass dry matter production and corn grain yield. He reported that levels of infestation giving 15-25% weed cover caused significant yield losses.

Researchers (37) in Yugoslavia reported that season-long johnsongrass competition reduced dry weight of corn by 66% and decreased the leaf surface area and photosynthesis compared with weed-free plots. Soil nutrient losses to johnsongrass plants amounted to about 102 to 137 kg N, 9 to 23 kg P and 50 to 83 kg K per hectare (37). Grupce (20) conducted an experiment in Yugoslavia in which he evaluated the morphological characters of corn which are affected by johnsongrass competition. His results indicated that johnsongrass infestation reduced the growth and size of corn, delayed the differentiation of vegetative and reproductive organs, reduced the leaf area and size of cobs and caused sterility in many of the flowers. Czimber et al. (14) revealed that the highest net assimilation rate (change in weight per unit leaf area) occurred later in johnsongrass than in corn but the highest crop growth rate (change in weight per unit ground area and time) occurred at the same time in both species.

Knake et al. (34) initiated a study in which he evaluated the competitive effects of an annual grass species, giant foxtail (Setaria faberi Herrm.), on corn. Giant foxtail is similar to johnsongrass in some respects and its competitive effects on corn may be indicative of those obtained by johnsongrass. Corn yield reductions of 25% were obtained when foxtail populations were at their highest (180 plants/m of row). He stated that the increase in foxtail dry matter was proportional to the decrease in corn dry matter. As foxtail populations increased, there was a decrease in yields of grain, cobs, stalks, diameter of cornstalks, ear weight, light intensity beneath the crop and soil temperature under the crop. Knake proposed that increased degree of lodging was proportional to the increased foxtail population which resulted in a general decrease in the diameter of cornstalks. In another study, Knake (33) found that plots which were seeded with foxtail three weeks after planting or later, did not yield significantly different from plots which were maintained weed free for the entire growing season. He concluded that the critical competition period in corn must be sometime prior to three weeks after planting.

Weeds may interfere in crop production not only through competition, but also through the release of biologically active substances into the environment which may enhance their competitive ability. It is now generally accepted that certain weed species possess this allelopathic capability. Abdul-Wahab and Rice (1) found that decaying johnsongrass rhizomes or leaves in the soil inhibited the germination of several weed species. They also reported that living johnsongrass roots and rhizomes exude a toxin or toxins that inhibit the germination and growth of several weed species. Lolas and Coble (36) indicated that johnsongrass rhizomes living or decaying in the soil exude, contain or produce substances that exhibit allelopathic characteristics to soybean growth.

Johnsongrass Control in Corn

McWhorter et al. (47) indicated that due to the extensive rhizome system, prolific seed production and the young age at which seedlings develop rhizomes makes johnsongrass eradication difficult. Possibly the easiest and least effective control of johnsongrass has been the passage of legislation by several states making the maturation of seed or the sale of johnsongrass seed or hay illegal. A realistic approach to johnsongrass control must revolve around an integrated system which includes crop rotation, tillage, and chemical control practices (3, 11, 17, 18, 21, 22, 28, 29, 32, 36, 47, 48, 59, 71).

Cultural Control

Crop Rotation. Crop rotation is one of many mechanisms recommended to reduce damage by problem weeds, insects and diseases which may accumulate in continuous cropping systems. Several researchers (3, 11, 45, 47) have advocated the use of a summer fallow program which utilizes tillage and herbicides in an attempt to control rhizome johnsongrass.

Growing early maturing crops, such as small grains allows for control measures to be implemented after the crop has been harvested and before johnsongrass makes its maximum growth (3). Evans et al. (17) and Overton et al. (59) reported that where corn is harvested for silage there is sufficient johnsongrass regrowth, which makes possible a foliar herbicide application or tillage before the johnsongrass goes dormant.

Tillage. Cates and Cox (13), as early as 1912, concluded that cultivation was not beneficial to the corn plant except for removing the weeds. However, in 1960, Meggett (50) provided evidence to show that when weeds were controlled throughout the growing season by herbicides, yields of corn were significantly increased by one cultivation, and under some conditions, a second later cultivation increased yields even more. He indicated that these effects were more pronounced on heavier soils, or in situations where the soil is in poor tilth as a result of continuous row cropping.

Burt et al. (11) stated that moldboard plowing followed by a single disking before applying herbicides consistently gave better results than leaving the land unplowed. Results from this same study indicated that plowing in the summer or fall followed by sufficient tillage to keep the johnsongrass regrowth less than 20 to 25 cm high, was effective in reducing the stand of johnsongrass plants from rhizomes, and resulted in increased yields of corn. Johnsongrass rhizome populations can be reduced when the soil is chiseled in the fall, which will expose the rhizomes to freezing temperatures during the winter (3). Mikulas (51) reported that deep plowing in autumn buried rhizomes deep enough to reduce the effects of winter freeze and recommended a shallow cultivation of 15 to 20 cm.

McWhorter et al. (47) reported that the effectiveness of an intensive preplanting tillage operation in johnsongrass control appeared to be directly related to rhizome dehydration. He reported that a soybean crop planted following 6 to 10 diskings yielded more than soybeans grown in the conventional manner, and as much as soybeans grown where chemical johnsongrass control was provided. Anderson et al. (2) reported that fall plowing or cultivation following the mature seed stage to inhibit rhizome growth would be an essential part of a complete control program.

Chemical Control

A complete johnsongrass control program should consist of: (1) fall plowing and/or a postemergence herbicide application after crop harvest in fall or in early spring; (2) either a preplant incorporated or a preemergence herbicide application to provide seedling control and/or rhizome suppression; and (3) timely cultivations to control escaped plants throughout the growing season. Hicks et al. (22) reported that the use of a pre-plow application of dalapon (2,2-dichloropropionic acid) for two seasons, a preplant incorporated treatment of EPTC for three seasons and tillage during all three years was effective in the control of johnsongrass while corn was being produced on the land.

Dalapon is a preplant postemergence herbicide that is foliarly applied. Dalapon translocates readily throughout the plant and tends to accumulate in young tissue (70). Hicks (21, 22) reported that dalapon applied to 20 to 71 cm johnsongrass in the early spring at the rate of 4.1 or 8.3 kg/ha significantly reduced the rhizome johnsongrass population. He also noted that a similar dalapon application in the fall significantly reduced the surviving rhizomatous johnsongrass population in the following spring (21).

Glyphosate (N-phosphonomethyl glycine) is a very broad spectrum, relatively nonselective herbicide that is very effective on deep-rooted perennial species and on many annual and biennial species of grasses, sedges and broadleaved weeds. It is applied as a post-emergence spray to foliage of vegetation to be controlled. Translocation occurs throughout the treated plant and to underground propagules of perennial species which prevents regrowth from these sites. Soil inactivation of glyphosate eliminates root uptake (70). Evans et al. (17) reported that a fall application of glyphosate at 1.1 kg/ha consistently provided better control of rhizomatous johnsongrass than did dalapon at 4.9 kg/ha or plowing. Jeffery et al. (29) conducted an experiment in which he evaluated the effectiveness of a preharvest application of glyphosate in corn. He concluded that maximum control and minimum crop injury was obtained with a glyphosate application after corn grain moisture falls below 30% and the black layer has formed at the base of the kernel. A fall application of 2.2 kg/ha glyphosate provides approximately 87% rhizome johnsongrass control. Application of glyphosate when grain moisture is too high may result in reduced seed weight and can also alter the progeny seedling emergence, vigor and weight. Evans et al. (17) and Overton et al. (59) both indicated that glyphosate or dalapon would be an effective fall treatment to control johnsongrass regrowth after corn silage harvest.

Kemp (32) reported that trifluralin, (α,α,α trifluoro-2,6-dinitro-N,N-dipropyl-p-toluidine) incorporated preplant, at 0.56 kg/ha, gave excellent control of seedling johnsongrass and did not injure corn. Standifer (66) specified that trifluralin inhibited lateral root development of johnsongrass seedlings. Millhollon (53) stated that when rhizome segments are planted within trifluralin-treated soil, 95% and 100% of the shorter rhizomes (2.5 cm) and 54% and 81% of the longer rhizomes (15 cm) were killed at 1.7 and 3.4 kg/ha, respectively. The authors concluded trifluralin effectiveness on johnsongrass rhizomes decreased with rhizome length and with increasing depth from the soil surface. Kemp (32) also suggested that a post-directed application of linuron 3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea, at 2.2 kg/ha gave the best late season johnsongrass control.

Kemp (32) reported that EPTC at 3.4 kg/ha gave excellent control of johnsongrass seedlings when applied preplant incorporated although slight crop injury occurred. Crop injury caused by the thiocarbamate herbicides EPTC and butylate was a common problem in many of the corn growing areas. However, in the early 1970's, there was a significant breakthrough with the discovery of the dichloroacetamides or "herbicide antidotes" which protect corn from thiocarbamate injury. According to Lay et al. (35), the herbicide antidotes act in corn to raise the glutathione and glutathione S-transferase levels in the roots, resulting in rapid detoxification of the thiocarbamate sulfoxides. In an experiment testing various herbicide antidotes, Stephenson et al. (67) found that R-25788, (N,N-diallyl-2,2-dichloroactamamide) was the most effective antidote for at least four different thiocarbamate herbicides. Stauffer Chemical Company subsequently marketed EPTC and butylate in combination with the herbicide antidote R-25788 as Eradicane and Sutan + , respectively.

In the early 1980's, the thiocarbamate herbicides encountered another obstacle. Obrigawitch et al. (57) reported that on certain soils receiving successive annual applications of EPTC, the herbicidal efficacy appears to decline. He also stated that EPTC was more rapidly degraded in soils that had prior exposure to EPTC than those soils with no previous exposure to EPTC. Results indicated that one prior application the previous year was sufficient to enhance EPTC breakdown. The half-life of EPTC under field conditions on a soil with eight previous successive annual applications was nine days compared to 18 days for the same soil with no prior EPTC history. Obrigawitch et al. (55) also reported an increased rate of butylate degradation on a soil exhibiting rapid EPTC breakdown. The rate of butylate degradation increased with each successive butylate application, but the degradation rate was not as high as those observed for EPTC. He concluded that an accelerated rate of soil microbial degradation may be responsible for reduced EPTC persistence in soils previously treated with EPTC (57).

The use of microbial inhibitors as herbicide extenders is a relatively new concept and one which could aid in the persistence of these thiocarbamate herbicides. In field studies conducted by Obrigawitch et al. (56) the addition of the herbicide extender R-33865 (0,0-diethyl-0-phenolphosphorothioate) to EPTC extended EPTC persistence in the soil and provided increased shattercane [*Sorghum bicolor* (L.) Moench] control. In two soils that exhibited rapid EPTC degradation, addition of R-33865 to EPTC extended the half-life from 9 to 18 days and from 6 to 15 days, respectively. Addition of R-33865 to EPTC on soils with no prior EPTC treatment did not extend persistence of EPTC in the soil. Addition of R-33865 to butylate extended its persistence in soils with and without prior EPTC application (55). Green et al. (18) observed that butylate or EPTC with R-33865 at 4.5 kg/ha did not provide additional control of johnsongrass greater than butylate alone. Although six weeks after application buytlate at 6.7 kg/ha provided 55% control compared to 75% from butylate with R-33865. EPTC at 6.7 kg/ha provided approximately 50% control at six weeks after application. However, EPTC with R-33865 provided at least 80% johnsongrass control. The authors (18) concluded that butylate or EPTC control of johnsongrass was enhanced with the addition of R-33865 at 6.7 kg/ha.

Overton et al. (59) reported that control of johnsongrass seedlings with EPTC or butylate plus R-25788 following fall treatments of glyphosate, dalapon or disking gave excellent control of 91 to 96%. Jeffrey et al. (28) stated that EPTC at 3.4 kg/ha and vernolate (S-propyl dipropylthiocarbamate) at 3.4 kg/ha controlled more rhizome johnsongrass than did alachlor (2-chloro-2,6-diethyl-Nmethoxymethyl) acetamide, at 1.1 kg/ha, butylate (3.4 kg/ha), trifluralin (1.1 kg/ha) or cultivation.

CHAPTER III

MATERIALS AND METHODS

Johnsongrass Competition in Corn

The johnsongrass competition studies were conducted in 1982 at the Middle Tennessee Experiment Station, Spring Hill, and at the Holston River Farm, Knoxville. The corn Cultivar 'Pioneer 3147' was planted at the rate of 49,000 plants/ha. Individual plots consisted of four rows spaced 91 cm apart and 6.1 m long. Each treatment was replicated four times in a randomized complete block design. Critical data were obtained from the two center rows.

Any broadleaf or grass weeds that escaped the herbicide treatments other than johnsongrass, were removed by hand-hoeing. Johnsongrass was mechanically removed by hand-hoeing from the weed-free check and from treatments 3 through 12. Johnsongrass plants from treatments 3 through 7 were removed at the soil surface at the designated biweekly intervals. The plants were harvested from a m^2 area between the two center rows. These harvested plants were dried at 70^oC for 48 hours and their dry weights recorded. The johnsongrass dry weights from treatments 8 through 15 were obtained from a m^2 area at the time of harvest, and their dry weights recorded. Harvested dry weights of johnsongrass were used as a measure of johnsongrass control obtained from the herbicides.

Corn grain and corn stover were harvested on September 22 and 23, respectively, at the Spring Hill experiment. While harvest dates were October 1 and 22 for the corn grain and corn stover, respectively, at the Knoxville experiment. A 3 m section from the two center rows was harvested at each location. Corn plant population was obtained from the area harvested. Corn ears were hand-harvested, while corn stover yields were obtained by removing the plant at the soil surface and field weights recorded. Corn grain yield is reported at 15.5% moisture.

Johnsongrass Competition in Corn, Spring Hill

The experiment was established on an area well infested with johnsongrass and suitable for corn production. Corn was planted May 6, 1982, on a Maury Silt loam having a pH of 5.9. Fertilizer was applied at the rate of 168 kg/ha N and 111 kg/ha K. Seedbed preparation was in the conventional manner. Cropping history for this area was corn and small grains, in 1981 and 1980, respectively.

The treatments used in this study were similar to those suggested by Buchanan (8) and are illustrated in Table 1. The experiment consisted of 14 treatments. Treatments 1 and 2 are the weedy and weed-free checks, respectively. In treatments 3 through 7 johnsongrass was allowed to grow in competition with corn for 2, 4, 6, 8 or 10 weeks after planting, and then allowing johnsongrass regrowth to occur. Treatments 13 and 14 were included to determine the relative control of johnsongrass from EPTC or butylate plus the herbicide antidote R-25788.

Preplant incorporated applications of commercial formulations of EPTC or butylate plus R-25788 at the rate of 4.5 kg/ha were made

Table 1. Treatments Used in the Johnsongrass Competition Study to Determine the Critical Johnsongrass-free Requirement of Corn and the Critical Duration of Johnsongrass Competition in Corn and the Relative Herbicide Control

1.	Weedy Check
2.	Weed-free Check
3.	Maintain weed-free 2 weeks after planting to harvest
4.	Maintain weed-free 4 weeks after planting to harvest
5.	Maintain weed-free 6 weeks after planting to harvest
6.	Maintain weed-free 8 weeks after planting to harvest
7.	Maintain weed-free 10 weeks after planting to harvest
8.	Maintain weed-free for 2 weeks after planting
9.	Maintain weed-free for 4 weeks after planting
10.	Maintain weed-free for 6 weeks after planting
11.	Maintain weed-free for 8 weeks after planting
12.	Maintain weed-free for 10 weeks after planting
13.	EPTC + R-25788
14.	Butylate + R-25788
15.*	EPTC + R-25788 + R-33865

*Treatment No. 15 occurs in the Knoxville study only, while all other 14 treatments occur at both locations.

on May 5, and incorporated by double disking with a tandem disc on the same date. The entire experimental area was sprayed with atrazine at 2.2 kg/ha on May 6 to control broadleaf weeds. The treatments were applied with a CO_2 powered tractor boom, delivering 189 L/ha at 2.1 kg/cm^2.

Johnsongrass Competition in Corn, Knoxville

This experiment was established on an area well infested with johnsongrass and suitable for corn production. Corn was planted on an Etowah loam-Huntington silt loam mixture on May 14, 1982. Fertilizer was applied at the rate of 174 kg/ha N, 78 kg/ha P, and 67 kg/ha K. Seedbed preparation was in the conventional manner. Corn had been produced on this area the three previous years.

The treatments used in this study were similar to those used in the Spring Hill experiment with one exception. An additional herbicide treatment; EPTC plus R-25788, plus the herbicide extender R-33865 at the rate of 4.5 kg/ha was used. This treatment was incorporated in the same manner as the other herbicide treatments. Also the entire experimental area was treated with an in-row application of carbofuran; (2,3-dihydro-2,2-dimethyl-7-benzofuranlymethyl-carbamate) at the rate of 1.12 kg/ha active ingredient to provide early season insect control.

The broadcast application of atrazine was sprayed with a tractor mounted boom sprayer, delivering 215 L/ha at 2.1 kg/cm^2. The preplant incorporated treatments were sprayed with a hand held,

CO_2 powered plot sprayer, delivering the same volume and pressure as the tractor mounted boom.

Johnsongrass Threshold in Corn

This experiment was conducted at the Middle Tennessee Experiment Station at Spring Hill, Tennessee, on a Maury silt loam having a pH of 5.9. The experiment consisted of eight treatments (Table 2).

Table 2. Johnsongrass Populations Used in the Threshold Study

Treatment Number	Johnsongrass Plants/6.1 m	Johnsongrass Plants/ha
1	0	0
2	1	1786
3	2	3572
4	4	7144
5	8	14288
6	12	21432
7	16	28576
8	30	53580

Individual plots consisted of four rows spaced 91 cm apart and 6.1 m long. Each treatment was replicated four times in a randomized complete block design.

Fertilizer rates used were the same as those used in the competition study at Spring Hill. The corn cultivar 'Pioneer 3147' was planted on May 5 into an area well infested with johnsongrass. The johnsongrass population was adjusted accordingly by hand-hoeing soon after emergence and maintained throughout the growing season.

The entire experimental area was treated with a tank mixture of atrazine at 1.3 kg/ha and alachlor at 2.2 kg/ha on May 6. Atrazine was applied to give broadleaf weed control while alachlor provided seedling grass control.

On September 22 the number of johnsongrass plants/plot was determined for each treatment and then johnsongrass plants were cut at soil surface, oven dried at 70^{o}C for 48 hours, and dry weights recorded. Corn grain yields were determined on the same date by hand harvesting a 3 m section from each of two center rows. Grain yields are reported at 15.5% moisture.

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

CHAPTER IV

RESULTS AND DISCUSSION

1. SPRING HILL

Critical Johnsongrass-free Requirement of Corn

Excellent johnsongrass control occurred when corn was maintained johnsongrass-free for as long as six weeks after planting (Figure 1). Corn maintained free of johnsongrass for four weeks after planting resulted in good johnsongrass control at the end of the growing season. However, plots which were maintained weed-free for less than four weeks after planting resulted in poor end-of-season johnsongrass control. Increasing the johnsongrass-free period from two to four weeks after planting significantly increased the end-of-season johnsongrass control from 59 to 86%, respectively. Maintaining corn johnsongrass-free for only two weeks after planting allows sufficient time for johnsongrass regrowth; therefore poor control was observed at the end of the growing season. Maintaining corn johnsongrass-free for four weeks after planting, or longer, allows corn to gain a competitive advantage resulting in good to excellent end-of-season control. Also, the removal of johnsongrass top growth for extended periods of time may exhaust the energy reserves in the rhizomes reducing their ability to sustain subsequent regrowth. No significant johnsongrass regrowth occurred in plots which were maintained johnsongrass-free for eight weeks after planting or longer.

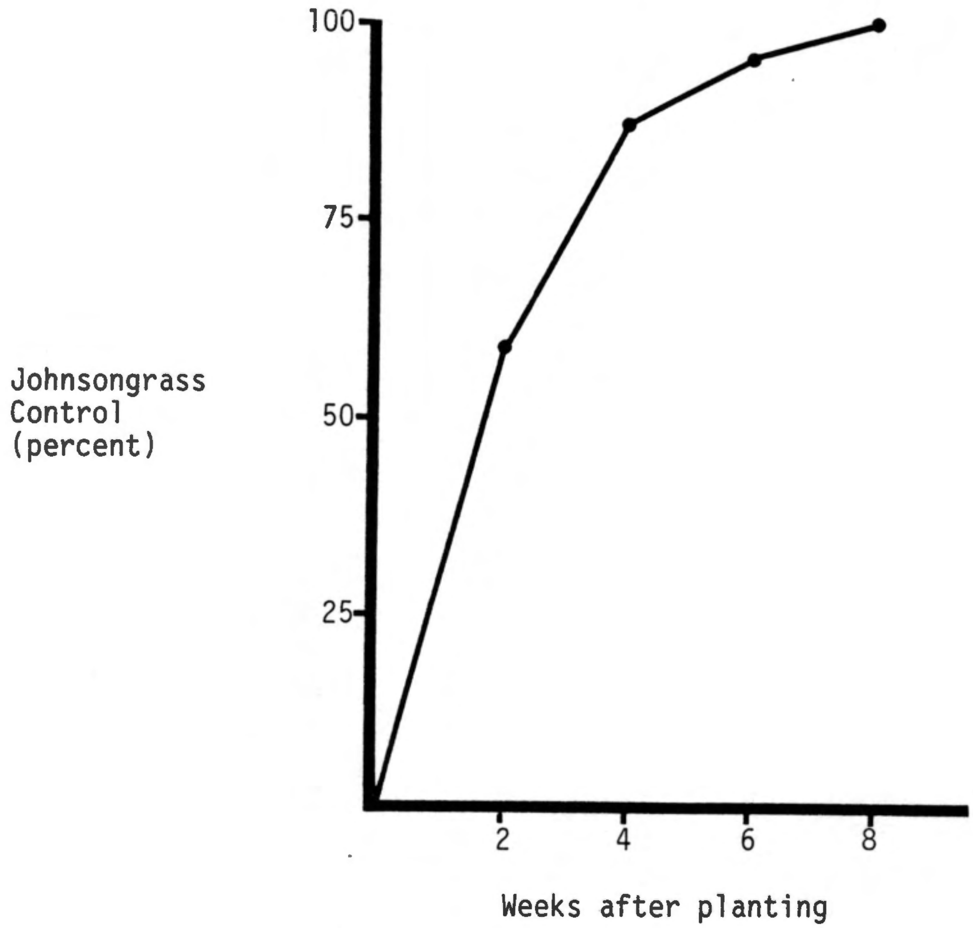

Figure 1. The influence of keeping corn johnsongrass-free for the respective number of weeks on end-of-season johnsongrass control, Spring Hill.

Generally, an inverse relationship between corn and johnsongrass plant dry weights occurred (Figure 2). The weedy check contained 2.5 times as much johnsongrass dry weight as plots maintained johnsongrass-free for two weeks after planting and 24 times as much as plots maintained johnsongrass-free for six weeks after planting. Johnsongrass dry weights in the weedy check were significantly higher than johnsongrass dry weights in plots which were maintained johnsongrass-free for only two weeks after planting (Figure 2). Johnsongrass dry weights in plots maintained johnsongrass-free for four or six weeks after planting were significantly lower than those from plots maintained weed-free for two weeks after planting, although they were not significantly different from each other.

Corn maintained johnsongrass-free for two weeks after planting yielded 40% more than corn in the weedy check. Corn kept free of johnsongrass for two weeks after planting yielded significantly lower than corn maintained johnsongrass-free for four weeks after planting (Figure 3). However, corn maintained johnsongrass-free for four weeks after planting or longer, did not yield significantly different than the weed-free check. Corn maintained johnsongrass-free for 4, 6, 8 or 10 weeks after planting yielded 45, 47, 50 and 48% more than the weedy check, respectively.

Corn maintained johnsongrass-free for two weeks after planting yielded 51% more stover than the weedy check. Corn stover yields from plots kept johnsongrass-free for only two weeks after planting were significantly lower than those obtained from the weed-free check (Figure 4). Stover yields of corn maintained johnsongrass-free for

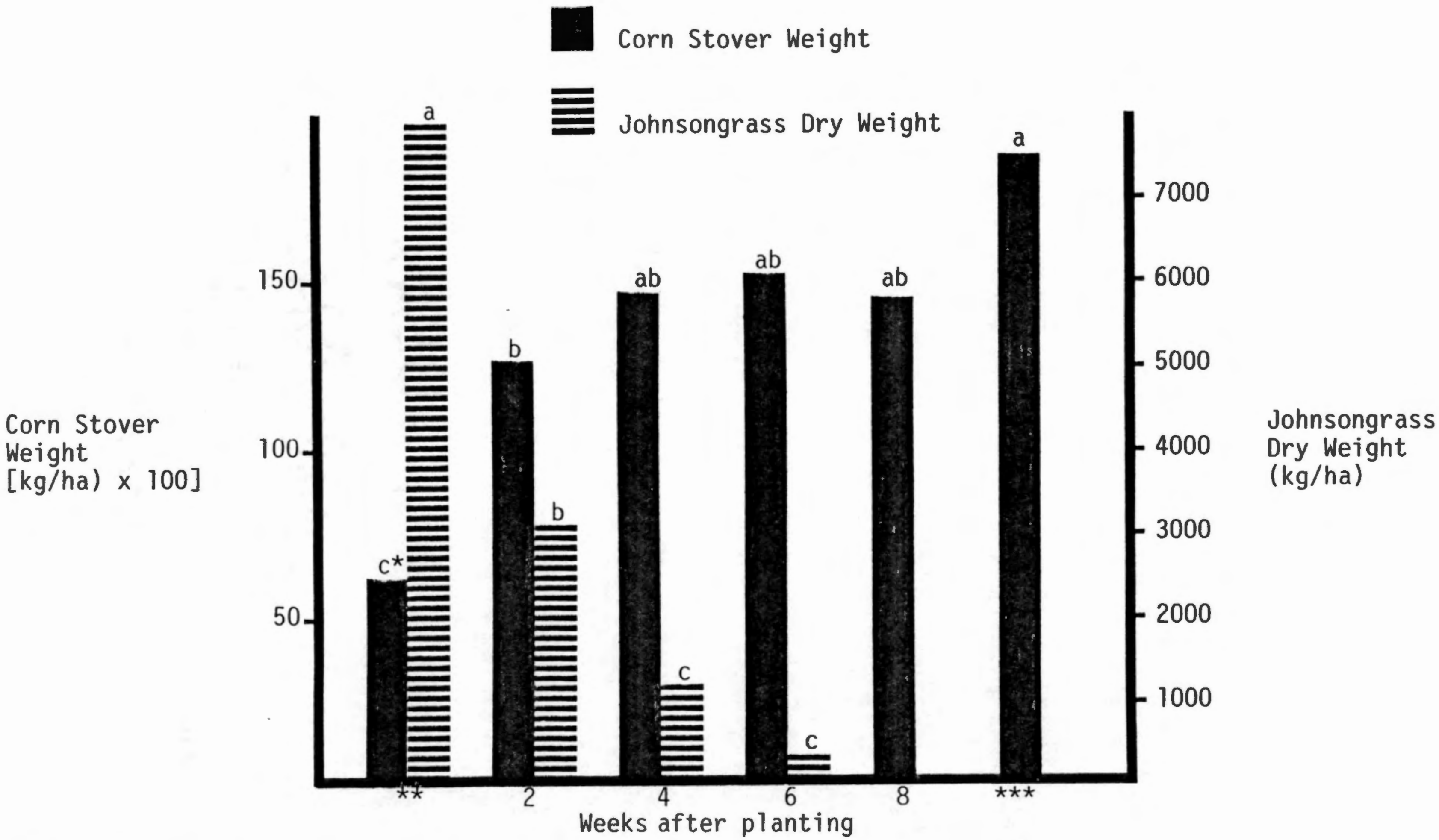

Figure 2. The influence of keeping corn johnsongrass-free for the respective number of weeks on corn and johnsongrass plant dry weights, Spring Hill.

*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 New Multiple Range Test.

** = Weedy Check *** = Weed-free Check

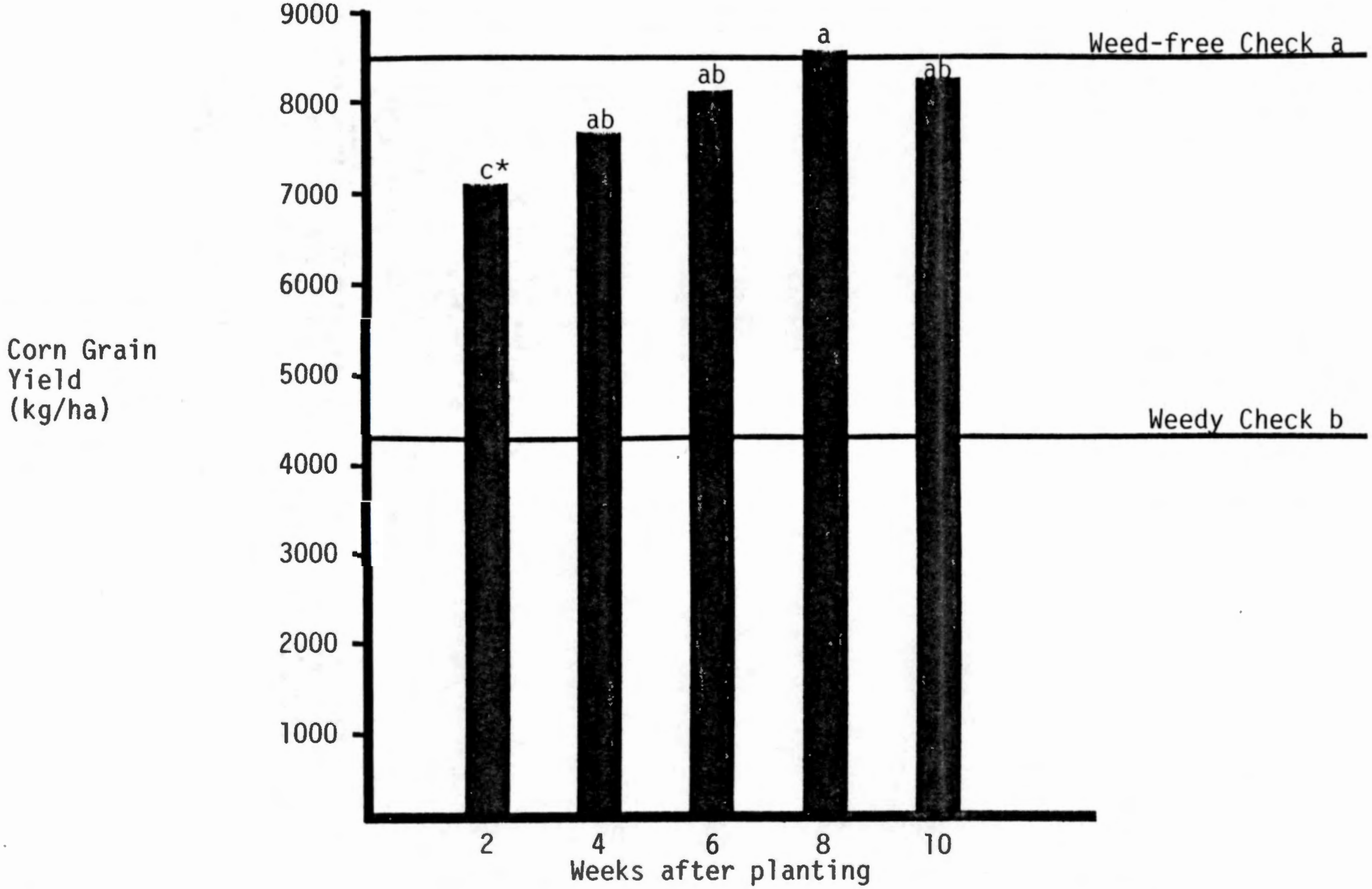

Figure 3. The influence of maintaining corn johnsongrass-free for the respective number of weeks on corn grain yield, Spring Hill.

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

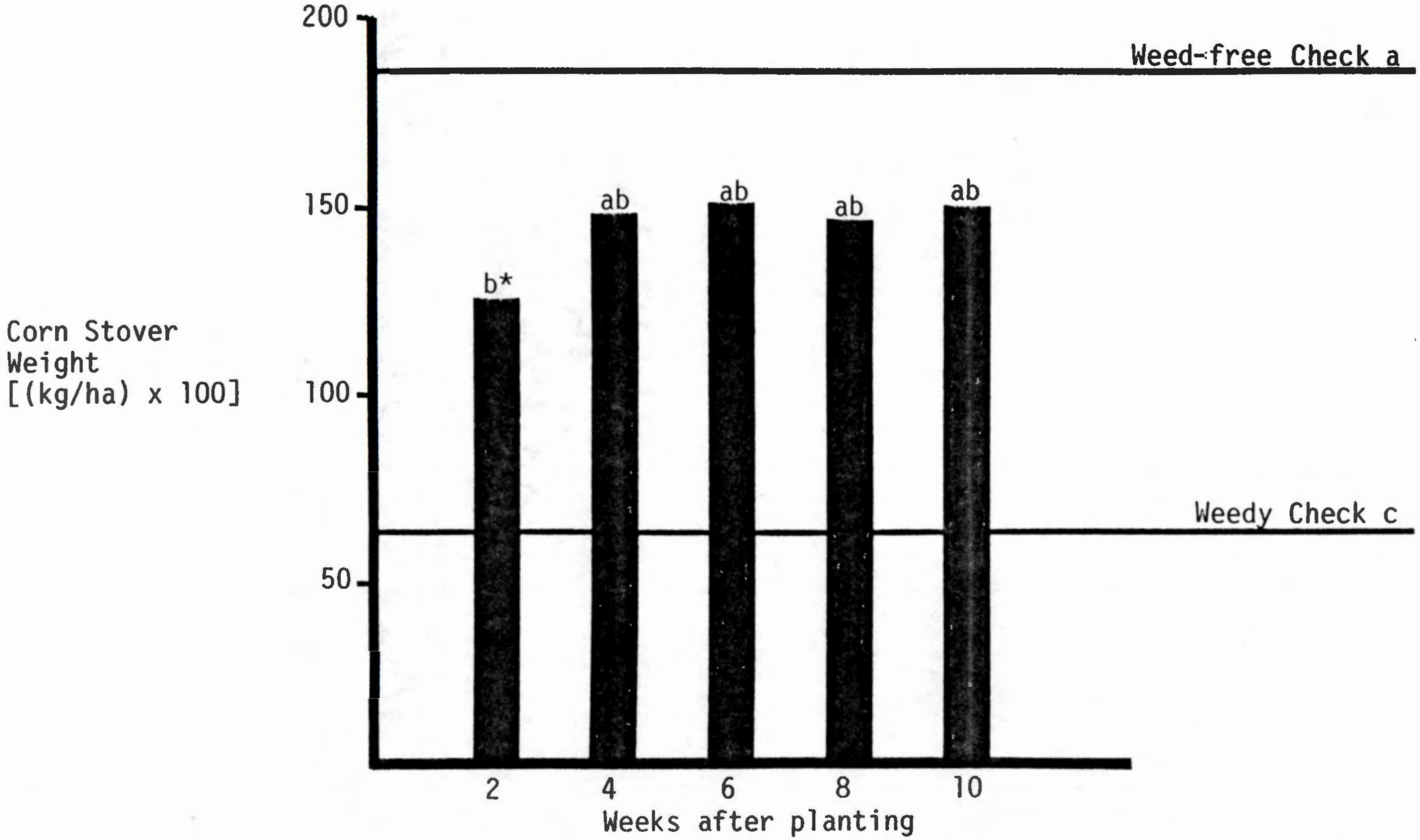

Figure 4. The influence of keeping corn johnsongrass-free for the respective number of weeks on corn stover weight, Spring Hill.

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

four weeks after planting or longer, were not reduced significantly. Maintaining corn johnsongrass-free for 4, 6, 8 or 10 weeks after planting increased corn stover yields 58, 59, 58 and 59%, respectively. The addition of the johnsongrass dry weights to the total corn plant weights in treatments having significantly less total plant weights increased the total biomass weight to that of the weed-free check (Table 3). Total biomass production was 33% higher in the weed-free check than in the weedy check.

A general increase in both grain and stover yields is apparent as the weed-free period increases. However, from the information presented in Figures 3 and 4 it is also apparent that a critical johnsongrass-free requirement in corn exists. It was determined from these results that the critical johnsongrass-free requirement of corn as indicated by both corn grain and corn stover yields is between two and four weeks after planting.

Critical Duration of Johnsongrass Competition in Corn

An exponential increase in johnsongrass dry weights occurred from two weeks after planting through eight weeks after planting (Figure 5). From eight to 20 weeks after planting a gradual decline in johnsongrass dry weights occurred. This decline in dry weight accumulation is primarily due to the maturation and natural senescence of the plant and also due to the increased partitioning of carbohydrates to the rhizomes after the blooming stage (60).

Season-long johnsongrass competition in corn resulted in a 50% reduction in grain yields and a 67% reduction in corn stover

Table 3. The Production of Dry Matter from Corn and Johnsongrass Grown in Competition, Spring Hill.

Treatments	Corn Stover Weight	Corn Grain Yield	Jogr Dry Weight	Total Biomass
	kg/ha			
Weedy Check	6247	4282	7847	18376bc*
Weed-free Check	18716	8549	-	27265a
Maintain weed-free for 2 weeks after planting	12736	7147	3209	23092ab
Maintain weed-free for 4 weeks after planting	14864	7700	1123	23687ab
Maintain weed-free for 6 weeks after planting	15103	8156	332	23591ab
Maintain weed-free for 8 weeks after planting	14793	8576	-	23369ab
Maintain weed-free for 10 weeks after planting	15086	8282	-	23368ab

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

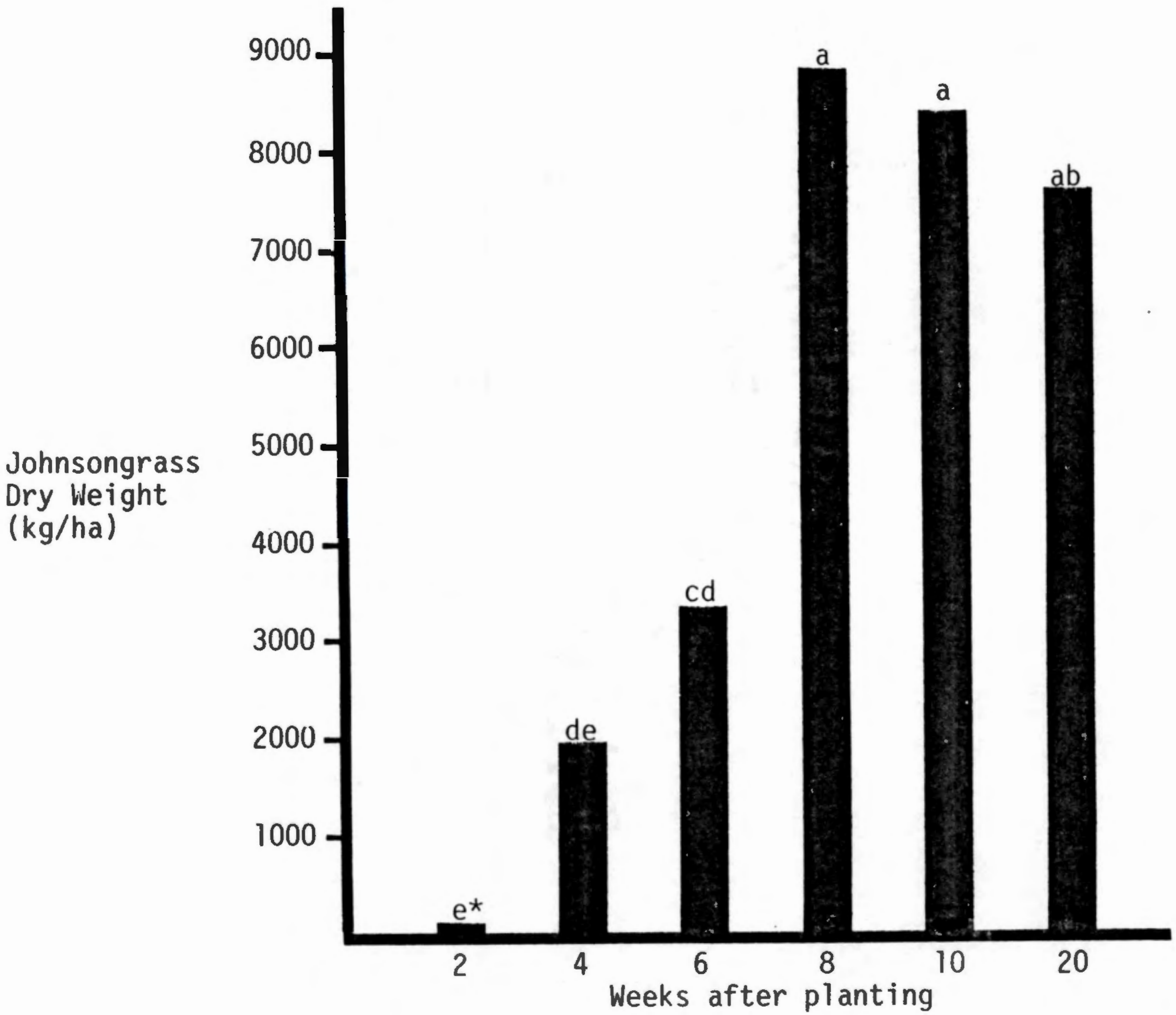

Figure 5. Seasonal growth of johnsongrass growing in competition with corn, Spring Hill.

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

yields. Allowing johnsongrass to grow in competition with corn for up to four weeks after planting did not significantly reduce corn grain yields (Figure 6). Johnsongrass growing in competition with corn for six weeks after planting or longer significantly decreased corn grain yields. Yields from corn maintained johnsongrass-free starting 6, 8, or 10 weeks after planting and continued to harvest were not significantly different from the weedy check. As the duration of johnsongrass competition increased there was a corresponding decrease in grain yield. Allowing johnsongrass to grow in competition with corn for 2, 4, 6, 8 or 10 weeks after planting resulted in corn yield reductions of 5, 9, 36, 40 and 43%, respectively. The critical duration of johnsongrass competition as indicated by corn grain yield was determined to be between four and six weeks after planting.

Corn stover weight was significantly reduced when johnsongrass was allowed to grow in competition with corn for four weeks after planting (Figure 7). This indicates that either corn plants tend to be strong competitors with johnsongrass plants during the first three weeks after corn planting or when johnsongrass is mechanically removed three weeks after corn planting and maintained in a johnsongrass-free environment the corn compensates for early season competition and resulting corn stover yields are equal to that of the weed-free check.

Allowing corn to grow in competition with johnsongrass for four weeks after planting resulted in significantly higher corn stover yields than when corn was allowed to grow with johnsongrass

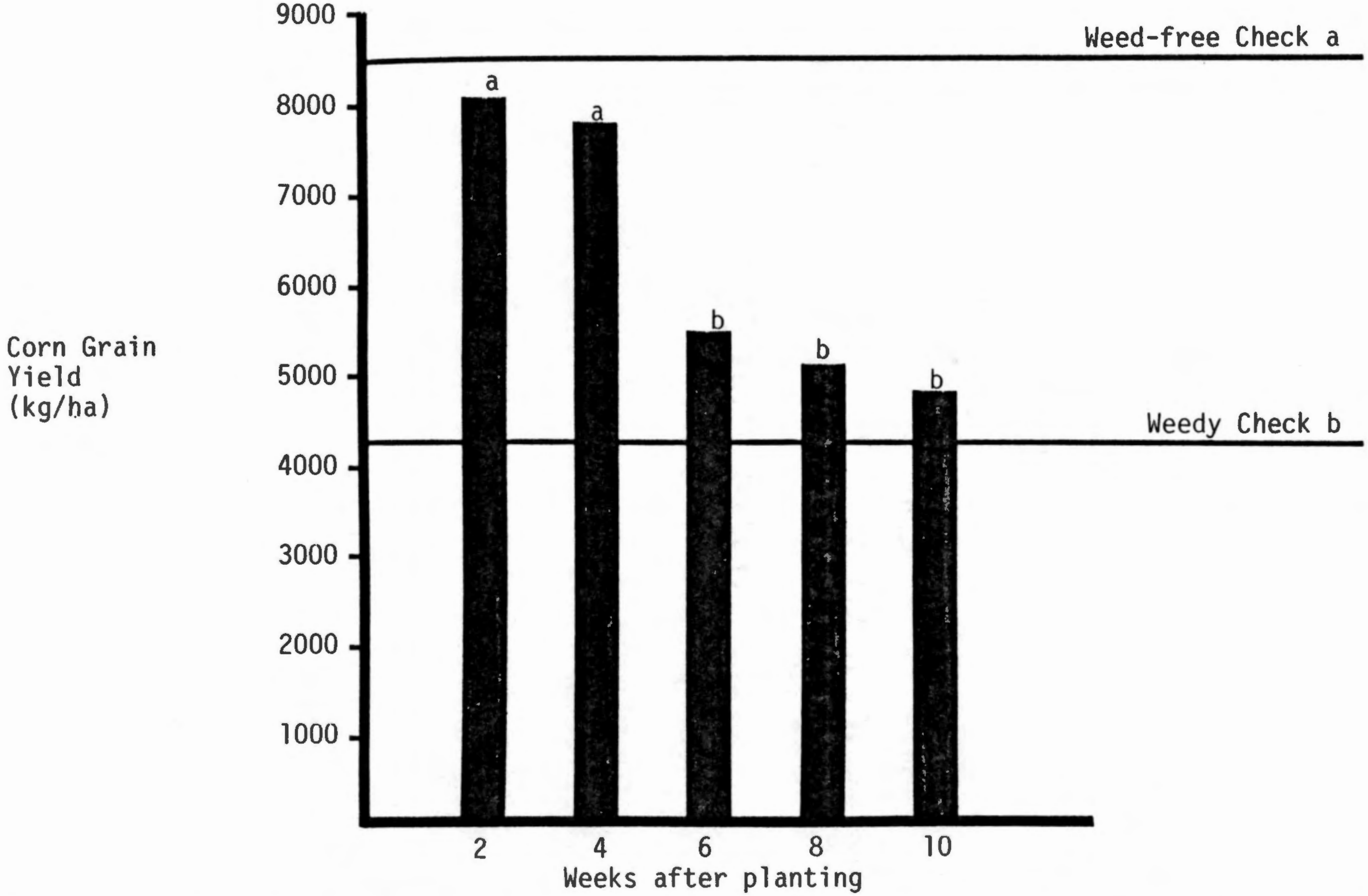

Figure 6. The influence of allowing johnsongrass to grow with corn for the respective number of weeks on corn grain yield, Spring Hill.

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

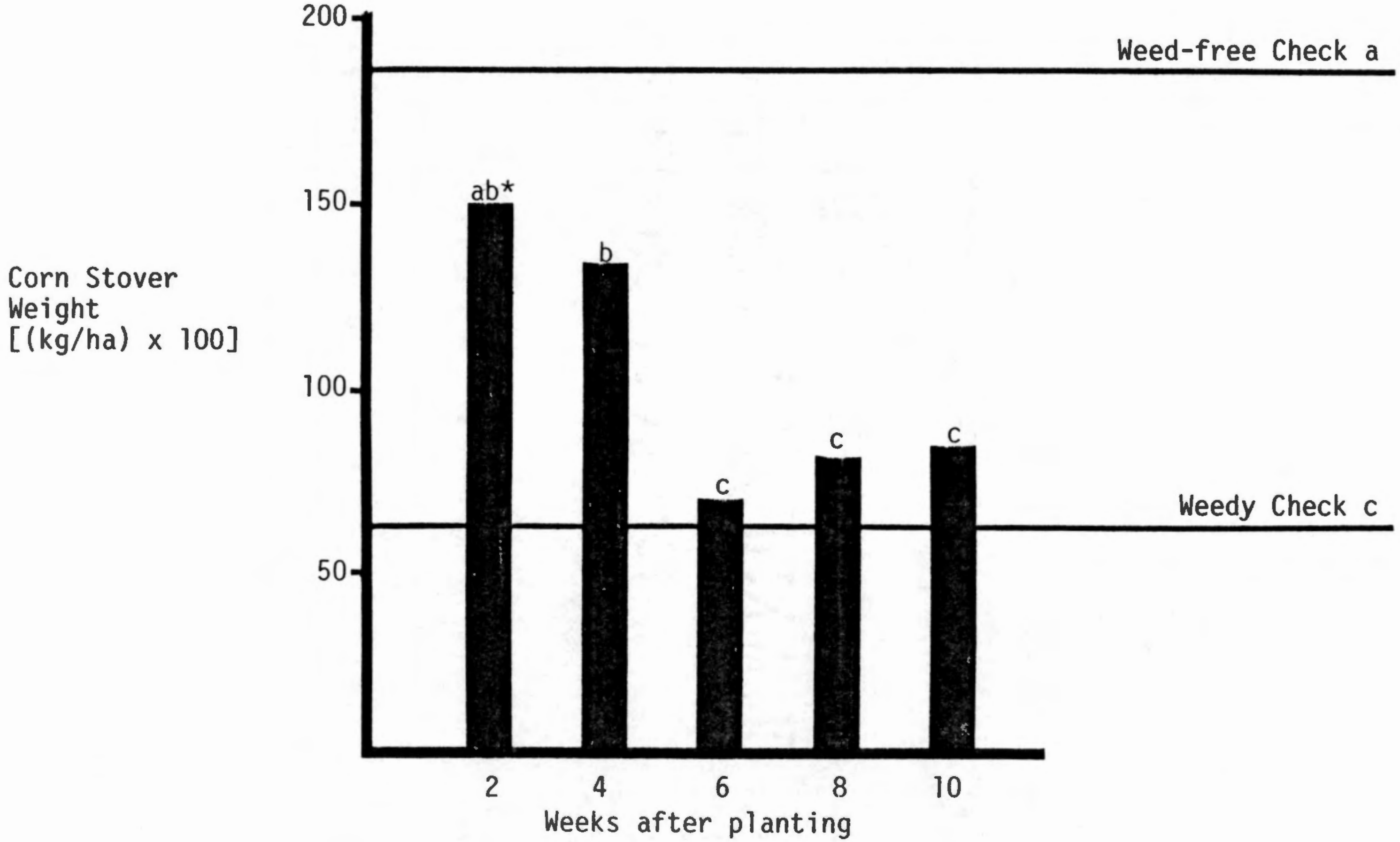

Figure 7. The influence of allowing johnsongrass to grow with corn for the respective number of weeks on corn stover weight, Spring Hill.

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

for six weeks after planting, or longer (Figure 7). Corn growing in competition with johnsongrass for 2, 4, 6, 8 or 10 weeks after planting reduced stover yield by 19, 28, 62, 56 and 55%, respectively. Severe yield reductions resulted from johnsongrass competition for six weeks after planting or longer. This may be attributable to the very low moisture conditions experienced during the month of June (Figure 8). Stover yields from corn grown in competition with johnsongrass for 6, 8 or 10 weeks after planting were not significantly different from one another, nor were they significantly different from stover yields in the weedy check (Figure 7). The critical duration of johnsongrass competition in corn, as indicated by stover yield, is determined to be between two and four weeks after planting.

Season-long johnsongrass competition in corn caused 20% lodging (Table 4). Corn maintained johnsongrass-free for two weeks after planting had a significantly lower percent lodging (6%) than the weedy check. Extended periods (six weeks or longer) of johnsongrass competition reduced corn stalk diameter and increased lodging.

Approximately ten weeks after planting, corn maintained weed-free was in the initial tasselling stage; however, corn grown in competition with johnsongrass for ten weeks after planting was still in the vegetative stage. These observations indicate that competition between johnsongrass and corn for the weeks after planting or longer, delays the transition of corn from vegetative to reproductive stage under these growing conditions.

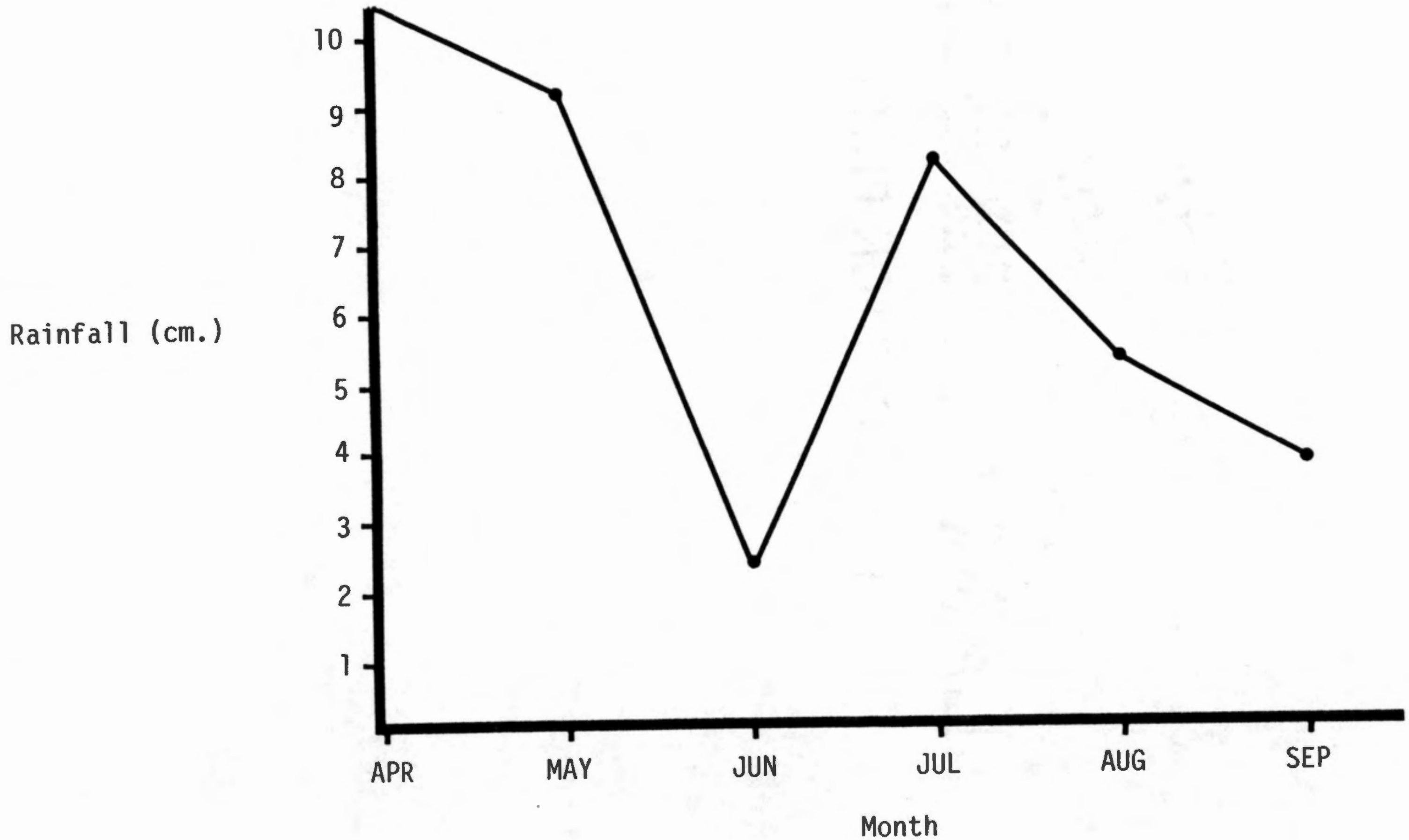

Figure 8. Rainfall data, Middle Tennessee Experiment Station, Spring Hill.

Table 4. The Effect of Johnsongrass Competition on Corn Stalk Lodging, Spring Hill.

Treatments	Percent Corn Lodging
Weedy Check	20a*
Maintain weed-free for 6 weeks after planting to harvest	15ab
Maintain weed-free for 8 weeks after planting to harvest	8ab
Maintain weed-free for 10 weeks after planting to harvest	4b
Maintain weed-free for 2 weeks after planting	6b

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

Chemical Johnsongrass Control

EPTC or butylate, plus the herbicide antidote (R-25788) resulted in johnsongrass control of 56 and 66%, respectively. There was no significant difference in johnsongrass control with these two herbicides (Table 5). Johnsongrass control obtained by the herbicides was not significantly different from that obtained when corn was maintained johnsongrass-free for two weeks after planting (Table 5). This same trend was established when corn grain yield is evaluated. Corn treated with the commercial formulation of EPTC did not yield significantly different from corn which was treated with butylate plus R-25788. Yields obtained from corn which had been treated with EPTC or butylate, plus R-25788 were not significantly different from corn which had been maintained weed-free two weeks after planting. This indicates that these herbicides were providing approximately two weeks of johnsongrass control. The herbicide treatments were not cultivated even though this is a recommended practice of controlling johnsongrass in corn. It is reasonable to assume that the herbicide treatments in combination with timely cultivation would have provided improved johnsongrass control.

Johnsongrass Threshold in Corn

Increasing johnsongrass plant populations from 0 to 30/6.1 meters of row was associated with significant corn grain yield reductions. Johnsongrass plant populations of 16/6.1 m or higher reduced corn grain yields significantly (Figure 9). While

Table 5. Johnsongrass Control and Corn Grain Yield from Two Thiocarbamate Herbicides, Spring Hill.

Treatments	Percent Johnsongrass Control	Corn Grain Yield (kg/ha)
Weed-free Check	100a	8549a
Maintain weed-free for 6 weeks after planting	96a	8156ab
Maintain weed-free for 4 weeks after planting	86ab	7700ab
Butylate + R-25788	66bc	6694b-d
Maintain weed-free for 2 weeks after planting	59c	7147bc
EPTC + R-25788	56c	5373de
Weedy Check	0d	4282e

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

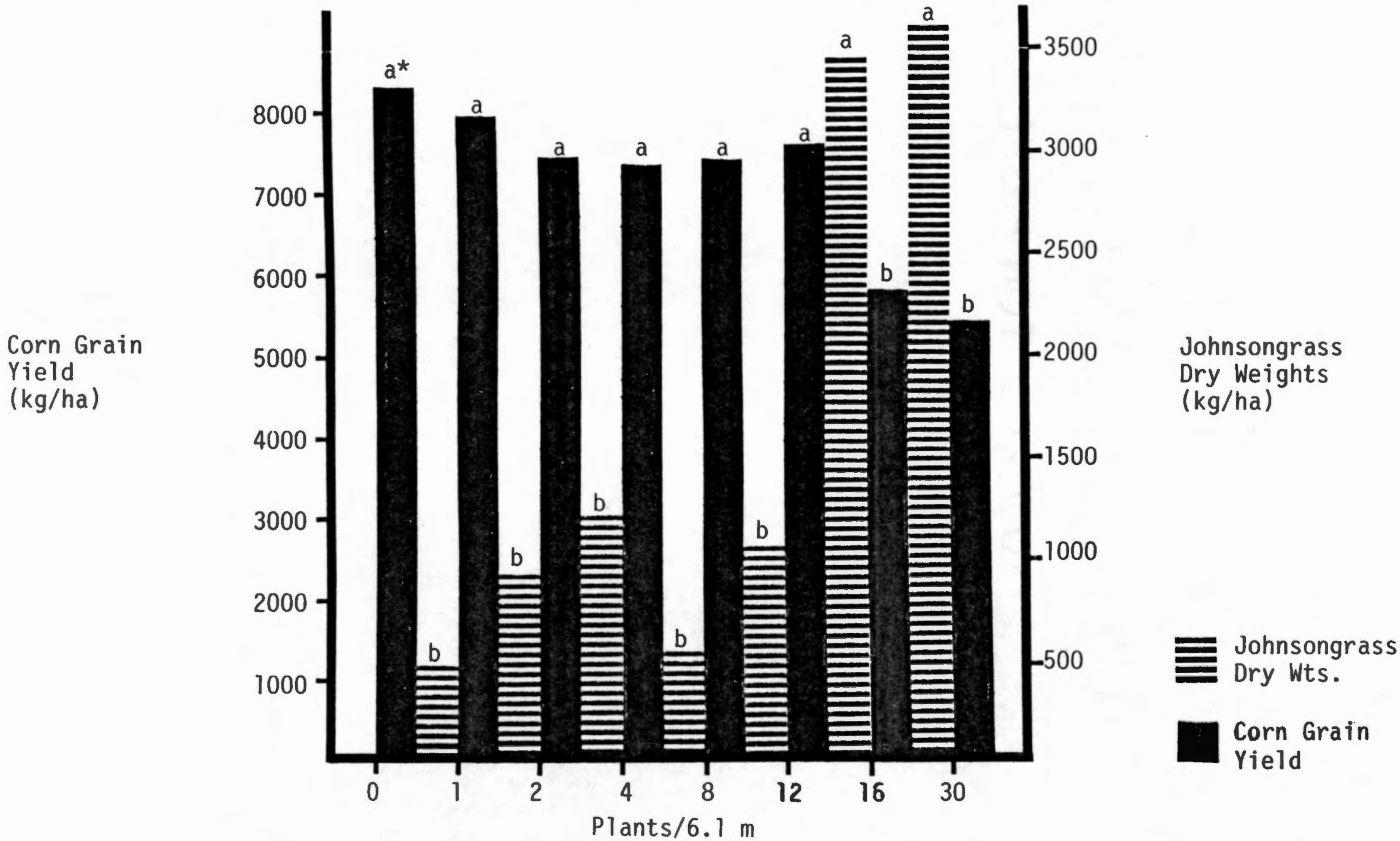

Figure 9. The effect of increasing johnsongrass plant number and dry weights on corn grain yield.

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

johnsongrass plant populations of 12/6.1 m or less did not reduce yields significantly.

Being able to accurately predict the potential yield reductions associated with specific weed populations is an integral part of any integrated pest management program. This experiment, however, was designed to equate a range of plant populations with yield reduction rather than a specific plant population. Further research is necessary in order to determine the specific economic threshold in corn.

2. KNOXVILLE

Critical Johnsongrass-free Requirement of Corn

A johnsongrass-free period for six or eight weeks after planting resulted in end-of-season johnsongrass control of 94 and 95%, respectively (Figure 10). When corn was maintained johnsongrass-free for four weeks after planting, end-of-season johnsongrass control was only good; approximately 80%. End-of-the-season johnsongrass control in corn maintained johnsongrass-free for only two weeks after planting was not significantly different from end-of-season johnsongrass control in corn plots which had been kept johnsongrass-free for 4, 6, 8 or 10 weeks after planting. As the johnsongrass-free period of corn increases, a corresponding increase in johnsongrass control and/ or a corresponding decrease in johnsongrass regrowth occurs. Again the removal of johnsongrass top growth for extended periods of time may play a role in reducing regrowth from rhizomes. Also, the shading effect of established corn on emerging johnsongrass may reduce

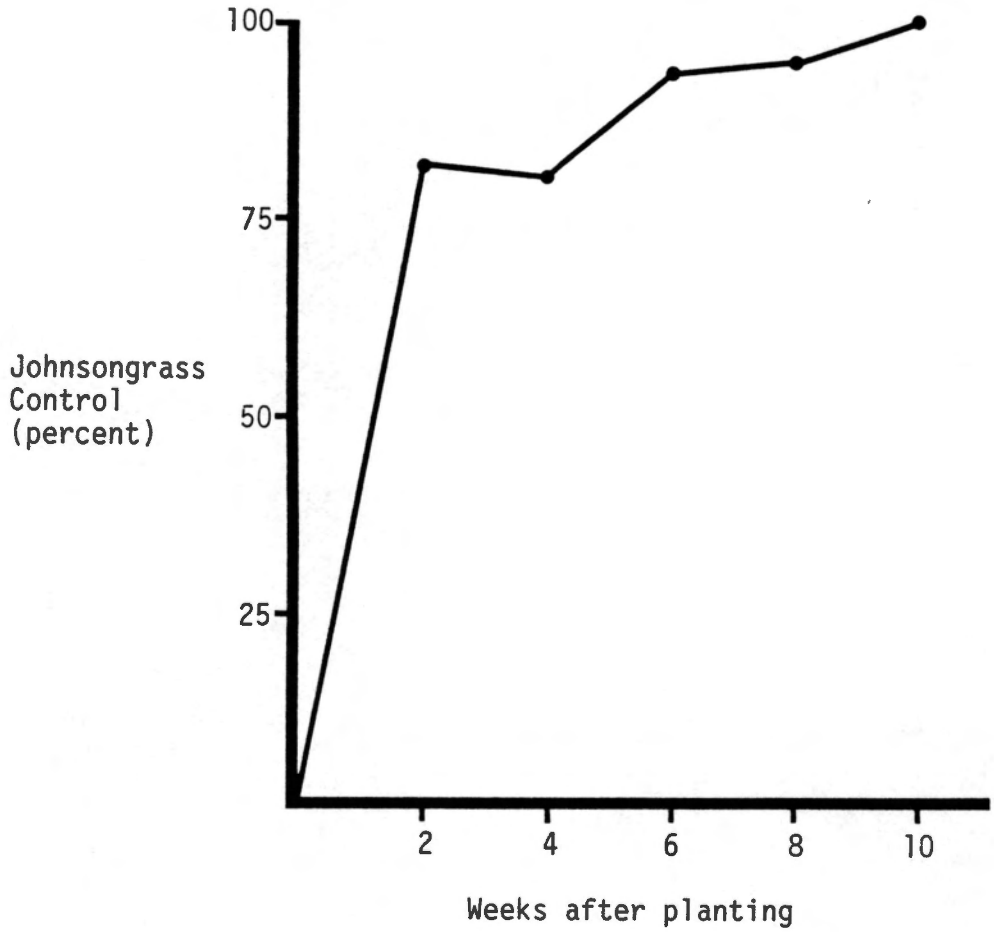

Figure 10. The influence of keeping corn johnsongrass-free for the respective number of weeks on end-of-season johnsongrass control, Knoxville.

regrowth. No significant johnsongrass regrowth occurred in plots maintained free of johnsongrass for ten weeks after planting.

Generally, there was an inverse relationship between corn and johnsongrass plant dry weights (Figure 11). The weedy check contained 5.5 times as much johnsongrass dry weight as plots maintained johnsongrass-free for two weeks after planting and 20 times as much as plots maintained johnsongrass-free for eight weeks after planting. Johnsongrass dry weights in the weedy check were significantly higher than johnsongrass dry weights in plots which had been maintained johnsongrass-free for two weeks after planting (Figure 11). Johnsongrass dry weights in corn maintained johnsongrass-free for 2, 4, 6, 8 or 10 weeks after planting were not significantly different from each other.

Corn maintained johnsongrass-free for two weeks after planting did not yield significantly different from the weed-free check. Corn which was maintained johnsongrass-free for 4, 6, 8 or 10 weeks after planting did not yield significantly different from one another and were not significantly different from the weed-free check (Figure 12).

Corn maintained johnsongrass-free for two weeks after planting resulted in a 37% increase in corn stover yields over that of the weedy check. Corn stover yields from treatments which were kept johnsongrass-free for two weeks after planting were not significantly different from those of the weed-free check (Figure 13). Corn maintained johnsongrass-free for four weeks after planting had corn stover yields significantly lower than corn maintained johnsongrass-free for eight weeks after planting. The addition of the johnsongrass

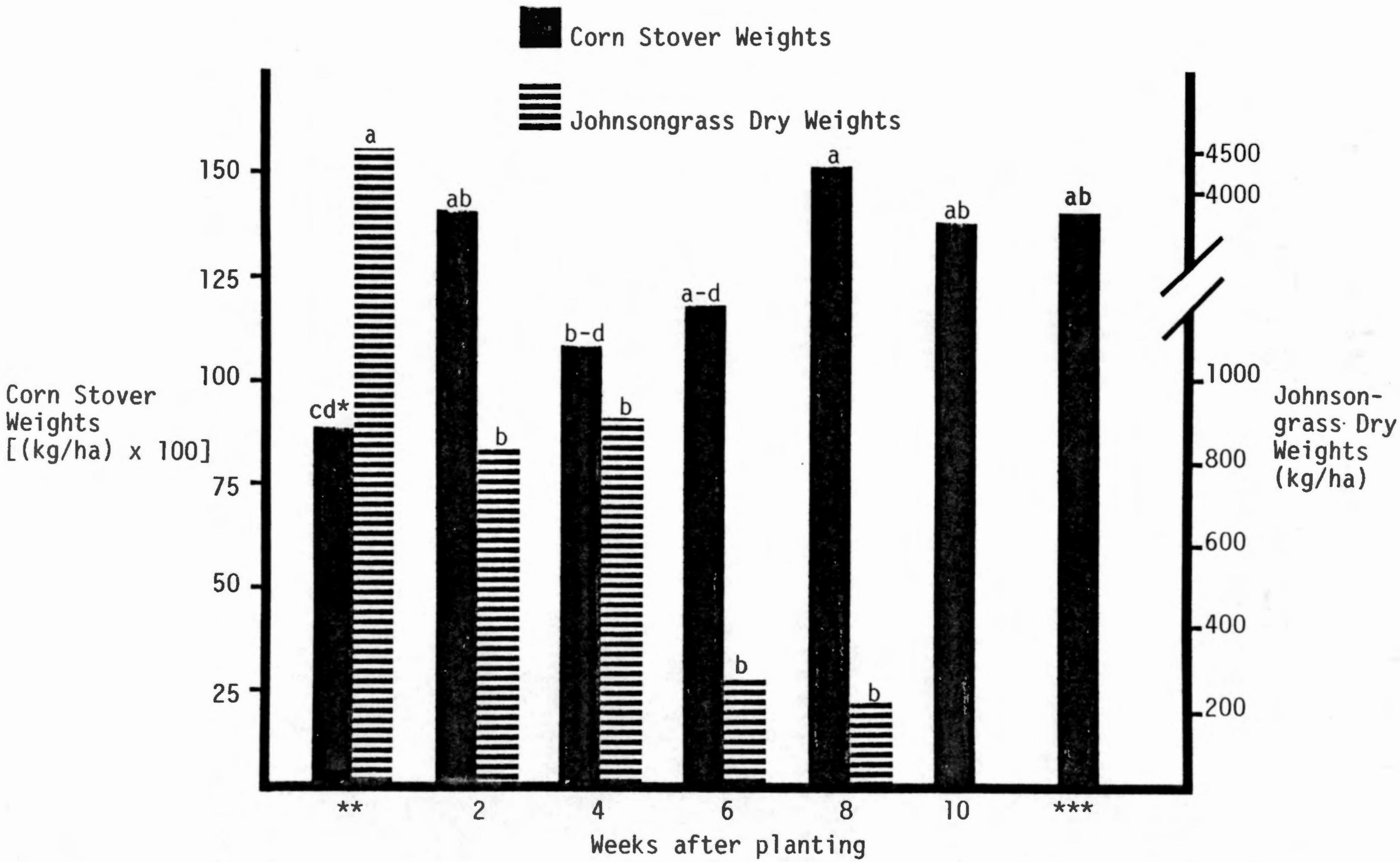

Figure 11. The influence of keeping corn johnsongrass-free for the respective number of weeks on corn and johnsongrass plant dry weights, Knoxville.

*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 New Multiple Range Test.

** = Weedy Check *** = Weed-free Check

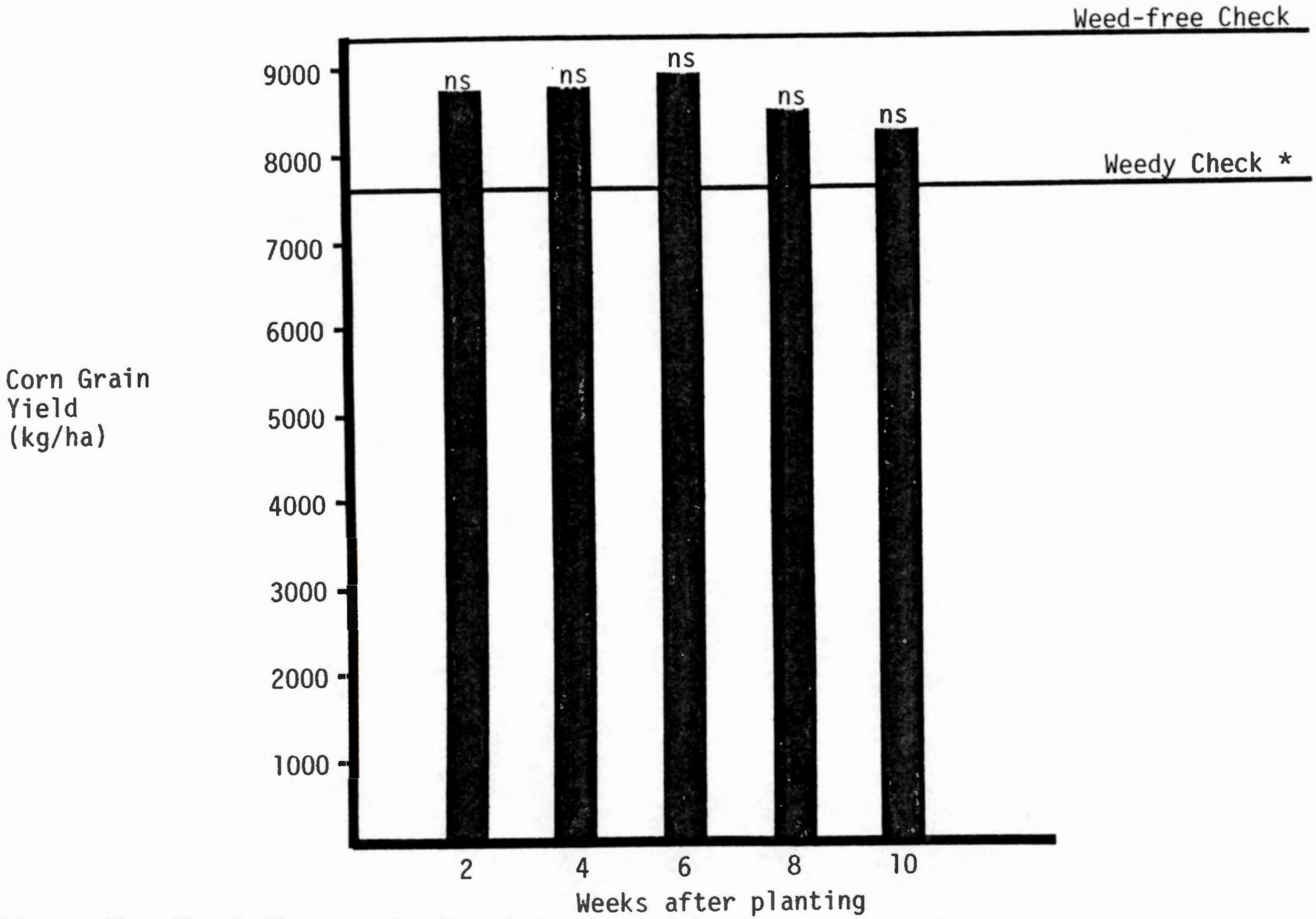

Figure 12. The influence of maintaining corn johnsongrass-free for the respective number of weeks on corn grain yield, Knoxville.

*Values significantly different from the weed-free check at the 0.05 probability level.

ns = not significant.

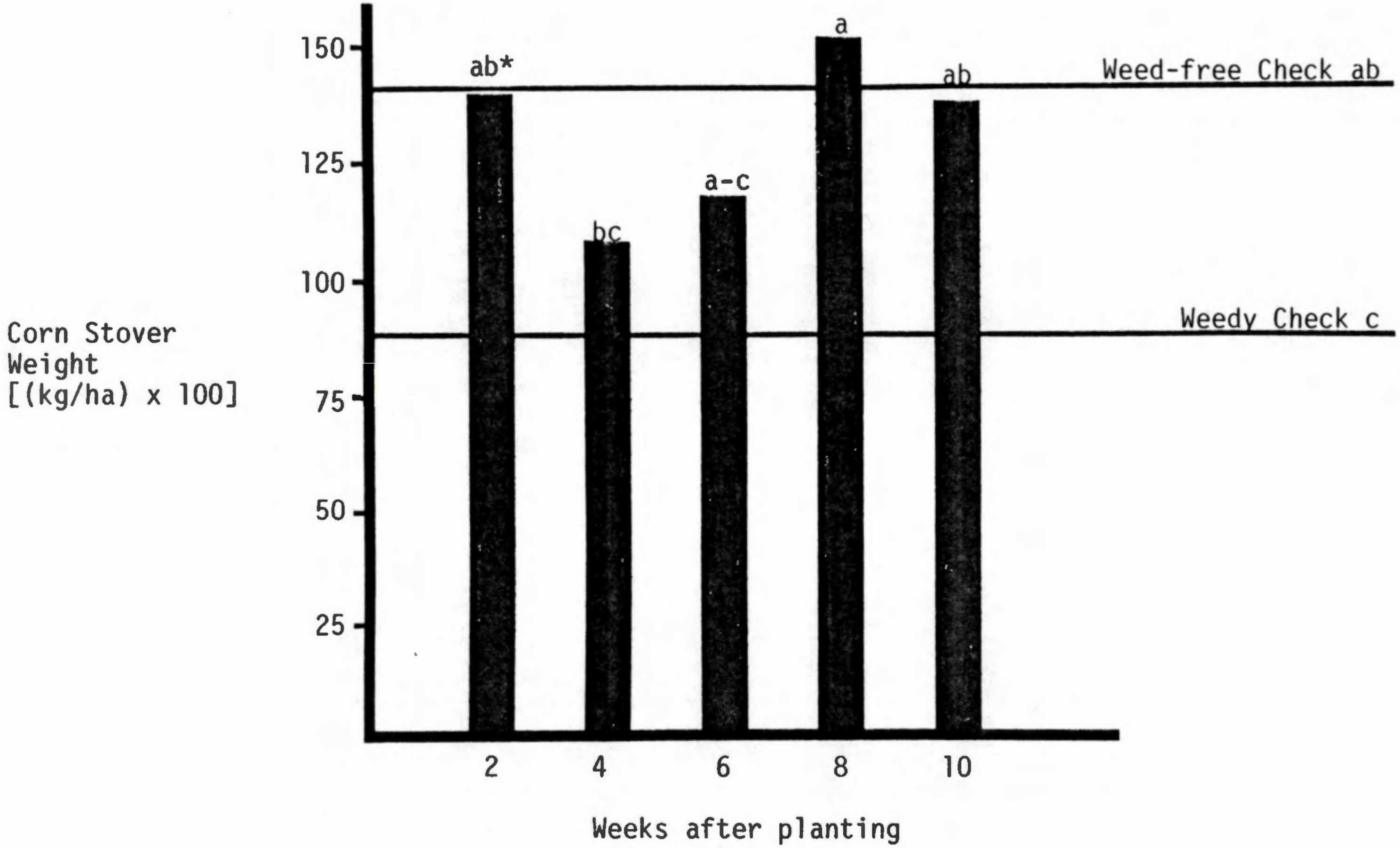

Figure 13. The influence of maintaining corn johnsongrass-free for the respective number of weeks on corn stover yields, Knoxville.

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

dry weights to the total corn plant weights in treatments having significantly less total plant weights increased the total biomass weight to that of the weed-free check (Table 6). Total biomass production was 10% greater in the weed-free check than the weedy check.

From evaluation of both the corn grain yield and the corn stover yields it can be determined that no critical johnsongrass-free requirement existed for corn under these experimental conditions. Several factors may be influential in reducing the competitiveness of johnsongrass in this study. A primary factor may be that this area never experienced any apparent stress, such as drought or nutrient deficiencies, which would have made the competition for essential growth factors more severe. Another important factor in reducing the competitiveness of johnsongrass in this study was that the overall johnsongrass population was small and primarily existed in patches as opposed to a uniform stand. The lush growing conditions in this experiment created an environment in which the essential growth factors were never severely limiting, thereby reducing the competitiveness of johnsongrass in corn.

Critical Duration of Johnsongrass Competition in Corn

An exponential increase in johnsongrass dry weight occurred from two weeks after planting through eight weeks after planting (Figure 14). From eight to 20 weeks after planting a gradual decline in johnsongrass dry weight occurred. This same trend has been experienced by other researchers (70), and is the same as that experienced in the experiment at Spring Hill.

Table 6. The Production of Dry Matter from Corn and Johnsongrass Grown in Competition, Knoxville.

Treatments	Corn Stover Weight	Corn Grain Yield	Jogr Dry Weight	Total Biomass
	kg/ha			
Weedy Check	8876	7659	4518	21053a*
Weed-free Check	14164	9331	-	23495a
Maintain weed-free for 2 weeks after planting	14089	8746	825	23660a
Maintain weed-free for 4 weeks after planting	10820	8756	908	20484a
Maintain weed-free for 6 weeks after planting	11806	8820	283	20909a
Maintain weed-free for 8 weeks after planting	15189	8510	225	23924a
Maintain weed-free for 10 weeks after planting	13835	8260	-	22095a

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

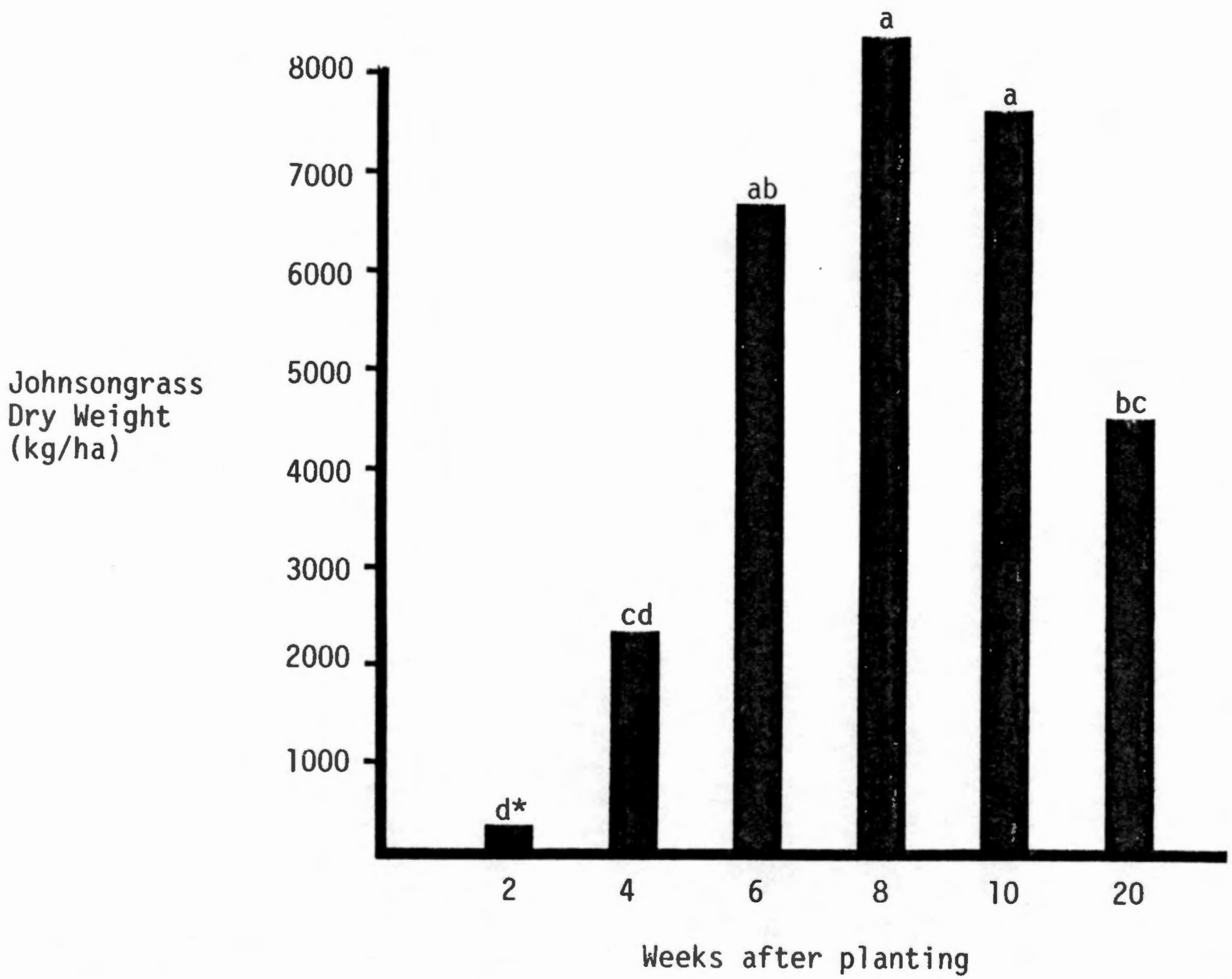

Figure 14. Seasonal growth of johnsongrass growing in competition with corn, Knoxville.

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

Season-long johnsongrass competition in corn resulted in an 18% reduction in grain yields and a 37% reduction in corn stover yields. Allowing johnsongrass to grow in competition with corn for up to six weeks after planting did not result in significant corn grain yield reductions (Figure 15). Johnsongrass growing in competition with corn for eight weeks after planting or longer caused significant grain yield reductions. Corn grain yields from corn which grew in competition with johnsongrass for 6, 8 or 10 weeks after planting was not significantly different from corn yield in the weedy check.

Corn stover weight was significantly reduced when johnsongrass was allowed to grow in competition with corn for eight weeks after planting (Figure 16). This indicates that under these growing conditions, corn can compete with johnsongrass for as long as seven weeks after planting before corn stover yields are significantly reduced. Stover yields from corn which grew in competition with johnsongrass for 2, 4 or 6 weeks after planting were not significantly different from one another nor were they significantly different from stover yield in the weedy check. Allowing johnsongrass to grow in competition with corn for four weeks after planting resulted in significantly higher corn stover yields than when johnsongrass was allowed to grow with corn for eight weeks after planting (Figure 16).

The critical duration of johnsongrass competition at Knoxville as indicated by both corn grain yield and corn stover yield was determined to be between six and eight weeks after planting.

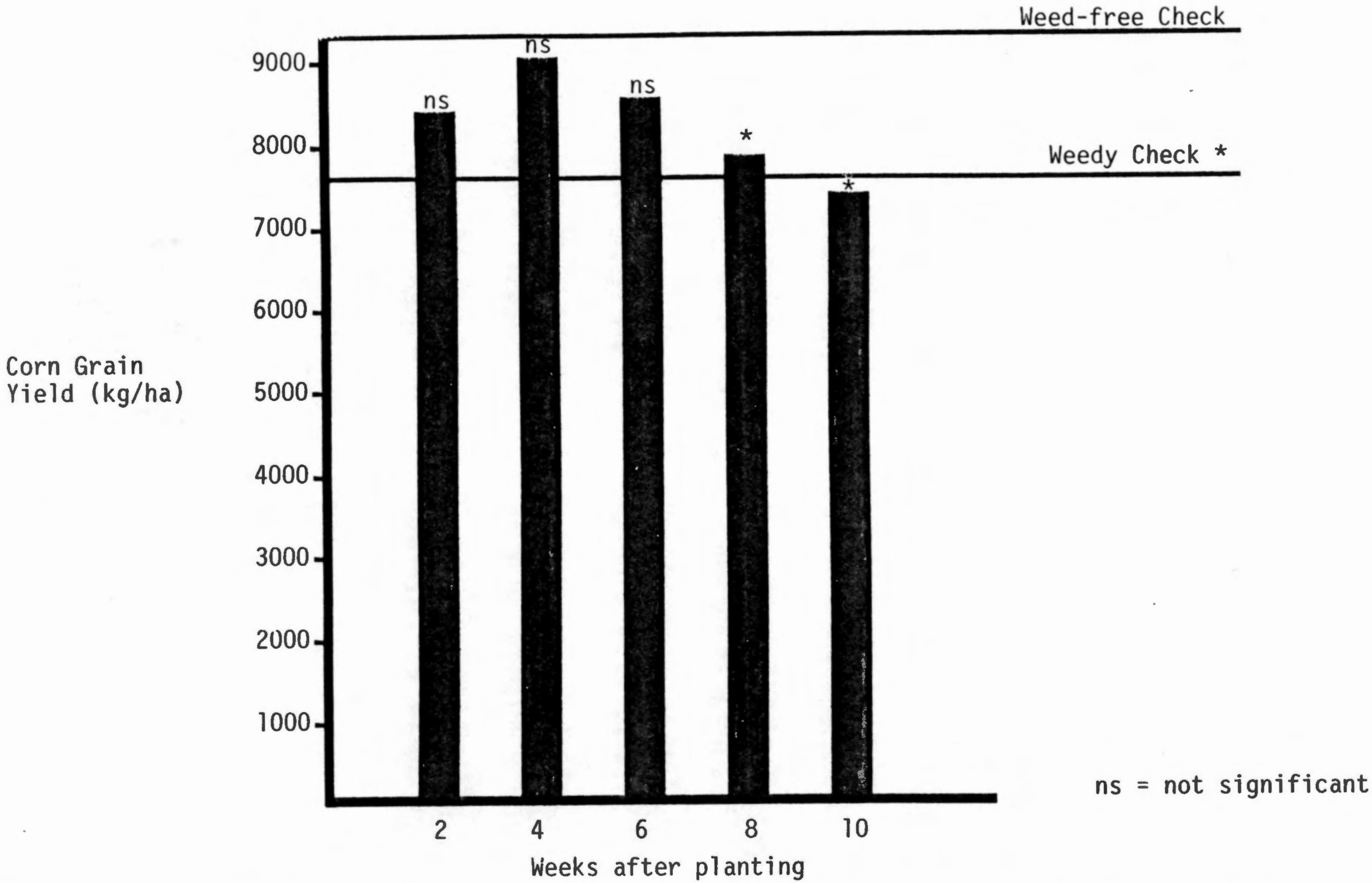

Figure 15. The influence of allowing johnsongrass to grow with corn for the respective number of weeks on corn grain yield, Knoxville.

*Values significantly different from the weed-free check at the 0.05 probability level.

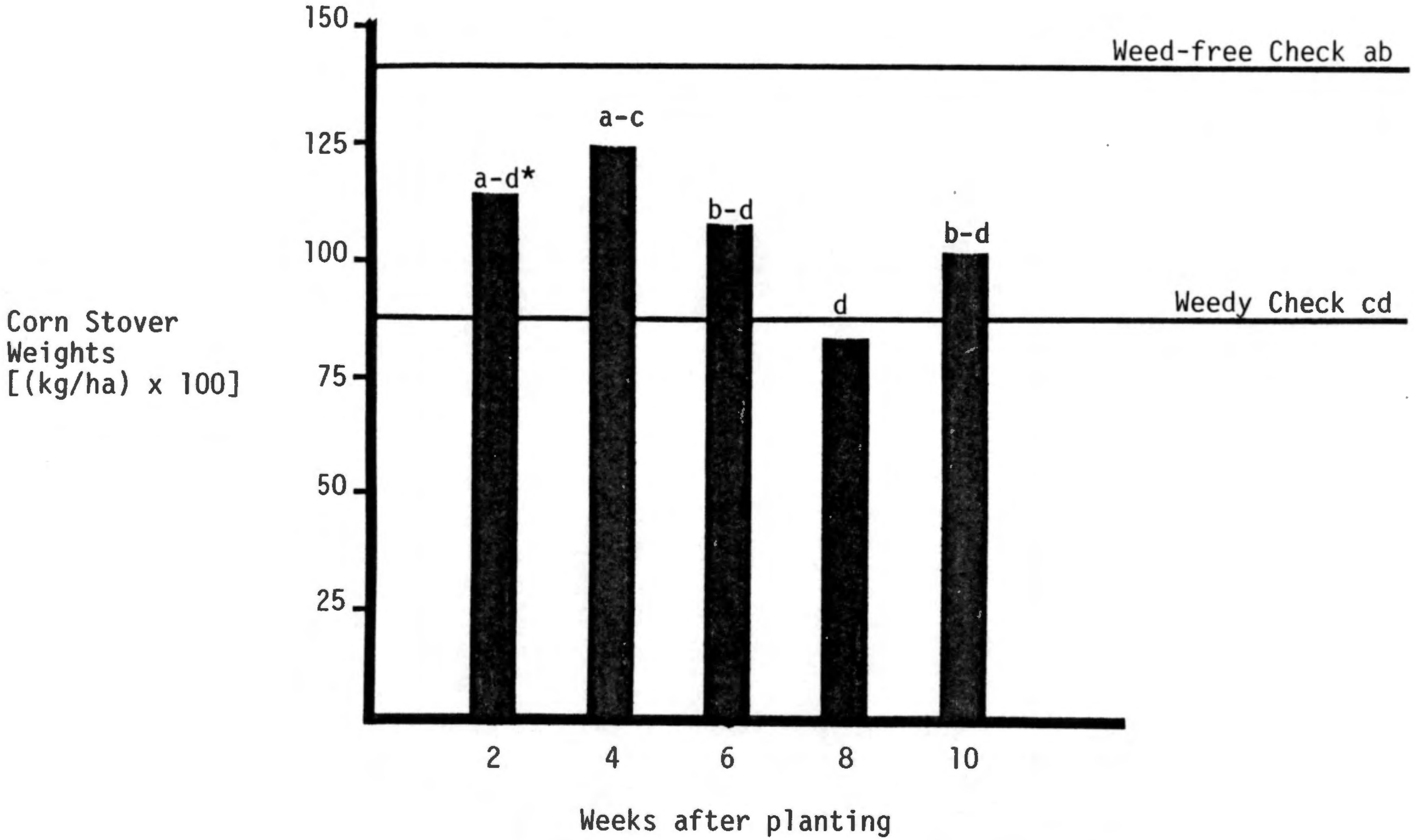

Figure 16. The influence of allowing johnsongrass to grow with corn for the respective number of weeks on corn stover weights, Knoxville.

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

Corn stalk lodging was also observed in the weedy check at the Knoxville study although actual numbers were not obtained. The delay in transition of corn from the vegetative to the reproductive stage was not as pronounced and therefore not as clearly defined under these growing conditions.

Chemical Johnsongrass Control

EPTC or butylate plus R-25788 did not provide acceptable control of johnsongrass in corn. Butylate plus R-25788 or EPTC plus R-25788 resulted in johnsongrass control of 19 and 37%, respectively. However, the addition of the herbicide extender R-33865 to EPTC plus R-25788 provided significantly better johnsongrass control than EPTC plus R-25788. EPTC plus R-25788 and EPTC plus R-25788 and R-33865 resulted in johnsongrass control of 37 and 80%, respectively (Table 7). EPTC in combination with R-25788 and R-33865 provided johnsongrass control which was not significantly different from that obtained when corn was maintained weed-free for ten weeks after planting. Corn treated with EPTC plus R-25788, butylate plus R-25788 or EPTC plus R-25788 and R-33865 did not yield significantly different from each other (Table 7). Corn treated with EPTC plus R-25788 or butylate plus R-25788 yielded significantly lower than the weed-free check, although corn treated with EPTC plus R-25788 and R-33865 did not yield significantly different from the weed-free check. A cropping history of corn treated with EPTC plus the herbicide antidote for the three previous growing seasons at this location may have played a role in reduced herbicide efficacy (55).

Table 7. Johnsongrass Control and Corn Grain Yield from Three Thiocarbamate Herbicides, Knoxville.

Treatments	Percent Johnsongrass Control	Corn Grain Yield (kg/ha)
Weed-free Check	100a*	9331
Maintain weed-free for 10 weeks after planting	100a	8260 ns
Maintain weed-free for 8 weeks after planting	95a	8510 ns
Maintain weed-free for 6 weeks after planting	94a	8820 ns
EPTC + R-25788 + R-33865	80a	8469 ns
Maintain weed-free for 4 weeks after planting	80a	8756 ns
Maintain weed-free for 2 weeks after planting	82a	8746 ns
EPTC + R-25788	37b	7500 **
Butylate + R-25788	19bc	6664 **
Weedy Check	0c	7659 **

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

**Values significantly different from the Weed-free Check at the 0.05 probability level.

ns = not significantly different from the Weed-free Check.

CHAPTER V

SUMMARY AND CONCLUSIONS

Season-long johnsongrass competition in corn grown at two locations resulted in an 18 to 50% reduction in grain yields and a 37 to 67% reduction in corn stover yields. The variation in the competitive ability of johnsongrass in corn is a result of the difference in the amount of rainfall and the uniformity of the johnsongrass population at the two locations. At the Knoxville location, adequate moisture conditions in combination with an overall low johnsongrass population either reduced the competitiveness of johnsongrass in corn or it allowed corn to compete favorably with johnsongrass and produce yields which are comparable to or above the average corn grain yields in Tennessee. However, at the Spring Hill location, a month-long drought period in conjunction with a high johnsongrass population resulted in severe yield reductions.

A critical johnsongrass-free requirement in corn of between two and four weeks after planting was observed at the Spring Hill location. The ability of johnsongrass regrowth to significantly reduce corn yields where it is mechanically maintained johnsongrass-free for less than four weeks after planting is indicative of the competitive nature of this weed under stressful growing conditions. No critical johnsongrass-free requirement existed for corn grown at the Knoxville location. This indicates that corn grown under more favorable conditions has a competitive advantage over johnsongrass regrowth.

The critical duration of johnsongrass competition in corn grown at Spring Hill was determined to be between four and six weeks after planting, while the critical duration of johnsongrass competition in corn grown at Knoxville was extended for two weeks and determined to be between six and eight weeks after planting.

Johnsongrass control provided by the herbicides EPTC or butylate, plus R-25788 was 56 and 66%, respectively, at Spring Hill. End-of-the-season johnsongrass control in corn maintained johnsongrass-free for two weeks after planting was not significantly different from that obtained by EPTC or butylate plus R-25788. Johnsongrass control provided by EPTC or butylate plus R-25788 was 37 and 19%, respectively, at Knoxville. The variation between locations in the percent johnsongrass control provided by these herbicides may be explained by evaluating the cropping history of each location. Growing corn treated with EPTC plus R-25788 for the three previous growing seasons probably reduced the herbicide efficacy at Knoxville. Evidence provided by Obrigawitch (55, 57) showing that repeated applications of EPTC at the same location significantly reduced the persistence of this herbicide in the soil coincides with the conclusions drawn here. A single application of EPTC plus R-25788 the previous year at Spring Hill may play a role in reduced johnsongrass control, although not of the same degree as that experienced after three annual applications. As shown by other researchers (18, 56) the addition of the herbicide extender R-33865 to EPTC plus R-25788 significantly increased the percent johnsongrass control. End-of-the-season johnsongrass control in corn treated with EPTC plus

R-25788 was only 37%; however, with the addition of R-33865 end-of-season johnsongrass control increased to 80%.

Periods of johnsongrass competition of six weeks after planting or longer are associated with increased corn stalk lodging. Season-long johnsongrass competition caused 20% lodging. Periods of johnsongrass competition for ten weeks or longer caused a delay in the transition of corn from the vegetative to the reproductive stage.

Significant corn grain yield reductions occurred when johnsongrass populations of 28576 plants per hectare were allowed to grow in competition with corn for the entire growing season.

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APPENDIX

APPENDIX

Table 8. Rainfall Data 1982, Middle Tennessee Experiment Station of The University of Tennessee at Spring Hill.

Day	May	June	July	Aug.	Sept.
1		.05			.43
2					.76
3					1.04
4		.38			
5		.13			
6			.51	.69	
7					
8	6.63*			.15	
9			1.60	.05	
10		.41	1.91	1.27	
11			1.60		
12					
13		.07			1.04
14					
15					
16				.08	.05
17				1.45	
18	.41				
19			1.55		
20	.28	.25			.20
21	1.37			.13	.08
22					
23	.05			.05	
24			.46	.15	
25			1.14	1.02	
26	.28		.05		.18
27	.15				
28	.05		.10		
29		1.02			
30					
31			.81	.28	
Total	9.22	2.31	9.73	5.32	3.78

*Rainfall recorded in centimeters.

Table 9. Rainfall Data 1982, Knoxville Experiment Station of The University of Tennessee at Knoxville.

Day	May	June	July	Aug.
1		.13		
2				
3			2.79	
4		.33		
5				.20
6				
7	1.17*			.91
8	.13		5.23	4.55
9				1.35
10		.71	2.46	
11			.25	
12		3.15		
13				
14				
15				
16	1.83	1.63		.05
17				7.32
18	.25		.25	
19			.89	
20				
21	.97	.43		
22	.03		.31	
23	2.36			1.32
24	.05		.10	.18
25	.25			
26		.66		
27	1.30	.56		.61
28	5.69	.05	3.71	
29		.28	.28	
30			2.85	.43
31			7.87	.33
Total	14.03	7.93	16.89	17.25

*Rainfall recorded in centimeters.

VITA

Kevin McDonald Perry was born in Louisville, Kentucky, on September 14, 1959. He is one of seven children born to Mr. and Mrs. Ben C. Perry. He received his primary and secondary education in the Jefferson and Todd County, Kentucky, school systems and was graduated from Todd County Central High School in June 1977.

In the fall of 1977 he entered Murray State University in Murray, Kentucky. In August 1979 he entered The University of Kentucky, Lexington, and in August 1981 he received a Bachelor of Science degree with a major in Entomology. On August 19, 1981, he wed the former Miss JoAnn Miller of Herman, Kentucky. In September of 1981 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 August 1983.