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DETECTION, INFLUENCE AND ECONOMICS OF ANNUAL GRASS INTERFERENCE ON SOYBEAN [GLYCINE MAX (L.) Merr.]

presented by

Dale Robert Mutch

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James J. Kells
Major professor

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DETECTION, INFLUENCE AND ECONOMICS OF ANNUAL GRASS INTERFERENCE ON SOYBEAN [GLYCINE MAX (L.) Merr.]

By

Dale Robert Mutch

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ABSTRACT

DETECTION, INFLUENCE, AND ECONOMICS OF ANNUAL GRASS INTERFERENCE ON SOYBEAN [*GLYCINE MAX* (L.) Merr.]

By

Dale Robert Mutch

The development of selective postemergence grass herbicides has enhanced the implementation of Integrated Weed Management systems. A knowledge of the influence of different weed species, their density, and allowable duration in a field, must be known for effective and economical postemergence herbicide applications. An ecological quadrat sampling method provided the most efficient scouting method for prediction of weed infestations requiring postemergence herbicide treatments in row crops.

Giant foxtail (*Setaria faberii* Herm.) and fall panicum (*Panicum dichotomiflorum* Michx.) infestations resulted in significant soybean [*Glycine max* (L.) Merr.] yield reductions. Soil type and moisture influenced the degree of soybean yield loss. Generally, annual grass interference were greater on sandy loam soil as compared to loam soil. On loam soil, dry conditions resulted in greater yield loss, while annual grass interference on sandy loam soil was greater during a high moisture season. In 1983 at annual grass weed densities of 14, 28, 56 plants/M^2 as well as the natural population of weed reduced soybean yield as percent of weed free control 52, 51, 51, and 51% on sandy loam

soil high moisture, respectively. At the same weed densities on loam soil with high moisture, soybean yield reductions were 19, 20, 26 and 26% respectively. In 1984 weed densities of 14, 28, 56 and 70 plants/M^2 on sandy loam soil with low moisture, reduced soybean yield 46, 44, 41, and 55%, respectively. At these same weed densities on loam soil with low moisture soybean yield reductions were 34, 54, 38, and 46%, respectively.

Soybean yield response curves were plotted by a non-linear model to predict annual grass interference by density and duration on soybean yield. Based on these yield response curves, tables on a computer spreadsheet were developed which predict net profit or loss from postemergence grass herbicide application at several points during the soybean growing season. Input variables to this procedure include expected yield goal bu/A, soybean price $/A, and herbicide application cost $/A.

DEDICATION TO MY SONS

NICOLAS ABRAM MUTCH

AND

LUCAS AVERY MUTCH

SPECIAL DEDICATION TO

BENJAMIN TORREY MUTCH

UNDERSTANDING

"I'll lend you for a little time a child of mine, He said,
"For you to love the while he lives, and mourn for when he's dead.
It may be six or seven years, or twenty two or three;
But will you, 'til I call him back, take care of him for Me?
He'll bring his charms to gladden you,
And should his stay be brief;
You'll have his lovely memories as solace for your grief.

I cannot promise he will stay, since all from earth return,
But there are lessons taught down there I want this child to learn.
I've looked this wide world over in my search for teachers true,
And from the throngs that crowd life's lanes, I have selected you.
Now, will you give him all your love, nor think the labor vain,
Nor hate Me, when I come to call to take him back again?"

I fancied that I heard them say, "Dear Lord, Thy will be done,
For all the joy Thy child shall bring, the risk of grief we'll run.
We'll shelter him with tenderness, We'll love him while we may,
And for the happiness we've known, forever grateful stay.
But should the Angels call for him much sooner than we planned,
We'll brave the bitter grief that comes, and try to understand."

Written by Edgar Guest

ACKNOWLEDGEMENTS

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INTRODUCTION

"Cursed is the ground for thy sake; in sorrow shalt thou eat of it all the days of thy life; thorns and thistles shall it bring forth to thee; and thou shalt eat the herb of the field" (Genesis III:17-18). Weeds were recorded as early as the biblical times. Hence, the interference from weeds on desirable crops is not a new field of study.

In the 1800's and early 1900's, weeds were managed principally by various non-chemical methods such as crop rotation, cultivation, and hand hoeing. The development of organic herbicides has resulted in a change in weed management strategies. In a report on Michigan pesticide use in soybeans [Glycine max (L.) Merr.] (71), it was reported that in 1978, 96% of the soybean acres were treated with herbicides for weed control as compared to 64% in 1970. In the same report, herbicides were used to control weeds on 67% of the acres of five field crops as compared to 24% and 1.5% for insecticides (insect control) or disease control, respectively. Therefore, herbicides have become an accepted practice in agriculture.

Weed interference with soybean is a complex subject requiring the consideration of numerous variables. For example, weed biology, weed seed production and dormancy, weed competition, selective herbicide availability, and the economic threshold of specific weeds on soybean performance.

The objective of this literature review is to identify previously reported research and desirable future research concerning annual grass interference in soybean.

CHAPTER 1

REVIEW OF LITERATURE

WEED BIOLOGY

Weeds have been grouped according to their similar life cycles. The three major classifications of plants, annuals, biennials, and perennials, are also applicable to weeds. Annuals complete their life cycles in one growing season. Annual weeds which complete their life cycle during spring to fall are referred to as summer annuals. Annual weeds which complete their life cycle during fall to spring are referred to as winter annuals. The majority of problem annual weeds in soybean are summer annuals. Biennial weeds require two growing seasons to complete their life cycle. A rosette is usually formed the first year, and the second year a flower stalk with viable seed is produced followed by death. Perennial weeds live for 3 or more years. Reproduction is commonly by propagation and spread by asexual means. Seed can be produced in all years, however, it is not uncommon for most of the seed to be nonviable, for example, quackgrass [*Agropyron repens* (L.) Beauv.] In contrast, johnsongrass [*Sorghum halpense* (L.) Pers.]seeds remain viable.

The understanding of a weed life cycles can enhance weed control in soybean. Generally, summer annual weeds are predominant in Michigan. Most herbicide usage in Michigan is directed for the control of annual weeds. Biennial weeds are not as common in soybean and therefore, not a major concern in soybeans in Michigan. Perennial weeds are a problem in Michigan soybeans. Furthermore, perennial weeds are difficult to control, due to their mechanisms of reproduction.

WEED SEEDS

The longevity of weed seeds can be influenced by dormancy, depth of burial, or tillage. Harper 1977 (37) concluded that 1) long lived seeds are characteristic of disturbed habitats, 2) most long lived seeds are annuals or biennials, 3) small seeds tend to have much greater longevity than large ones. Beal (7) and Duval (34) established long term burial studies. Both studies concluded that seeds that retained the ability to germinate the longest were from weeds species. Odum (63) found viable seed in common lambsquarters (*Chenopodium album* L.) and corn spurry (*Spergula arvensis* L.) seed dated to be 1700 years old.

The natural decline in weed seeds in buried soil could be by soil pathogens, predation, or desiccation. Radosevich and Holt (68) reported that possibly the best way to handle weed seeds in the soil is to leave them buried in order to maintain dormancy and to allow their eventual death by predation or senescence.

Therefore, increased use of no-tillage systems in soybean could impact weed seed populations in the soil. However, extremely proficient weed control (100%) would be required to prevent the reestablishment of weed seeds in the upper 2.5 cm of the soil surface.

A comparative study was reported by Palmbald (65) where nine weed species were evaluated for seed production per pot as influenced by weed population density. The highest density 200-fold seed input never resulted in even as much as a 2 fold output of seed. It can be concluded from this experiment that plant density-dependent mortality and plasticity together regulate the seed output of a population. Therefore, given the proper conditions, very low populations of weeds have the ability to produce massive quantities of seeds.

It is known that annual weeds are capable of prolific seed production. In 1932, Stevens (80) reported that single plants of green foxtail [*Setaria viridis* (L.) Beauv.] produced 34,000 seeds, barnyardgrass[*Echinochloa crus-galli* (L.) Beauv.] produced between 2,000 to 4,000 seeds (41), 1977, common lambsquarters produced between 13,000-500,000 seeds (41), 1977, and redroot pigweed (*Amaranthus retroflexus* L.) 117,400 seeds (80).

Schweizer and Zimdahl (74) reported in a 6-year continuous corn (*Zea mays* L.) study that annual application of atrazine (2-chloro-4 ethylamino-6-isopropylamino-*s*-triazine) at 1.7 kg/ha resulted in very few weed seeds produced during a 5-year period and no weed seeds produced during a sixth year. In this same study however, 3 years of no atrazine applications resulted in a weed seed reserve in soil of 648 million seeds/ha, half the population of the start but a sufficient reserve to reestablish weed populations.

Roberts (69) and Dunham et al. (32) reported that tillage practices alone failed to reduce the number of weed seeds in soil. Herbicides, tillage, and crop rotations however, could maintain weed seeds in soil at a level of 25 million or less/ha (69).

Robertson (70) reported that the reservoir of seeds in agricultural soils at four locations in Minnesota ranged from 9 to 430 million/ha. Chancellor (19) reported 32 locations in England had reservoir of weed seeds in soil that ranged from 15 to 237 million/ha.

Even though weed seed production can be managed, the weed seed pool in the soil remains (68). Weeds have many mechanisms of dispersal. Under natural field situations, weeds are disseminated by wind, water (flooding), animals, and humans (machinery). Therefore, it has become difficult for the vast majority of farm land to eliminate their weed seed pool in the soil with traditional herbicide applications.

Dormancy of weed seeds is well documented, however, the mechanisms of dormancy are not well understood. Certainly, a complete understanding of these specific dormancy mechanisms would enhance the feasibility of eradication of a weed seed pool.

Weed seed reserves in agricultural soils are well documented. Additionally, these reserves are extremely difficult to eradicate. The accurate identification of weed species in combination with weed interference research data could enhance the growers ability to make economic weed control decisions without increasing their seed reserve in the soil.

WEED COMPETITION/INTERFERENCE

Weeds have been recognized as a pest in cultivated crops since ancient times. Some early observations of weed competition were reported by Decandolle (28) in 1832. He reported crop rotation decisions were based on the current planted crop not being inhibited by toxic substances left by the preceding crop. Today, in weed science this phenomenon would be evaluated for the potential of allelopathic toxins. Brenchley (13) in 1920 reported that specific weed species could be associated with certain cultivated crops, while other weed species were common to all cultivated crops. She concluded that weeds compete with crops mainly in three ways, above ground for light, and below ground for nutrients and moisture.

Putnam reported (67) weed competition (allelospoly) can be defined as the depletion of one or more limiting resources such as light, nutrients or water. Allelopathy is defined as the production of chemicals by living or decaying plant tissue which interferes with the growth of a neighboring plant. Allelomediation (indirect sources) is defined as effects of physical or biological environment that interfere with growth of a neighboring plant. Interference is a term which combines all these mechanisms and can be defined as the effect the presence of a plant has on the environment of its neighbor plant. This effect can be positive (additive) or negative (subtractive) and sometimes neutral (no effect) (67).

Competitive Interference (Allelospoly) surveys conducted in 1971 indicated that the average United States soybean yield in 28 states was reduced by 12% due to weed interference (3). A more recent survey in 1984 indicates the soybean yield in the Lake States was reduced annually by 14% (20). It was concluded from these studies that known weed densities left in the field throughout the growing season will reduce soybean yield by a predictable amount.

Soybean Density and Row Widths. It has been determined that both soybean plant population, and the width of soybean row influences weed interference. When soybean stands were less than 30 to 49 plants/M or row, soybean yield reductions were increased (81). Yield reductions were ten-fold when soybean plant populations were reduced from 30 to 49 plants/M of row to 10 plants/M of row (81). Soybeans planted in narrower row spacing than 102 cm resulted in increased yield from mixed annual grass and broadleaf weed populations due to increased early shading by the crop (17). Burnside concluded this yield response was due to earlier shading, more optimal distribution of plants and greater efficiency in use of light, nutrients, and moisture. Yield increases were reported from 76, 51, 25 cm wide rows of 10, 18, and 20% as compared to 102 cm row widths (80). Weeds emerged for 7 weeks for 40 inch(102 cm) row as compared to 6 weeks for 20 inch(51 cm) row spacing (18). Soybean yield was less for

40 inch(102 cm) row spacing while weed seed yields were increased as compared to 20 inch(51 cm) rows(18).

Several researchers have reported differences in soybean cultivar competitiveness to weeds (14, 15, 40, 58, 59). In contrast, Staniforth (77) reported four cultivars with different maturity dates, all demonstrated equivalent responses to annual weed competition. Hinson and Hanson (40) reported the primary factor involved in the soybeans competitive ability was the photoperiodic response.

Annual Grass Density on Interference to Soybean. Knake and Slife reported on several studies conducted in Illinois on giant foxtail (*Setaria faberi* Herrm.) (50, 51, 52, 53, 54). They reported giant foxtail densities 54, 12, and 6 plants/ft. (30.5 cm) of row decreased soybean yield 28, 18, and 10% respectively. They concluded giant foxtail interference resulted in fewer pods per soybean plant with little effect on beans/pod or bean size. Staniforth and Weber (79) reported yellow foxtail [*Setaria viridis* (L.) Beauv.] at densities of 6 and 12 plants per foot of soybean row reduced soybean yield 3 and 11% respectively when left in the field all season. They reported weeds delayed maturity about 1 day, decreased height about 2 inches (5 cm) and increased lodging of soybeans 2 to 6%. Staniforth (78) evaluated three foxtail weeds for their interference on soybean. He concluded giant foxtail was more competitive than either yellow foxtail or green foxtail due to more vigorous growth and increased dry matter production.

Annual Grass Duration on Interference to Soybean. Knake and Slife (51, 52) studied the effect of giant foxtail seeded the same day as the soybean, 3, 6, 9, 12 weeks later compared to a weed-free control on soybean yield. The average giant foxtail plant density was 45 plants/ft (30.5 cm). Soybean yield was reduced only when foxtail seed was planted with soybeans. Staniforth and Weber (79), evaluated yellow foxtail effect on soybean yield when removed at different soybean growth stages. They concluded foxtail infestations prior to soybean stage 5 (nine to ten trifoliolate leaves unrolled) did not cause severe yield reductions. Soybean yield reductions increased when weeds were left in the field to stage 7 (pods plainly evident in tops of plants) of the soybean were greatest from weeds left in the field until stage 9 (top pods almost fully developed with beans approaching "green bean" stage) or soybean maturity. Dawson (26) reported annual weeds which emerged soon after field bean planting caused significant yield reductions in field beans, but those emerging 5 to 7 weeks later had no effect on yield. The duration period before weed interference affecting soybean yield may be related to soil moisture. Hammerton (36) reported giant foxtail interference was greatest when soil moisture was adequate early in the season. Staniforth (76) concluded soybean yield reduction was least from Setaria spp. when soil moisture was a) adequate over the whole season, b) limiting over the whole season, or c) limiting to the end of vegetative growth stage and then adequate to soybean maturity. Young, Wyse, and Jones (83) reported minimum density of quackgrass required to reduce soybean yield is not static, but may be related to soil moisture supply. Zimdahl (84) concluded the greatest soybean yield reductions occurred when water was limiting during the reproductive period, or when total soil moisture was limiting for the whole season.

Allelomediation (indirect sources). Weed densities in the field all season increased soybean harvesting losses from a combine harvester by 3.5% (66). Smooth pigweed,(*Amaranthus hybridus* L.) caused greater soybean harvest loss as compared to giant foxtail (61,62). Harvesting soybean prior to weed desiccation due to frost, increased soybean threshing and separating losses when forward speed increased from 1 to 3 mph (61). The author is unaware of any literature citing an association between insects or diseases with annual grasses which decrease soybean yield.

Allelopathy. Giant foxtail has been reported to have allelopathic potential. Schreiber and Williams (73) reported that decaying roots of giant foxtail greatly inhibited corn root growth. Bell and Koeppe (8) reported that giant foxtail inhibited corn growth 35% by an allelopathic mechanism while a 90% reduction resulted from competition and allelopathy. Bhowmik and Doll (11) supported these data and found aqueous extracts of giant foxtail residues reduced radicle and coleoptile growth of corn. Incorporation of these residues in the soil inhibited seedlings of soybean and corn height and fresh weight.

Fall panicum (*Panicum dichotomiflorum* Michx.) has been reported to have allelopathic potential. Bhowmik and Doll (10) reported water extracts of fall panicum plant residues inhibited growth of soybean hyopcotyl. They also reported that fall panicum plant residues mixed in sand resulted in inhibition of height, growth, and fresh weight of soybean shoots and roots.

Fuerst and Putnam (35) outlined the requirements to prove competitive interference and allelopathic interference. Their steps to prove competitive interference are 1) Identification of the symptoms of interference, 2) Demonstration that the presence of the agent is correlated with reduced utilization of resources by the susceptible weed, 3) Demonstration of which resources depleted by the agent are limiting resources and 4) Simulation of that interference in the absence of the agent by reduction of the supply of resources to levels that occur during interference. They described proof of allelopathic interference as 1) Identification of the symptoms of interference, 2) Isolation, assay, characterization and synthesis of compounds, 3) Simulation of the interference by supplying the toxin as it is supplied in nature and 4) Quantification of the release, movement, and uptake of the toxin. Without these determinations, the researcher must classify the weeds influence on the crop as interference.

Review of the literature indicates annual grass weeds can reduce soybean yield. The literature reports giant foxtail competition against soybean to be ordinarily caused by limiting water. Allelopathic potential has been reported for giant foxtail and fall panicum to soybean. From the literature reviewed, the term interference appears more appropriate in both cases. As described previously by Fuerst and Putnam, neither competition nor allelopathy were proven.

Methods To Study Interference:

The first method to be discussed is called an additive design. These designs usually involve two species, a crop and a weed which are grown together. Generally, the crop density is held constant while weed densities are varied. Therefore, a bioassay is established to interfere with the crop species. The evaluation is usually determined by crop seed production as compared to weed density. This approach is used widely because of the relevance to many field situations where one species is established in an area at a fixed density, the area is then "invaded" by the other (68). They reported the value of the additive approach is the ability to determine directly the cost (crop loss) that is associated with the absence of weed control.

A substitutive experiment is a method or replacement series experiment which was introduced by DeWit 1960. The main characteristic of this method is that the proportions of two species I and J in mixture are varied while overall density I and J is maintained constant (37). Four different predictive models have been proposed of these interactions by Harper (37). Harper proposed a relative crowding coefficient (RCC) when yield in mixtures can be determined:

$$\text{Relative Crowding Coefficient of A with respect to B} = \frac{\text{Mean yield per plant A in the mixture}}{\text{Mean yield per plant B in the mixture}} - \frac{\text{Mean yield per plant of A in pure stand}}{\text{Mean yield per plant of B in pure stand}}$$

and a Relative Yield (RY) when combined yield cannot be predicted:

$$\text{RY} = \frac{\text{Yield of A in mixture}}{\text{Yield of A in pure stand}}$$

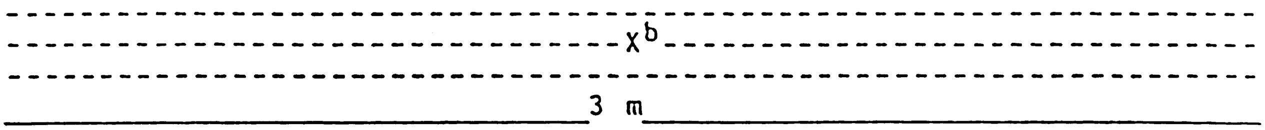
A large RCC value indicates a high degree of aggressiveness of one species relative to the other. Calculation of both species (RY) added together give the relative yield total (RYT). RYT values of about 1.0 indicates that the same resource is being utilized by both species. RYT values less than 1.0 imply mutual antagonism and greater than 1.0 imply species avoid competition, make different demands on resources or maintain a symbiotic relationship (36). Radosevich and Holt reported the substitutive method may create a more accurate assessment of competitiveness than the additive method. However, the series appears ideally suited for greenhouse studies, but artificial under field conditions.

The systematic design method concept was introduced by Nelder. His designs evaluated single species interference, and consist of a grid of points with each point representing the position of the plant. Bleasdale modified Nelder designs for row crop interference evaluation. Two designs can be used, a "fan" design and "parallel row" design (68). Huxley and Maingu (42) utilized a systematic design for evaluation of intercropping systems. The systematic design shows promise for interference studies however, establishment of the experiment may be time consuming and difficult.

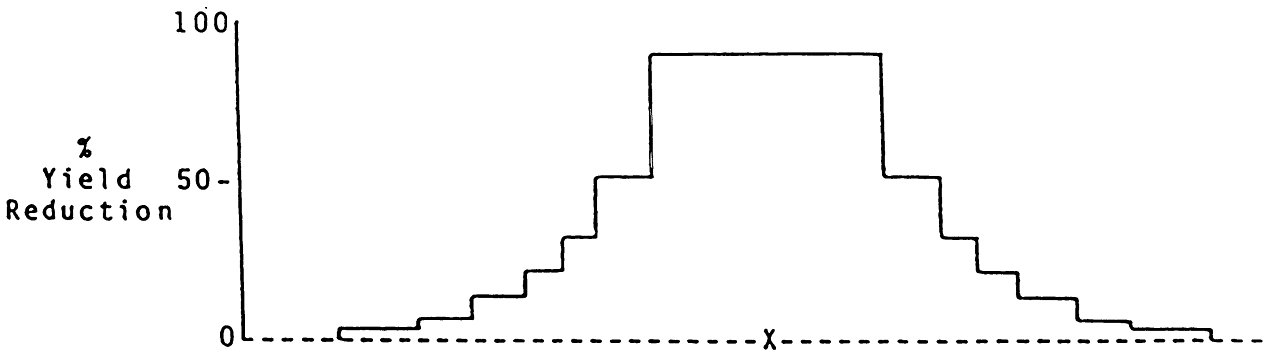
Coble (24) at North Carolina State University has developed a new approach to studying weed interference called the sphere of influence. This method evaluates the influence of a single weed species on neighboring soybean plants. Soybeans are planted in non-weed 3-M^2 plots and thinned to create a uniform stand. Weed seeds are planted or weed transplants are placed in the middle of the row in between the soybean plants. It is essential that the weed plant emerges prior to or at the same time as the soybean plant. Each 3 M^2 plot is replicated 10 times. Individual soybean plants in the plot are measured for yield. Therefore, the influence of the single weed species in the soybean row can be evaluated for its direct effect on its neighboring soybean plants. This effect is measured for distance from the weed within the soybean row and the weeds effect on neighboring soybean rows (Figure 1). A sphere of weed influence can then be established for a single weed on soybean yield (Figure 2). A single weed will have greater influence on its direct neighbor, and therefore have a decreasing effect on the soybean plants in the row as distance from the weed species increases, and in neighboring rows. When the sphere of the individual weed species is known, a competitive index of that weed species can be calculated and compared to other weed species. The advantages of this method are a) minimal space is required, b) the experiment can be replicated several times, c) the experiment can be conducted with current field equipment, and d) several weed species can be evaluated in the same experiment. Some disadvantages may be a) prevention from other weed interference is essential and b) the experiment is time consuming and labor intensive.

Figure 1. Experimental plot where weed species was established in the center of the row in uniform soybean stand.

Figure 2. The sphere of influence of a single weed species on neighboring soybean plants.



a = uniform soybean stand established
b = weed species placed in the center of soybean row



SCOUTING FOR WEEDS

In Michigan and throughout the United States, Integrated Pest Management (IPM)/Crop Pest Management (CPM) programs evolved around insect pest scouting after crop emergence. Hence, much research was initiated addressing insect sampling, population, and life cycles of insects in crop production. Michigan State University (MSU) pioneered much of this research and hired pest scouts who monitored pests (diseases, insects, weeds and nematodes) in the six regions of the state. In 1981, the MSU IPM program reorganized and developed Extension program leader positions to intensify scouting efforts in field crops, forestry, fruit, and vegetable. Since 1981, scouted field crop acreage has increased seven-fold and approximately 70,000 acres were monitored in 1985. The MSU Cooperative Extension Service Field Crop IPM program utilizes a computerized data base management system known as Cooperative Crop Monitoring System (CCMS) to summarize pest and crop information collected by scouts. Weeds are the number one pests in field crops, representing approximately 80% of the recorded observations by the scouts.

The availability of postemergence herbicides and cultivation in row crops, has increased the importance of early weed detection in field crops. For this reason, many IPM/CPM programs have introduced weed monitoring to their list of pests. Montana State University has developed a sampling method for wild oat (<u>Avena fatua</u> L.) in which they use a M-pattern and 20 samples

(4). The University of Kentucky scouts monitor a 30 foot strip in a marked 75 foot spot in the field in 5 locations of a 50 acre field (39). These same 75 foot strips are monitored throughout the season. The University of Illinois (9) reports accurate and thorough coverage of a field for weed scouting, without mention of a specific sampling procedure. The University of Missouri utilizes 5 samples for 60 acres or less for the weed scouting methods (29). Purdue University (46) reports observations should be made, preferably, at five locations in the field to provide a representative sample of the vegetation. In North Carolina, Coble (23) reports weed monitoring should occur 14 to 17 days after the soybean planting date, with one representative sample of the weed species and their density recorded from a 30 cm band over a 10 step sampling area and repeated every 2 ha of the soybean field.

Sampling methods for weeds vary and no clear cut information has been available to identify the best method of weed monitoring. However, weed scientists have reported (23, 60) that more samples, greater than 5 (the commonly used insect sample size) is needed to monitor weeds.

Previously, the weed mapping discussed was for enhancement of early current season grower weed control decisions. Most IPM/CPM programs additionally provide late season weed maps. These maps highlight weed escapes and assist growers on evaluation of their herbicide program. A specific sampling procedure for this map does not appear to be as critical since it is an accumulation of seasonal scouting efforts.

POSTEMERGENCE HERBICIDES IN SOYBEAN

Acifluorfen (sodium 5-(2-chloro-4-(trifluoromethyl)-phenoxy)-2-nitrobenzoate), and bentazon (3-isopropyl-1H-2,1,3-dioxide) are commercially available to selectively control broadleaved weeds in soybean (48). Fomesafen (5-(2-chloro-4-(trifluoromethyl) phenoxy)-N-(methylsulfonyl)-2-nitrobenzamide), is a selective broadleaved herbicide in soybean expected to be available in 1986 or 1987 (43). Many selective postemergence grass herbicides are available in soybean. Diclofop-methyl(methyl 2-(4-(2,4-dichlorophenoxy) phenoxy) propanoate, a restricted use pesticide (1), fluazifop-P-butyl(R)-2(4-((5-(trifluoro-methyl)-2-pyridinyl) oxy) phenoxy) propanoate (14), and sethoxydim 2-(1-(ethoxyimino) butyl)-5-(2-(ethylthio) propyl)-3-hydroxy-2-cyclohexen-1-one (6) have been available to soybean growers since 1983. New selective grass postemergence herbicides which may become available for use in soybean in the future are DPX-Y6202 2-(4((6-chloro-2-quinoxalinyl) oxy) phenoxy) propionic acid, ethyl ester (33), and haloxyfop-methyl, methyl 2-(4-((3-chloro-5-(trifluoromethyl)-2-pyridinyl) oxy) phenoxy) propanoate (31).

Oliver et al. (64) compared several postemergence herbicides for control of annual grasses in soybean. They reported the order of phytotoxicity was haloxyfop-methyl, sethoxydim, fluazifop-butyl. Sethoxydim efficacy on 25 cm giant foxtail was reported excellent by Lueshchen (57). Different tillage systems were evaluated for total postemergence weed control by Kinsella and Burdick (49). They reported sethoxydim provided an advantage in grass species, giant foxtail, barnyardgrass, and volunteer corn control over alachlor (2-chloro-2',6'-diethyl-N-(methoxymethyl) acetanilide (2-chloro-N-(2,6-diethylphenyl)-N-methoxy-methyl acetamide) in no-till and conservation tillage or trifluralin α,α,α,-trifluoro-2,6-dinitro-N-N-dipropyl-*p*-toluidine in conventional tillage soybeans. Harvey and Fawcett (38) reported phytotoxicity of sethoxydim, haloxyfop-methyl, fluazifop-butyl to wild prosso millet (*Panicum milaceum* L.) was greater when plants were 20 to 30 cm tall than 8 to 13 cm tall. Chaney and Kapusta (21) reported variation in the height of giant foxtail between locations greatly affected the control afforded by fluazifop-butyl, however, sethoxydim control was unaffected by weed height. The results presented have only touched a small proportion of data available on these new selective grass herbicides. Generally, haloxyfop-methyl and DPX-Y6202 have been reported to be the most effective new herbicides. Sethoxydim has provided greater annual grass control to taller weeds than fluzaifop-butyl. The first selective grass herbicide, dichlofop-methyl, is primarily used for wild oat control in the North Central region because of lack of activity on perennial grasses, such as quackgrass.

ECONOMIC THRESHOLDS IN SOYBEANS

Knake (55) reported that unlike insects, diseases and nematodes, weeds will occur in cultivated row crops every year at population threshold levels that will cause severe crop losses unless controlled. Chandler et al. (20) reported annual losses due to weeds in soybean in the Lake States (Minnesota, Wisconsin and Michigan) to be 142 million dollars. Shaw (75) reports more than 1800 weed species cause serious economic losses and each year, 10 to 50 different species of weeds infest each of our major food crops. Knake (55) reported, because there are many kinds of weeds with varying periods of germination and with highly divergent life cycles, they obviously cannot be managed by a single method. Therefore, weed scientists have initiated Integrated Weed Management System (IWMS). Shaw (75) reports an IWMS approach utilizes cultural, mechanical, biological, ecological and chemical methods in a directed agroecosystem approach. Blair and Parochetti (12) reported the use of widespread, weed-science IPM strategies require establishment of damage thresholds for weeds in various cropping situations.

The development of selective postemergence herbicides in soybean has enhanced the success of the IWMS and the economic threshold concept in soybean. Application of these compounds, integrated with improved weed scouting methods and weed interference data, give growers alternate weed management strategies.

Increased grower awareness for the total system and IPM was reported in a recent article in Agrichemical Age (47). Iowa estimates 10-15% of its field crop base, Nebraska 10% Wisconsin 8%, Indiana 7% and Illinois 5% of field crop land are scouted by formal pest management programs (47). Michigan field crop acreage scouted still remains less than 1% (56). Anderson (2) reports IPM is a very key idea in most states because of the economic crunch in agriculture.

A symposium on Economic Thresholds of Weeds was conducted at the Weed Science Society of America national meeting in 1985. Schreiber (72) reported environmental conditions such as temperature and moisture can significantly alter threshold levels by influencing crop and weed growth. He also concluded the economics of maintaining zero weed levels in the field is questionable in todays agriculture systems.

Dawson (27) reported the concept of period thresholds. He reported lack of any weed control practice would result in annual weed "saturating populations" in almost all fields where annual crops are grown in North America in the 1980's. The "saturating population" of an annual weed can be defined as the numerical weed density that causes harmful effects to crop plants. In most row crop situations, weeds can grow with the crop for a certain period of time before yield loss occurs. Therefore, a period threshold for postemergence weed control exists for many weed species. Dawson (27) reported this to be at 5 weeks. Weeds that damage crops before or soon after emergence have a zero period threshold and must be controlled immediately. Fields which remain weed-free for an extended period of time after crop emergence can tolerate late weed emergence with no weed interference. Dawson reports this period threshold to be 10 weeks after crop emergence. He concluded a critical period for weed removal therefore, to be between 5 weeks and 10 weeks after crop emergence. A period concept could be different for different weed species and crop grown. The period threshold concept therefore, given sufficient weed interference data could be utilized for postemergence herbicide applications on soybean.

Researchers have utilized interference data to determine the economics of herbicide applications. Coble (22) reported a competitive index (CI) for 34 weed species. Each species is given a competitive value from 0 to 10 where 10 represents the highest interference to soybean. $CI = b_1/b \times 10$ where CI is the competitive index value for the species in question, b_1 is the slope of the linear regression line for the species, b is the slope for common cocklebur (_Xanthium pensylvanicum_ Wallr.) (North Carolina's most interfering weed species in soybean) and the multiplier converts the index to a 0 to 10 scale. Through monitoring the field, a competitive load (CL) can be determined. The CL is the average number of species per 10 meter of soybean row. By totaling the CL for each species, a total competitive load (TCL) can be determined for the weed species in the field (23). Each TCL accounts for 0.5% yield loss and the economics for postemergence herbicide application can be determined.

Researchers at the University of Illinois have determined the effects of five weed species in soybean (5). They reported predetermined yield reductions based on the densities of 2 annual grasses and 3 annual broadleaf species in a field to calculate the economics from postemergence herbicide applications. Mutch et al. (60) reported an equation to predict economic return from postemergence herbicide application for annual grass control in soybean. They reported Economic return = (yield with treatment) - (yield without treatment) x (soybean price) - herbicide cost). This process could be applied to any weed species or mixed population where adequate weed interference data exists. Unlike other predictive methods, this procedure allows for consideration of the economics of late postemergence herbicide treatments.

Evaluation of weed thresholds are based on certain assumptions (22, 23). Coble reports 1) weed and soybean emerge at the same time, 2) no intraspecific competition among weed present, 3) soybean are grown in 76 cm rows, 4) weather is normal for crop growth. Mutch et al. (60), add potential harvesting losses from remaining vegetation and weed seed production on subsequent crops, as additional limitations.

Weed interference data still needs to be collected (22, 23, 60). Weed scientists have initiated methods to implement weed thresholds into pest management programs (5, 22, 23, 60). Proper sampling by scouts can provide growers with the economics of postemergence herbicide applications.

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CHAPTER 2

A COMPARATIVE ANALYSIS OF THREE WEED SAMPLING METHODS FOR ROW CROPS

ABSTRACT

Three unique weed monitoring methods were compared in 1984 in a 20 hectare irrigated, reduced-till corn (*Zea mays* L.) field at the Kellogg Biological Station in southwest Michigan, for evaluation of the field distributions of velvet leaf (*Abutilon theophrasti* medic.) and hemp dogbane (*Apocynum cannabinum* L.). The monitoring methods were compared for accuracy and efficiency, and consisted of: 1) walking through the field in an "M-pattern" (quick survey); 2) quadrat sampling (ecological survey); and 3) walking every fifth row (management survey). The quadrat sampling method was given the highest efficiency rating. The five-row sampling method was the most accurate, however, extremely labor intensive. The M-pattern required the lowest total labor, however, provided insufficient information on weed distribution, and therefore, was given a low efficiency rating.

INTRODUCTION

Weed sampling or the early detection of weeds in row crops such as corn or soybean [Glycine max (L.) Merr.] provides a cornerstone for postemergence weed management in Integrated Pest Management (IPM)/Crop Pest Management (CPM) programs. These programs train scouts to help growers maximize profits by monitoring the growers fields and alerting him to potential pests (weed, insect, nematode, disease and crop physiological disorders) outbreaks. The pest information is used by the grower to enhance timely pesticide applications or to prevent unnecessary treatments.

Initially, IPM/CPM programs evolved around insect pest scouting after crop emergence. With the availability of post emergence herbicides and cultivation in row crops, the benefits of early weed detection became apparent. For this reason, many IPM/CPM field crop programs have introduced weed monitoring to their lists of pests scouted.

Sampling methods vary and no clear cut information has been available to identify the best method of weed monitoring. Montana State University reported a sampling method for wild oat (Avena fatua L.) in which they use a M-pattern with 20 samples (1). The University of Kentucky monitors a 30 foot strip in a marked 75 foot row in 5 different field locations for a 50 acre field (5). These same 75 foot areas are monitored throughout the season. The University of Missouri and Purdue University take 5 weed samples for 60 acres or less (4, 2).

The objectives of this research were to a) evaluate the M-pattern for post emergence weed control decisions, b) to compare the M-pattern sampling method with two other weed sampling methods and c) to determine which sampling method is the most cost effective for labor and accuracy.

MATERIALS & METHODS

General Site Description. Field studies were conducted in 1984 in a 20 hectare irrigated corn field at the Kellogg Biological Station (KBS) in Hickory Corners, Michigan. The site is characterized by a Kalamazoo sandy loam soil type with gentle slopes and has been chisel plowed (reduced-tilled) for five consecutive years.

On May 3, 1984, Great Lakes field corn varieties 542 and 547 were planted at approximately 23,000 plants/acre. A three way herbicide tank mix of alachlor (2-chloro-2',6'-diethyl-N-(methoxy-methyl) acetanilide (2-chloro-N-(2',6'-diethylphenyl)-N-methoxymethylacetamide) at 3.36 kg/ha, plus atrazine (2-chloro-4-(ethylamino)-6-(isopropylamino)-s-triazine) at 1.12 kg/ha, plus cyanazine (2-((4-chloro-6-(ethylamino)-5-triazin-2-yl)amino)-2-methylpropionitrile (2-chloro-4-(1-cyano-1-methylethylamino)-6-ethylamino-5-triazine) at 1.12 kg/ha was applied preemergence on May 4.

Three weed infestation sampling methods were evaluated in corn. This research focused on velvetleaf (<u>Abutilon theophrasti</u> Medic.), hemp dogbane (<u>Apocynum cannabinum</u> L.) and quackgrass [<u>Agropyron repens</u> (L.) Beauv.] .

<u>Weed Infestation Assessment Studies</u>. The M-pattern sampling method allows for 5 samples taken in the 20 hectare field (figure 1). The method has traditionally been used for insect scouting. On June 7, the density and distribution of weeds was determined by quickly walking the site and recording sections of the field that were densely populated with weed species. These weeds were recorded on a field map.

The quadrat method (ecological survey) allows for 20 samples per 20 hectares taken at random (figure 2). On July 7, the weed population was surveyed with a random quadrat technique to determine weed dominance. A stick was thrown into the field, landing at point 1. Beginning at point 1, all weeds in 10 meters of row, and 38 cm to either side of the row were recorded. This procedure was repeated at twenty random points in the field. Relative density (RD), relative frequency (RF), and prominence values (PV) of velvetleaf, hemp dogbane, and quackgrass were determined (table 1). RD, RF, and PV were determined in reference to Cox (3), where

$$RD = \frac{\text{density of a species}}{\text{total density for all species}} \times 100$$

$$RF = \frac{\text{frequency of a species}}{\text{sum frequencies all species}} \times 100$$

and the PV = RD + RF.

Figure 1. M-pattern sampling method.

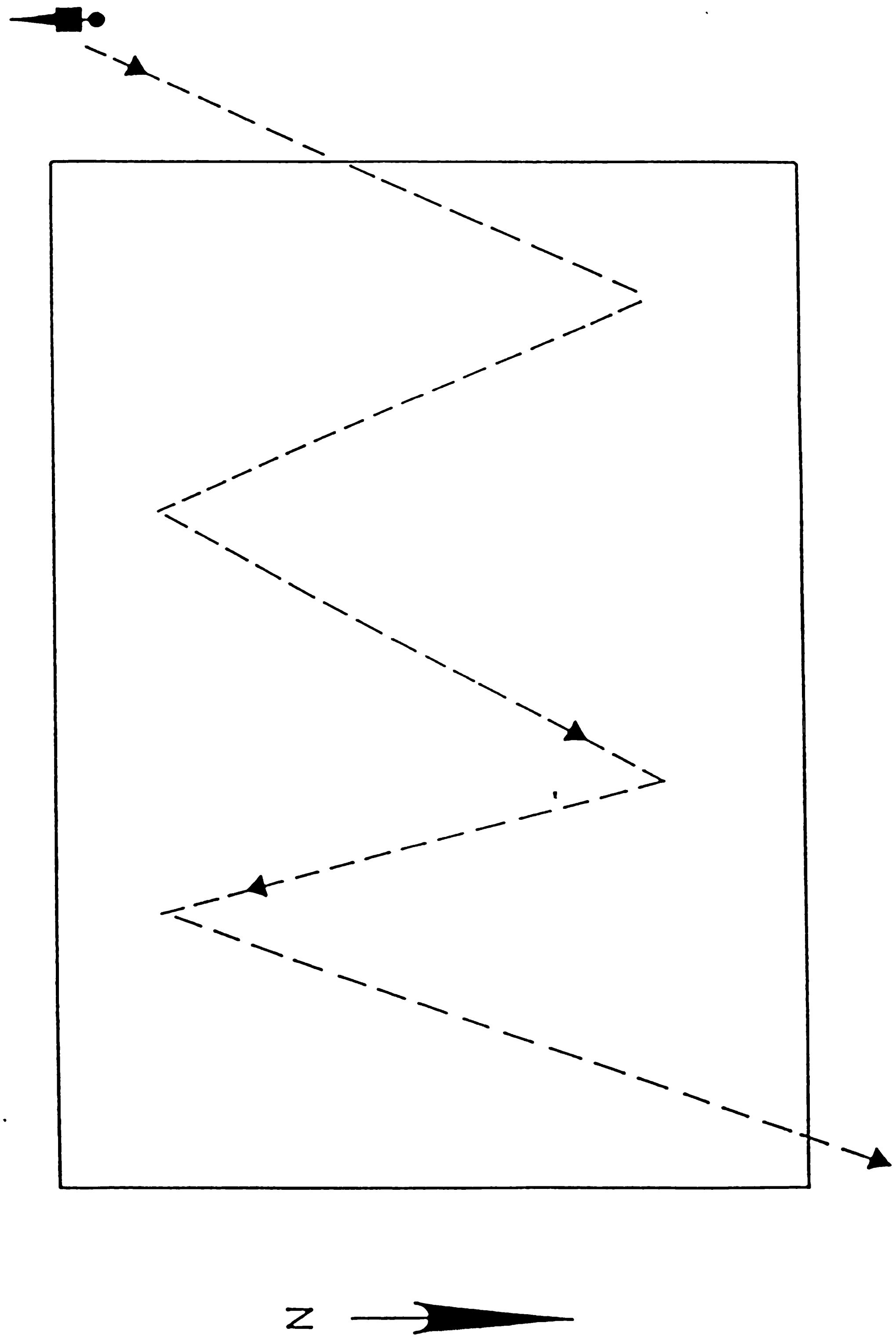

Figure 2. Quadrat sampling method.

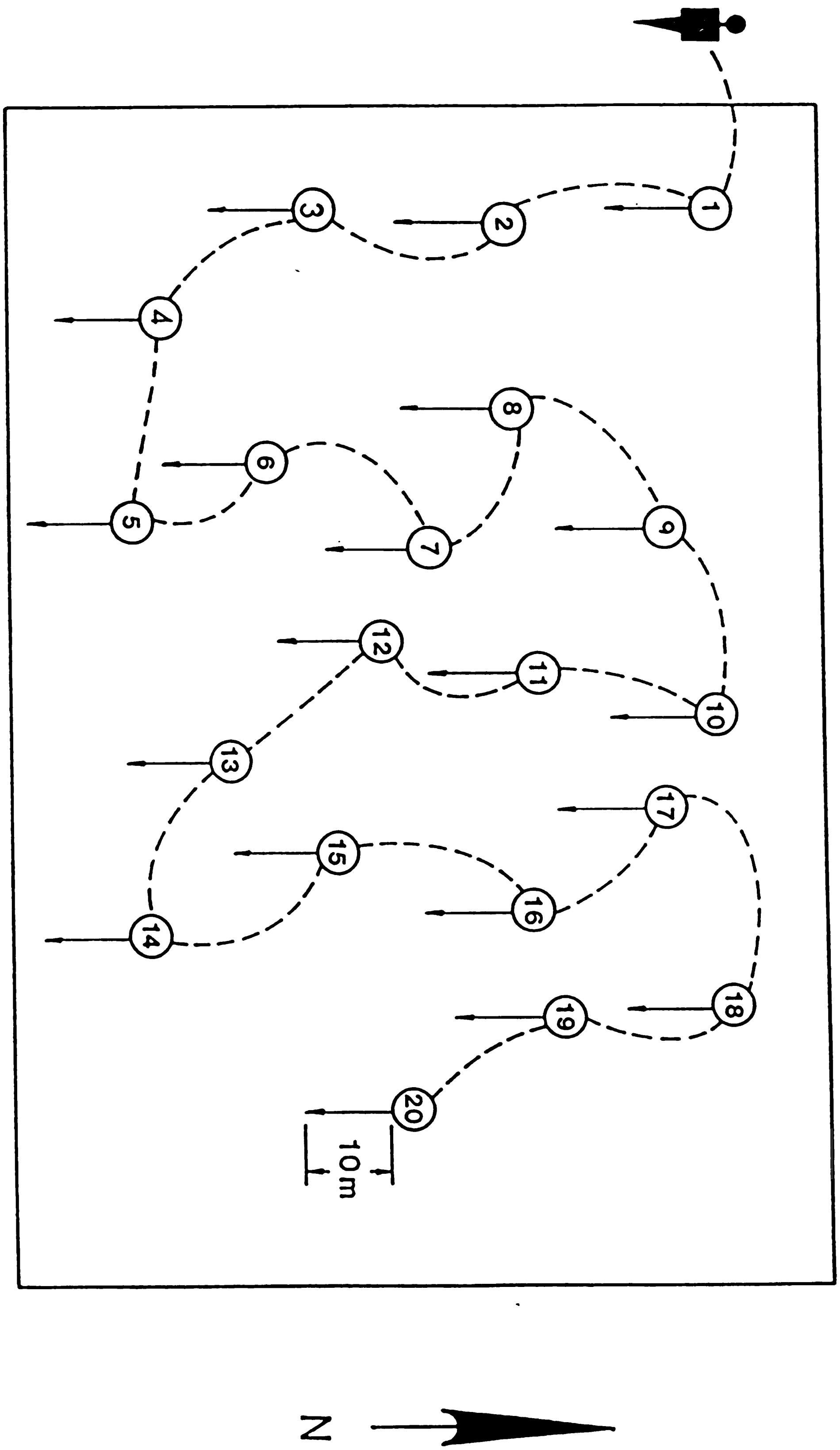
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Table 1. Relative weed abundance as determined by Quadrat sampling method[a].

	Relative Value/m^2		
Species	Density[b]	Frequency[c]	Prominence Value[d]
Velvetleaf	52.8	42.3	95.1
Hemp dogbane	25.7	38.5	64.2
Quackgrass	21.5	19.2	40.7

[a]Cox, G.W. 1976. Laboratory Manual of General Ecology, pp. 32-37. Wm. C. Brown Co., Dubuque, Iowa. 343 pages.

[b]Relative Density = $\frac{\text{density of a species}}{\text{total density for all species}} \times 100$

[c]Relative Frequency = $\frac{\text{frequency of a species}}{\text{sum frequency all species}} \times 100$

[d]Prominence Value = relative density + relative frequency

The five row method allows for every fifth row of the 20.23 hectare field to be monitored for weeds (figure 3). On July 18-20, a detailed weed map of the field was conducted. For this method, the scout walked every fifth row of corn and weed populations were summarized at 100-pace intervals (approximately 91 meters for the length of the field). Each weed species was given a population density rating of zero, low (1-5 plants/100 paces), medium (5-10), or high (>10). The summary of these weed levels were entered into a computer and contour weed maps of velvetleaf and hemp dogbane were generated for the field.

RESULTS AND DISCUSSION

M-Pattern. The M-pattern sampling method provided a very general weed infestation assessment (figure 4). This method is the least accurate of all methods evaluated, as no attempt was made to quantitatively evaluate weed densities or their location in the field.

This method was originally developed for IPM/CPM insect scouting. Unlike insects, however, non-transient weeds have definitive boundaries which can be treated as unique sites within a larger field. This method took one scout approximately 2 hours of field time and 1 hour office time at an approximate cost of $18.00 (Table 2). The M-pattern provided insufficient data for effective post emergence weed control decisions. Weed distributions were only recorded at the five sample sites with incomplete field representation.

Figure 3. Five row sampling method.

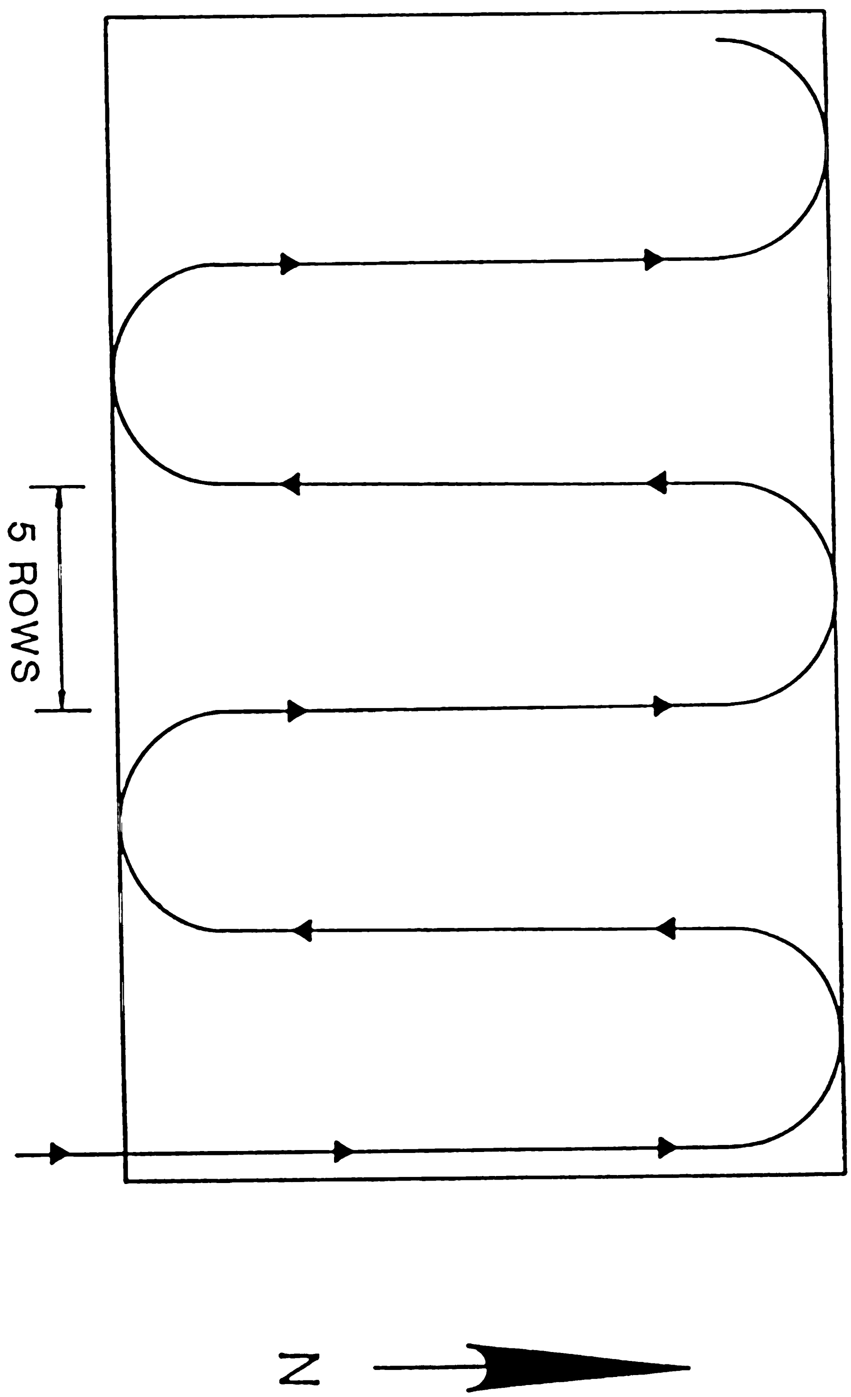

5 ROWS
N

Figure 4. Distributions of velvetleaf and hemp dogbane when sampling the field with a M-pattern.

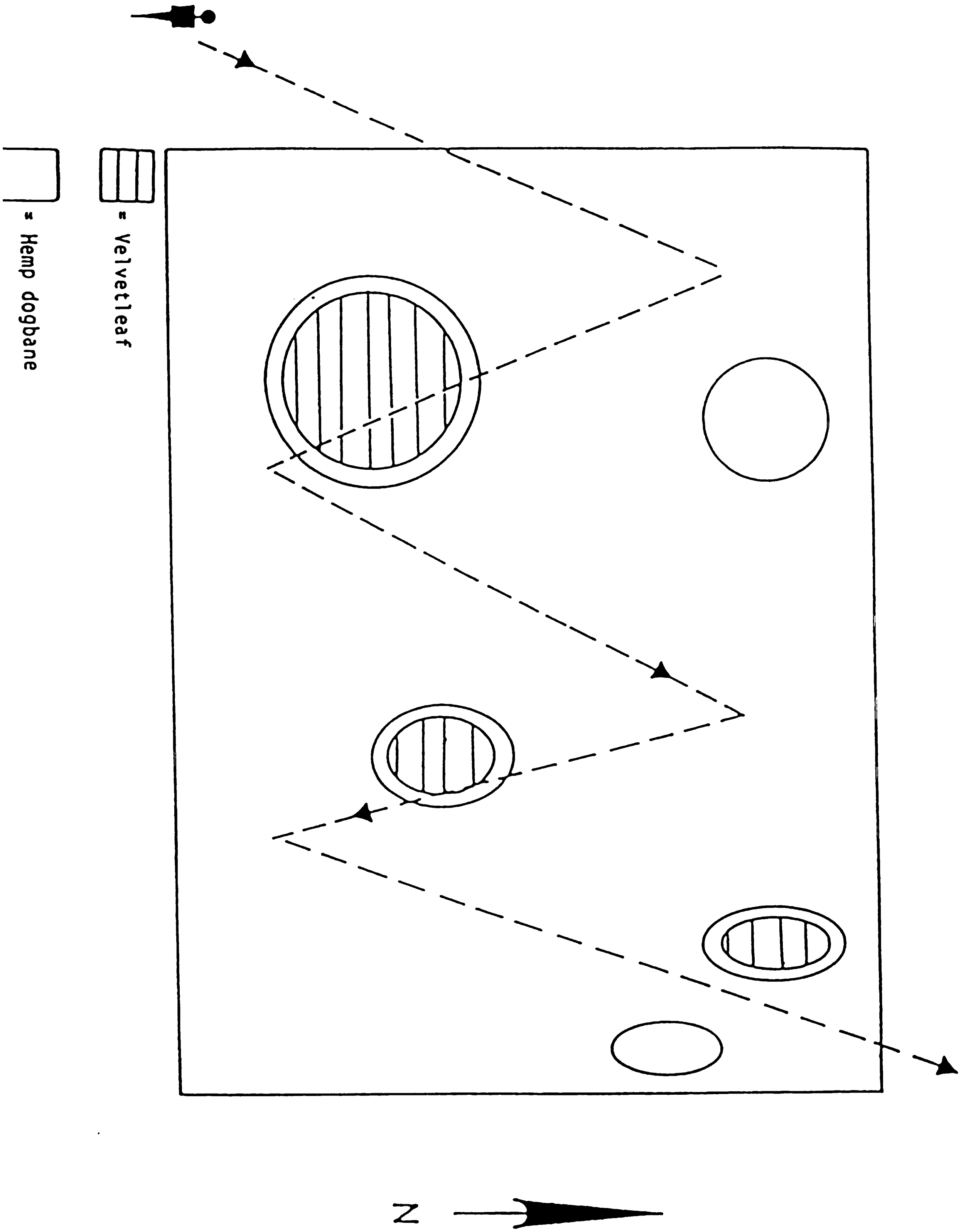

= Velvetleaf
= Hemp dogbane
N

Table 2. Comparison of time, cost, and efficiency of three weed infestation sampling methods.

Sampling Method	Total[a] Labor	Field[b] Cost	Usefulness[c] Rating	Efficiency[d] Rating
	(hours)	($)	(0 to 10)	(%)
M-pattern	3	18	1	33
Quadrat	8	48	5	62
Five-Row	38	228	10	26

[a]Total Labor = Field time plus office time

[b]Field Cost = Based on $6.00/hour labor

[c]Usefulness Rating = 0=none 10=extremely useful

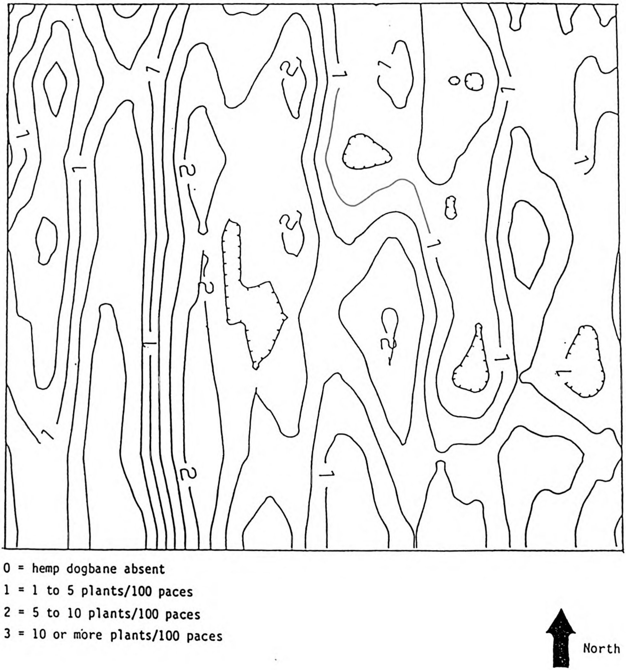
[d]Efficiency Rating = $\frac{\text{usefulness rating}}{\text{total labor}} \times 100$

Quadrat Method. Results from the random quadrat method indicated that velvetleaf PV=95.1 was the most abundant weed present at the site (table 1). Prominence Values for hemp dogbane and quackgrass were 64.2 and 40.7, respectively. Other weed species were found only infrequently.

This method took one person approximately 4 hours of field work and 4 hours of office time, at an approximate cost of $48.00 (table 2). The sampling method provided a rating of relative weed abundance, but not a rating of yield interference. The Prominence Values do not include factors for species-specific propagation potential and subsequent yield interference. The PV of velvetleaf does not include its seed production potential nor its ability to compete with the corn crop. Increased interference research with weeds, therefore, would enhance the usefulness of the Prominence Value as a decision making tool for weed control. Coble (2) reported competitive index values for 34 weed species for soybean in North Carolina. A competitive index value for weed species could be integrated into the quadrat sampling method to predict weed distribution and potential yield losses. More competitive weeds like velvetleaf may only require PV of 70 where less competitive weeds like yellow foxtail [*Seteria lutescens* (Weigel) Hubb.] may require PV of 95 before weed control strategies need to be implemented.

Five-Row Method. Results from the five-row intensive survey indicated that hemp dogbane was present in approximately 80% of the field (figure 5). Velvetleaf was scattered throughout the field in a uniform pattern (figure 6).

Figure 5. Contour map of hemp dogbane abundance, using the 5-row weed sampling method.



0 = hemp dogbane absent

1 = 1 to 5 plants/100 paces

2 = 5 to 10 plants/100 paces

3 = 10 or more plants/100 paces

An accurate detailed map of weed distributions was provided by this method. This method could identify and locate weed populations in rows or sections of a field requiring post emergence weed control. The disadvantage of the five-row method however, is the increased amount of labor required. This method took approximately 30 hours of field time plus 8 hours of office time at an approximate cost of $228.00 (table 2).

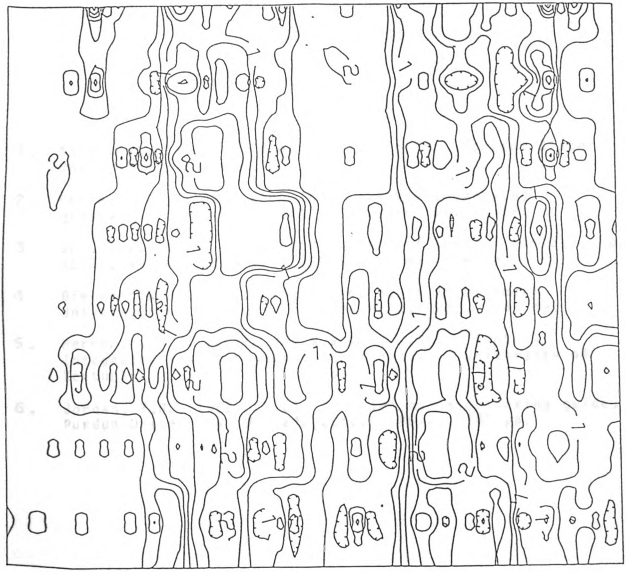
CONCLUSIONS

The M-Pattern sampling method did not provide sufficient information for grower implementation of post emergence weed control. Inconclusive weed information can result by utilizing this sampling method.

The Quadrat Method provided a rating of relative weed abundance. We believe this particular sampling method shows tremendous potential as a tool in making post emergence weed control decisions. The resulting weed map procedure represents total field weed abundance, without excessive labor cost increase. This method resulted in our highest efficiency rating, 62% (table 2). Increased weed interference research on row crops could enhance the integration of the Prominence Value of a weed species with potential crop yield loss.

The Five-Row Method quantified and qualified weed distributions. Post emergence weed control decisions can be implemented with this technique. The sampling method, however, is impractical due to its excessive labor costs.

Figure 6. Contour map of velvetleaf abundance, using the
5-row weed sampling method.



0 = Velvetleaf absent
1 = 1 to 5 plants/100 paces
2 = 5 to 10 plants/100 paces
3 = 10 or more plants/100 paces

North

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CHAPTER 3

THE INFLUENCE OF ANNUAL GRASS INTERFERENCE ON SOYBEAN PERFORMANCE

ABSTRACT

Soybeans [*Glycine max* (L.) Merr.] were grown in 1983 and 1984 on two different soil types with natural infestations of giant foxtail (*Setaria faberii* Herrm.) and fall panicum (*Panicum dichotomiflorum* Michx.). Annual grasses were thinned to densities of 0, 14, 28, 56 plants/M^2 and compared to natural infestations. At each density, grasses were selectively removed by foliar application of 0.22 kg/ha sethoxydim {2- 1-(ethoxyimino) butyl -5- 2-(ethylthio) propyl -3-hydroxy-2-cyclohexene-1-one} at 2, 4, 6, and 8 weeks after grass emergence.

Several soybean plant parameters were measured. Soybean height and pods/plant were generally reduced at all weed densities and were generally predictive of potential soybean yield. Soybean yield was influenced by soil type and soil moisture conditions. During growing seasons with high moisture, soybean yield reduction was less severe on loam texture soils. In 1983 (high moisture), at full season duration, soybean yield reduction was 52, 51, 51, and 51% at weed densities

14, 28, 56 and 515 plants/M^2 respectively. In contrast, in 1983 on loam soil (high moisture), at full season duration, yield reduction was 19, 20, 26, and 26% at weed densities 14, 28, 56 and 491 plants/M^2 respectively. In 1984 (dry season), similarly greater soybean yield reductions resulted on sandy loam soils as compared to loam soils. However, greater yield reductions resulted on loam soils also. In 1984 at full season duration on sandy loam soils, soybean yield reductions were 46, 44, 41, and 55% at weed densities 14, 28, 56 and 70 plants/M^2 respectively. On loam soil, soybean yield reductions at full season duration were 34, 54, 38, and 46% at weed densities 14, 28, 56 and 70 plants/M^2 respectively. These data indicate a relationship between soil type and moisture during the growing season in the influence of annual grass interference on soybean performance.

INTRODUCTION

A survey in 1984, concluded that soybean yield is reduced annually by 14% due to weeds (1). The development of selective postemergence grass herbicides in soybean has enhanced weed management flexibility. The understanding of the economics of postemergence herbicide applications in modern agriculture have become increasingly more important. Weed interference research can assist growers making these economic decisions.

Annual grass interference to soybean has been studied for the effect of weed density and duration. Knake and Slife (5) reported giant foxtail, densities of 54, 12, and 6 plants/ft. of row decreased soybean yield 28, 18, and 10% respectively. Staniforth and Weber (6) reported yellow foxtail, [*Setaria lutescens* (Weigel) Hubb.] densities of 6 and 12 plants per foot of soybean row reduced soybean yield 3 and 11%, respectively, when left in the field all season. Staniforth (8) evaluated three foxtail species for their interference on soybean. He concluded giant foxtail was more competitive than either yellow foxtail or green foxtail, [*Setaria viridis* (L.) Beauv.] due to more vigorous growth and increased dry matter production. Knake and Slife (4) studied the effect of giant foxtail seeded same day, 3, 6, 9, and 12 weeks and compared these durations to a season long weed free control. At an average giant foxtail density of 45 plants/ft soybean yield was reduced only when foxtail seed was planted at the same time with soybeans. Staniforth and Weber (6) evaluated removal of yellow fotail at different soybean growth stages.

They concluded foxtail infestations prior to soybean stage 5 (nine to ten trifoliolate leaves unrolled) did not cause severe yield reductions. Dawson (2) reported annual weeds which emerged soon after planting caused significant yield reductions in field beans, however, those emerging after 5 to 7 weeks has no effect on yield. The duration period in which soybeans can tolerate giant foxtail may be related to the soil moisture. Hammerton (3) reported giant foxtail interference was greatest when soil moisture was adequate early in the season. Staniforth (7) concluded Setaria spp. interference on soybean yield was greatest when soil moisture was a) adequate over the whole season, b) limiting over the whole season, or c) limiting to the end of vegetative growth stage and then adequate to soybean maturity. Young, Wyse, and Jones (9) reported that the minimum density of quackgrass [Agropyron repens (L.) beauv.] required to reduce soybean yield is not static, but may be related to the soil moisture supply. Zimdahl (10) concluded the greatest soybean yield reductions occurred when water was limiting during the reproductive period, or when total soil moisture was limiting for the whole season.

Annual grasses interference on other soybean growth parameters have been reported. Knake and Slife (5) reported giant foxtail interference on soybean resulted in fewer pods/plant with little effect on bean/pod or bean size. Staniforth and Weber (6) reported yellow foxtail delayed maturity about 1 day, decreased height about 2 inches and increased lodging of soybeans 2 to 6%.

Annual grasses are a problem in Michigan soybeans each year. Farmers are often required to make decisions concerning postemergence herbicide applications. Selective grass herbicides allow soybean growers to control annual grasses after soybean emergence. Therefore, research is needed to assist farmers on the timing and need for postemergence annual grass weed control in soybean.

Specific objectives of this research were to determine the influence of annual grass density and duration on soybean yield and growth.

MATERIALS AND METHODS

The effect of annual grass density and duration of interference was evaluated in two field studies at East Lansing, Michigan in 1983 and repeated in 1984. Density and duration studies were established in areas uniformly infested with natural stands of giant foxtail and fall panicum. Experiments were conducted on a Riddles sandy loam soil (Riddles - fine-loamy, mixed, mesic Typic Hapludalfs) with 2.9% organic matter and a Capac loam soil (Capac - fine-loamy, mixed, mesic Aeric Ochraqualfs) with 2.8% organic matter in both and 1983 and 1984.

General Field Procedures. All experimental areas received 3 kg/ha N, 38 kg/ha P_2O_5 and 37 kg/ha K_2O as a banded application at planting. Broadleaf weeds were minimal on all sites and plots were maintained free of broadleaf weeds by hand-weeding and hoeing.

"Corsoy 79" soybeans were planted May 12, 1983 and June 2, 1984 on the riddles sandy loam soil, and on May 17, 1983 and June 4, 1984 on the capac loam soil. Weed emergence was on May 24, 1983 and June 9, 1984 on the sandy loam soil and May 30, 1983 and June 9, 1984 on the clay loam soil. Soybean emergence occurred on the same day as weeds in all cases. All plots were 2.3 M x 9.1 M with approximately 28 plants/M in the row. Each plot contained 3 rows spaced 76 cm apart. The experimental design was a randomized complete block with each annual grass density and duration replicated four times.

Mean monthly precipitation values for the 2 years as compared to the 30 year average are shown in Table 1. In 1983, rainfall was plentiful through the growing season. However, in 1984, above average moisture was only provided in May (10.9 cm), while only 0.5 cm of rain fell in June. Therefore, the 1984 growing season experienced extended periods of below-normal rainfall.

<u>Influence of Annual Grass Density and Duration on Soybean Performance.</u> Annual grasses were hand thinned to densities of 0, 14, 28, and 56 plants/M^2 and compared to the natural infestation. At each established weed density, grasses were selectively removed by foliar application of 0.22 kg/ha sethoxydim plus 2.3 L/ha crop oil concentrate, at 198 L/ha at 276 KPa, at 2, 4, 6 and 8 weeks after grass emergence and compared to full season weed duration. Weed free plots were hand-weeded and hoed weekly.

Prior to harvest, 10 soybean plants/plot were randomly

Table 1. Precipitation at East Lansing

MONTH	1983	1984	30 YEAR AVE.
		(cm)	
APRIL	10.6	4.5	7.3
MAY	11.5	10.9	6.5
JUNE	11.2	0.5	8.9
JULY	6.4	5.2	7.1
AUGUST	6.1	4.2	7.7
TOTAL	45.8	25.3	37.5

selected from the center row of each plot and sampled to determine the influence of annual grass density and duration on soybean growth, soybean population, height, number of pods, and weight of 100 seeds. Data reported are the means of 10 plants/plot with four replications. At maturity, 6.1 M of the middle row of each plot was hand harvested and thrashed with a portable soybean harvester. Soybean yields were adjusted to 13% moisture. All data presented were evaluated by analysis of variance with mean separation using Duncan's multiple range test.

Soybean yield response as influenced by annual grass interference were analyzed and plotted by a commercial non-linear regression software package[a]. This package has 31 standard models to fit the data. Yield data was plotted graphically to determine curve shape. Approximately, five models provided curves to fit the data. After plotting these five models, the equation B(1)/(1. + B(2) * EXP(-(B(3) * X + B(4) * X ** 2))) provided the highest R^2 value and was utilized for all data. The iteration of the data was calculated by the Marquardt method.

RESULTS AND DISCUSSION

All soybean plant parameters on both sandy loam and loam soil were higher in 1983 (high moisture) as compared to 1984 (low moisture). Data presented have been presented by different soil type and year because trends were different for soil types and soybean parameters were significantly lower in

[a]Plot IT. 1985. Computer Resource Services. 4352 Doncaster, Holt, MI 48842.

1984. On sandy loam soil in 1983 annual grass interference resulted in soybean parameter decreases in yield, height, pods/plant and an increase in seed weight (Table 2). Soybean density, on the other hand, was not reduced at all weed densities and duration periods. Seed weight increases were recorded at all weed densities 14, 28, 56, and 515 after 8, 6, 4, 4 weeks duration. The seed weight increase can be explained by the soybean plants having fewer pods/plant and therefore, larger seeds. Soybean height at this site had reductions at weed densities 14, 28, and 56 plants/M^2 at 6 weeks duration of 10, 9, 11% respectively as compared to the hand weed control. Natural weed populations of 515 plants/M^2 resulted in a 17% reduction in height at 4 weeks duration. Pods/plant reduction resulted at weed densities 14, 28, and 56 plants/M^2 at 6 week duration of 22, 18, and 18% respectively. A 16% pods/plant reduction occurred at 515 plants/M^2 at 4 week duration period. Soybean yield was reduced significantly at weed densities 14, 28, and 56 plants/M^2 at 6 week duration which represented a 30, 24, and 27% decrease as compared to the hand weeded control. The greatest and earliest yield reductions resulted from the natural weed population. A 10% yield reduction at 515 plants/M^2 resulted at 2 weeks while full season duration resulted in a 51% yield loss.

In 1983 at the loam soil site and high moisture annual grass interference resulted in less reductions in the soybean parameters measured (Table 3). Similar to the sandy loam site, however, soybean density was unaffected. Seed weight increase resulted at full season weed duration. Yield was reduced at weed

Table 2. Effect of annual grass density and duration on soybean performance, at site I (sandy loam) 1983[a].

Annual Grass Density	Annual Grass Duration	Soybean yield	Soybean density	Soybean height	Pods/ plant	Weight/ 100 seeds
(Plants/M^2)	(wks)	(kg/ha)	(Plants/M)	(cm/plant)	(no.)	(g)
14	0	3263 a	24.3 a	110 a	50 a	16.2 b
	2	3270 a	24.2 a	110 a	46 a	16.3 b
	4	3247 a	23.9 a	108 a	44 a	16.2 b
	6	2277 b	23.6 a	99 b	39 b	16.4 ab
	8	2007 c	23.4 a	96 b	37 b	16.6 ab
	Full season	1586 d	23.1 a	81 c	32 c	17.0 a
28	0	3263 a	24.3 a	110 a	50 a	16.2 b
	2	3151 a	24.1 a	111 a	47 a	16.0 b
	4	3172 a	24.1 a	108 a	49 a	16.4 ab
	6	2473 b	23.8 a	100 b	41 b	16.6 ab
	8	2167 c	23.7 a	97 b	36 b	17.1 a
	Full season	1611 d	23.6 a	84 c	28 c	17.2 a
56	0	3263 a	24.3 a	110 a	50 a	16.2 b
	2	3245 a	24.2 a	108 a	47 a	16.2 b
	4	3250 a	24.1 a	104 a	47 a	16.6 ab
	6	2387 b	23.8 a	98 b	41 b	17.0 a
	8	2142 c	23.5 a	94 b	34 c	17.0 a
	Full season	1599 d	23.4 a	82 c	26 d	17.3 a
515[b]	0	3263 a	24.3 a	110 a	50 a	16.2 c
	2	2940 b	24.1 a	105 a	47 ab	16.0 c
	4	2031 c	23.9 a	91 b	42 b	16.4 bc
	6	1915 cd	23.8 a	89 b	37 c	17.0 ab
	8	1790 de	23.5 a	78 c	32 d	17.1 ab
	Full season	1592 e	23.1 a	76 c	28 d	17.5 a

[a]Means within a column and weed population followed by the same letter are not significantly different at the 5% level by Duncan's multiple range test.

[b]Natural annual grass population

Table 3. Effect of annual grass density and duration on soybean performance, at site II (loam) 1983[a].

Annual Grass Density	Annual Grass Duration	Soybean yield	Soybean density	Soybean height	Pods/ plant	Weight/ 100 seeds
(Plants/M^2)	(wks)	(kg/ha)	(Plants/M)	(cm/plant)	(no.)	(g)
14	0	2843 a	24.0 a	103 a	48 a	16.6 b
	2	2834 a	23.9 a	103 a	46 a	17.2 ab
	4	2849 a	24.0 a	101 ab	46 a	17.2 ab
	6	2748 a	23.8 a	97 b	46 a	17.0 ab
	8	2387 b	23.6 a	96 bc	42 b	17.0 ab
	Full season	2317 b	23.5 a	93 c	42 b	17.5 a
28	0	2843 a	24.0 a	103 a	48 a	16.6 b
	2	2848 a	24.0 a	101 ab	49 a	17.0 ab
	4	2823 a	23.9 a	101 ab	47 a	17.2 ab
	6	2818 a	23.8 a	100 ab	46 ab	17.6 a
	8	2562 b	23.6 a	96 bc	43 b	17.2 ab
	Full season	2286 c	23.4 a	92 c	38 c	17.5 a
56	0	2843 a	24.0 a	103 a	48 a	16.6 b
	2	2838 a	23.9 a	100 a	47 a	16.6 b
	4	2794 a	23.7 a	98 a	46 a	17.1 ab
	6	2702 a	23.6 a	99 a	45 a	17.5 a
	8	2619 a	23.5 a	98 a	44 a	17.2 ab
	Full season	2113 b	23.4 a	90 b	35 b	17.9 a
491[b]	0	2843 a	24.0 a	103 a	48 a	16.6 b
	2	2618 ab	23.7 a	95 b	44 ab	17.0 ab
	4	2562 b	23.6 a	95 b	44 ab	16.9 ab
	6	2535 b	23.6 a	94 b	43 b	17.4 ab
	8	2276 c	23.5 a	91 b	40 b	17.2 ab
	Full season	2090 c	23.0 a	84 c	37 c	17.8 a

[a]Means within a column and weed population followed by the same letter are not significantly different at the 5% level by Duncan's multiple range test.

[b]Natural annual grass population

densities of 14, 28, 56, and 491 at 8 week duration representing 16, 10, 8, and 20% yield loss respectively. When compared to the sandy loam site 38, 34, 34, and 45% yield loss occurred at 14, 28, 56, 515 weed densities respectively at 8 week duration (Table 2). These data suggest possibly greater annual grass interference on sandy loam soil as compared to loam soils when high moisture is available to soybeans.

In 1984 a sandy loam soil and loam soil were evaluated for annual grass interference, however, low moisture was provided for optimum soybean growth (Table 1). All soybean parameters measured were lower at both sites when compared to 1983, however, similar trends were observed.

In 1984, soybean density at the sandy loam site was unaffected at all weed densities and duration period (Table 4). Seed weight increase resulted at weed densities of 14, 28, 56, and 70 at 4, 6, 4, and 4 week duration. Seed weight increase appeared earlier in 1984 as compared to 1983 sandy loam soil. This may be explained possibly by thinner established soybean stands or by the earlier appearance of soybean parameter reductions in 1984 as compared to 1983 sandy loam site. Soybean height was reduced at weed densities 14, 28, 56 and 70 plant/M^2 by 7, 12, 16, and 23% respectively at a 6 week duration period. Similarly pods/plant at a 6 week duration and at weed densities 14, 28, 56, and 70 resulted in reductions of 14, 17, 13, and 19% respectively as compared to the hand weed control. Soybean yield was decreased by 38% in 1984 as compared to 1983. Soybean yield loss at 8 week duration was 25, 38, 42, and 55% at weed densities

Table 4. Effects of annual grass density and duration on soybean performance, at site I (sandy loam) 1984[a].

Annual Grass Density	Annual Grass Duration	Soybean yield	Soybean density	Soybean height	Pods/ plant	Weight/ 100 seeds
(Plants/M^2)	(wks)	(kg/ha)	(Plants/M)	(cm/plant)	(no.)	(g)
14	0	2014 a	21.8 a	84 a	35 a	14.4 c
	2	1889 a	21.6 a	84 a	34 a	14.6 bc
	4	1619 b	21.3 a	81 ab	32 ab	15.3 b
	6	1613 b	21.3 a	78 b	30 b	16.1 a
	8	1520 b	20.9 a	79 b	29 b	15.8 a
	Full season	1096 c	20.6 a	69 c	24 c	15.8 a
28	0	2014 a	21.8 a	84 a	35 a	14.4 b
	2	1888 a	21.6 a	83 a	35 a	14.7 b
	4	1563 b	21.4 a	79 b	33 a	15.2 ab
	6	1338 c	21.2 a	74 c	29 b	15.6 a
	8	1244 cd	20.8 a	72 c	26 c	15.6 a
	Full season	1124 d	20.7 a	68 d	22 d	15.5 a
56	0	2014 a	21.8 a	84 a	35 a	14.4 b
	2	1780 b	21.5 a	80 ab	32 ab	14.6 b
	4	1710 b	21.4 a	79 b	31 b	15.5 a
	6	1232 c	20.9 a	71 c	27 c	15.5 a
	8	1160 c	20.7 a	69 c	24 d	15.6 a
	Full season	1185 c	20.6 a	68 c	24 d	15.7 a
70[b]	0	2014 a	21.8 a	84 a	35 a	14.4 b
	2	1808 a	21.5 a	81 a	34 ab	14.9 ab
	4	1503 b	20.9 a	74 b	31 b	15.4 a
	6	1058 c	20.6 a	65 c	25 c	15.5 a
	8	906 c	20.5 a	59 d	20 d	15.7 a
	Full season	906 c	20.5 a	59 d	20 d	15.7 a

[a]Means within a column and weed population followed by the same letter are not significantly different at the 5% level by Duncan's multiple range test.

[b]Natural annual grass population

14, 28, 56, and 70 plants/M^2 respectively. This yield loss is similar to 1983 sandy loam when comparing to the hand weeded control each year. During the 1984 season however, interference by annual grasses against soybean growth or yield parameters with exception to soybean density, were recorded in most situations at least 2 weeks earlier.

In 1984 at the loam soil site soybean plant parameter measurements resulted in similar trends as compared to 1983 loam soil site. Soybean plant density was not affected at all weed densities or duration periods (Table 5). Seed weight was increased at weed densities 28 and 56 plants/M^2 at Full Season duration, and 8 weeks at 70 plants/M^2. Soybean height reduction at 6 week duration were 4, 6, 0, and 8% at weed densities 14, 28, 56, and 70 plants/M^2 respectively. Pods/plant reduction at 8 week duration were 22, 20, 18, and 35% at 14, 28, 56, and 70 plants/M^2 weed densities. Soybean yield in 1983 was 32% greater than yield on the loam soil in 1984. When comparing each year to the hand weeded control however, similar trends could be found. At an 8 week duration, soybean yield was reduced 23, 22, 15, and 41% at 14, 28, 56, and 70 plants/M^2 respectively. This represents a greater yield loss when compared to 1983 however, in both years weed interference occurred at the 8 week duration.

Soybean yields were evaluated for full season duration periods at all weed densities and compared to soil type and year (Table 6). Soybean yield loss was greater in both 1983 and 1984 from sandy loam soils as compared to loam soils. Yield loss on sandy loam soils was greater but similar, in 1983 (high moisture)

Table 5. Effects of annual grass density and duration on soybean performance, at site II (loam) 1984[a].

Annual Grass Density	Annual Grass Duration	Soybean yield	Soybean density	Soybean height	Pods/ plant	Weight/ 100 seeds
(Plants/M^2)	(wks)	(kg/ha)	(Plants/M)	(cm/plant)	(no.)	(g)
14	0	1950 a	22.3 a	89 a	40 a	14.7 a
	2	1955 a	21.9 a	90 a	39 a	15.0 a
	4	1959 a	21.9 a	86 ab	40 a	14.7 a
	6	1801 a	21.8 a	85 b	38 a	15.2 a
	8	1504 b	21.4 a	80 c	31 b	15.3 a
	Full Season	1283 c	21.2 a	76 d	28 b	15.8 a
28	0	1950 a	22.3 a	89 a	40 ab	14.7 b
	2	1969 a	22.0 a	89 a	39 ab	15.0 ab
	4	1923 a	22.0 a	89 a	42 a	14.9 b
	6	1692 b	21.7 a	84 b	34 bc	15.1 ab
	8	1519 c	21.6 a	83 b	32 c	15.3 ab
	Full Season	896 d	21.1 a	73 c	22 d	16.0 a
56	0	1950 a	22.3 a	89 a	40 a	14.7 b
	2	1924 a	22.1 a	89 a	40 a	15.4 ab
	4	1936 a	22.1 a	88 a	39 a	15.3 ab
	6	1872 a	22.0 a	89 a	39 a	15.1 ab
	8	1658 b	21.8 a	84 b	33 b	15.2 ab
	Full season	1202 c	21.5 a	77 c	27 c	16.2 a
70[b]	0	1950 a	22.3 a	89 a	40 a	14.7 b
	2	1890 a	22.1 a	88 a	39 ab	14.9 ab
	4	1668 b	22.0 a	83 b	35 b	14.9 ab
	6	1522 b	21.7 a	82 b	34 b	15.4 ab
	8	1143 c	21.6 a	78 bc	26 c	16.0 a
	Full season	1051 c	21.4 a	74 c	24 c	15.9 a

[a]Means within a column and weed population followed by the same letter are not significantly different at the 5% level by Duncan's multiple range test.

[b]Natural annual grass population

Table 6. Soybean yield as influenced by annual grass density and full season duration in 1983 and 1984[a].

Sandy loam soil 1983			Loam soil 1983			Sandy loam soil 1984			Loam soil 1984		
Annual grass density	Soybean yield	Yield reduction	Annual grass density	Soybean yield	Yield reduction	Annual grass density	Soybean yield	Yield reduction	Annual grass density	Soybean yield	Yield reduction
(weeds/M^2)	(kg/ha)	(%)	(weeds/M^2)	(kg/ha)	(%)	(weeds/M^2)	(kg/ha)	(%)	(weeds/M^2)	(kg/ha)	(%)
0	3263 a	0	0	2843 a	0	0	2014 a	0	0	1950 a	0
14	1586 b	52	14	2317 b	19	14	1096 b	46	14	1283 b	34
28	1611 b	51	28	2286 b	20	28	1124 b	44	28	896 c	54
56	1599 b	51	56	2113 c	26	56	1185 b	41	56	1202 b	38
515	1592 b	51	491	2090 c	26	70	906 c	55	70	1051 c	46

[a]Means within a column followed by the same letter are not significantly different at the 5% level by Duncan's multiple range test.

as compared to 1984, In contrast, season long annual grass weed infestations on loam soils during low moisture conditions (1984) resulted in much greater yield loss when compared to 1983. These data suggest that the effect of annual grass interference to soybean yield are influenced by soil type and soil moisture supply. Data trends are consistent with report findings of Young et al. (9). They reported that when soil moisture is abundant, denser weed stands are required to cause a reduction, whereas in dry years, moderate densities can compete effectively with soybean for available soil moisture and cause yield reductions. On both soil types natural weed densities were greater in 1983 as compared with 1984, however, greater yield loss resulted from dry conditions. This trend does, however, contrast with the observation of Knake and Slife (5). They reported giant foxtail, did not reduce soybean yield as much during dry growing seasons as with years with adequate moisture. Additional research is needed to evaluated the influence of soil type and soil moisture on the interference of annual grasses on soybean.

A non-linear regression model was used to compare annual grass interference data from this research. In 1983 reduction in yield occurred at an earlier duration period at the sandy loam site as compared to the loam soil. At 14 plants/M^2 a steep decrease in yield resulted 4 weeks after weed emergence on sandy loam soil as compared to a slight decrease in yield at 6 weeks after weed emergence at 14 plants/M^2 on loam soil (Figure 1). Similar regression curves resulted at weed densities 28 and 56 plants/M^2 in 1983 (Figure 2, 3). The greatest decrease in

Figure 1. Influence of annual grass interference on soybean yield in 1983. Annual grass population was 14 plants/M^2.

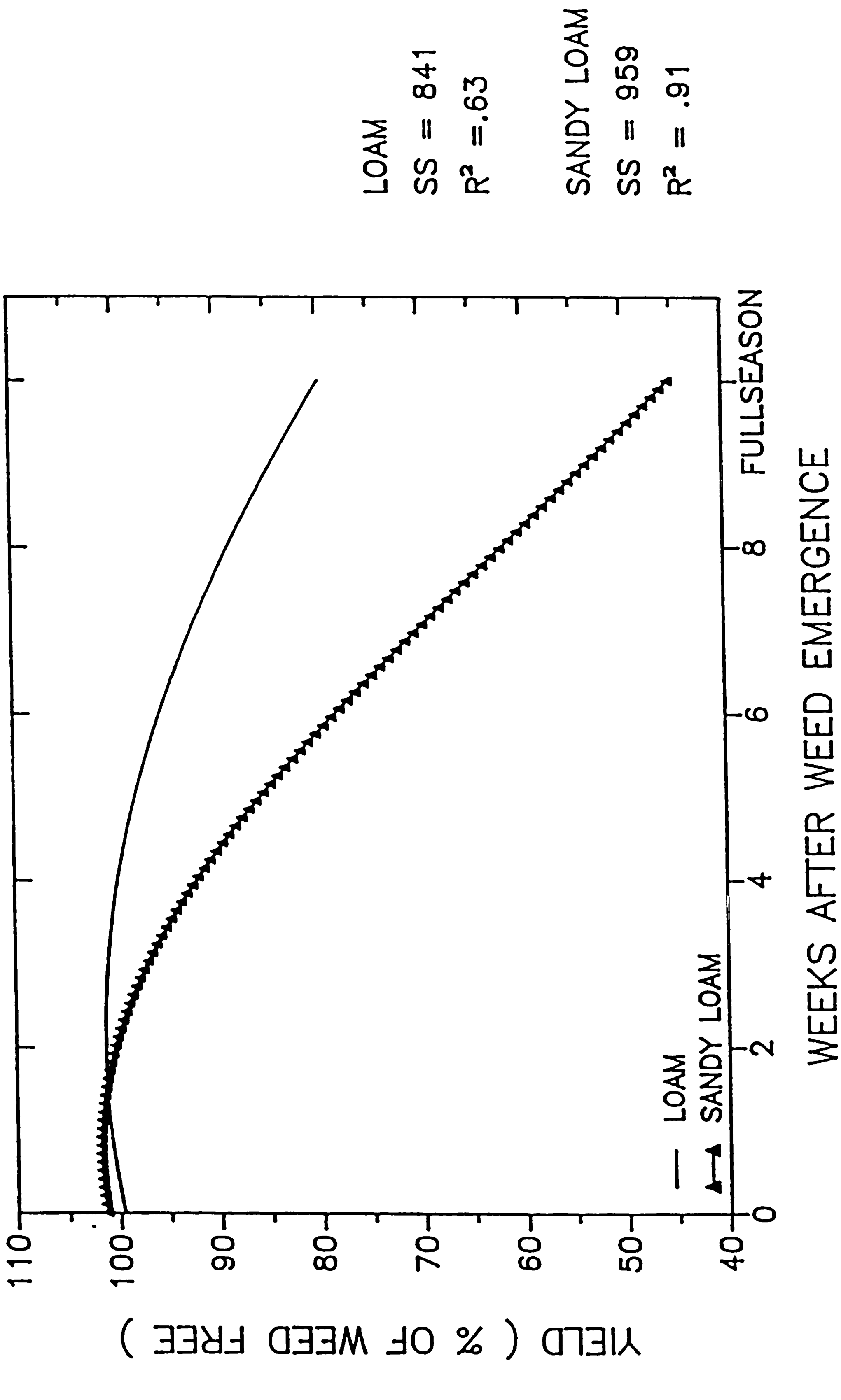
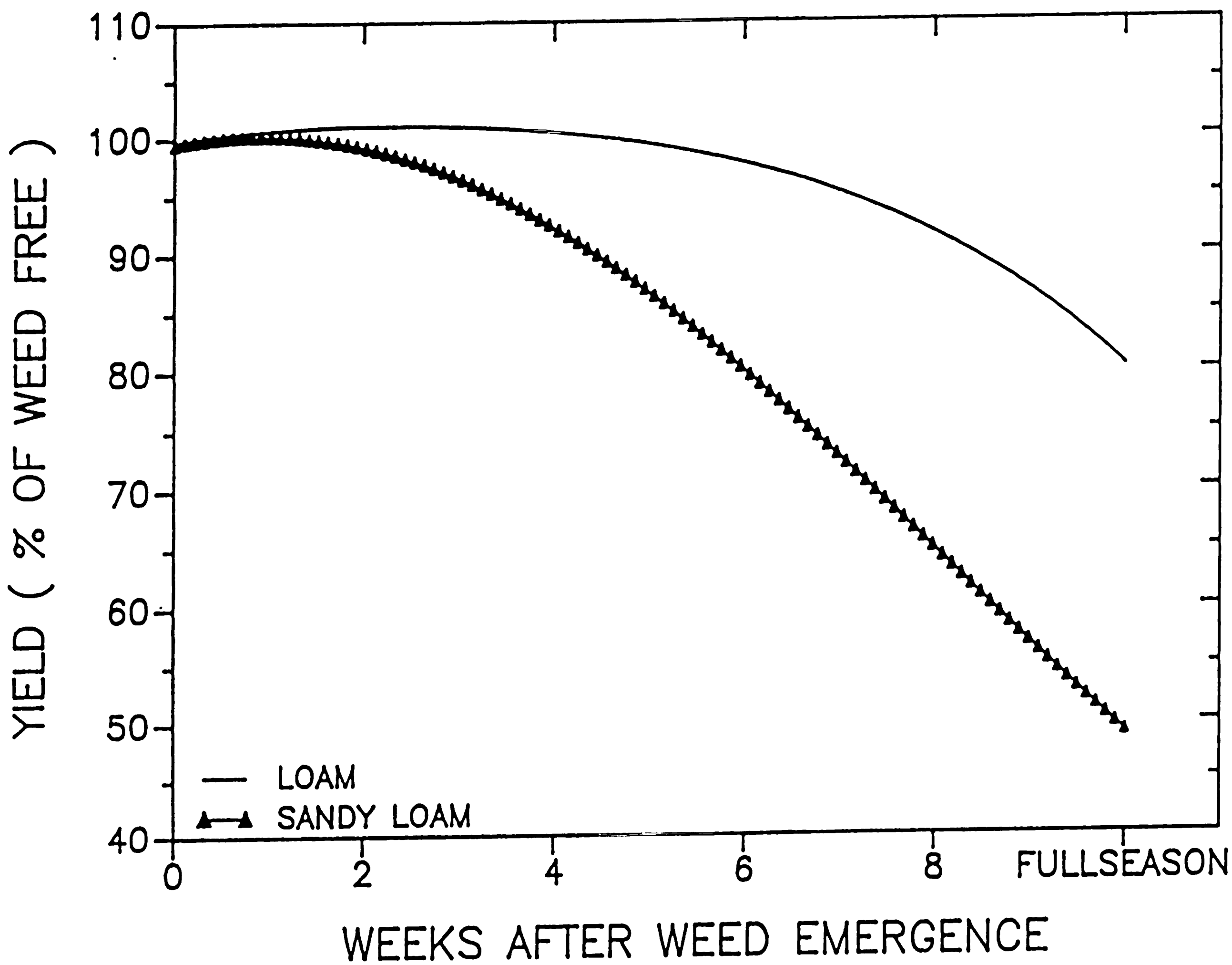

LOAM
SS = 841
R² =.63
SANDY LOAM
SS = 959
R² = .91
LOAM
SANDY LOAM
YIELD (% OF WEED FREE)
110
100
90
80
70
60
50
40
0
2
4
6
8
FULLSEASON
WEEKS AFTER WEED EMERGENCE

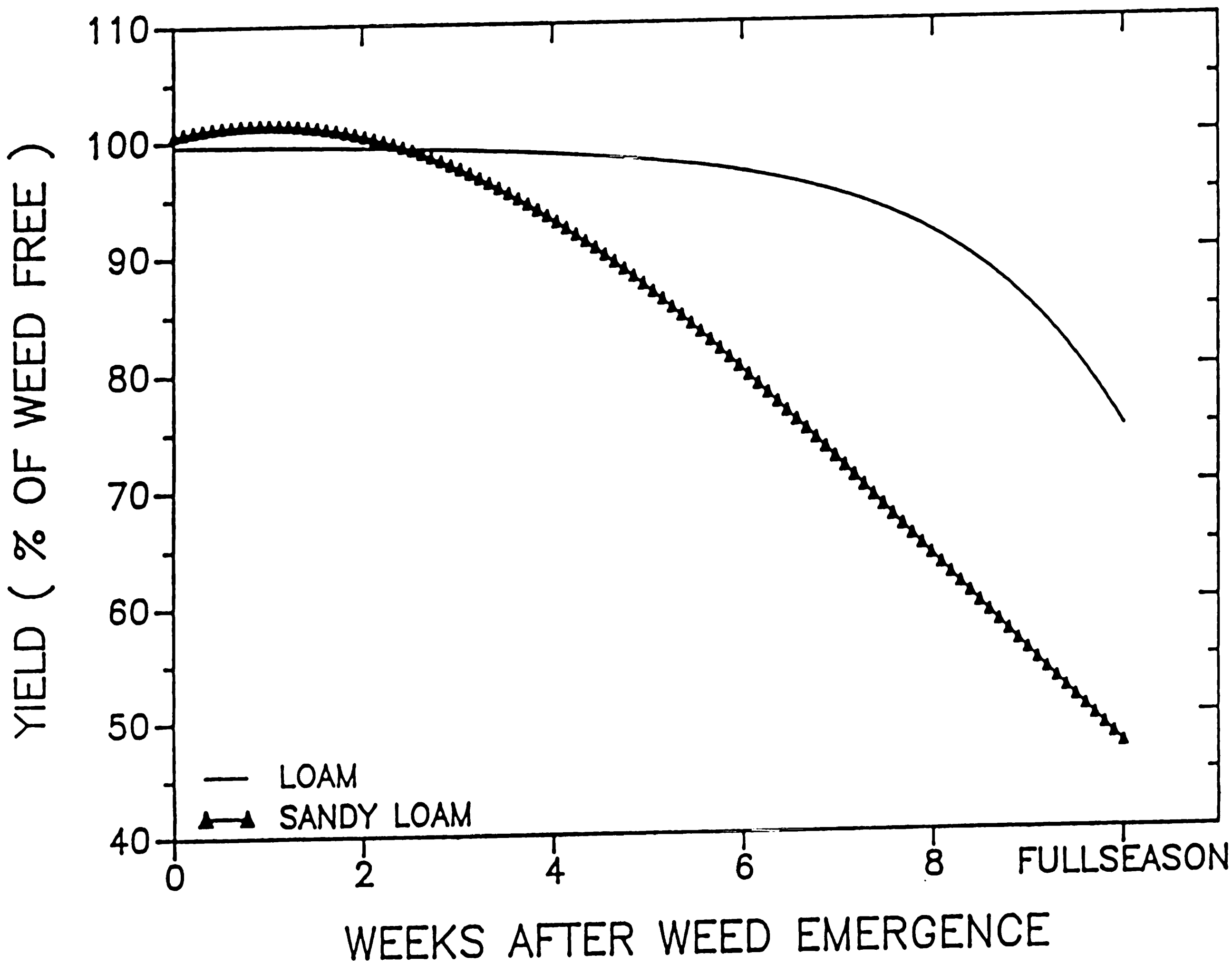
Figure 2. Influence of annual grass interference on soybean yield in 1983. Annual grass population was 28 plants/M^2.



LOAM
SS = 893
R^2 = .59

SANDY LOAM
SS = 1007
R^2 = .89

Figure 3. Influence of annual grass interference on soybean yield in 1983. Annual grass population was 56 plants/M^2.



LOAM

SS = 554

R^2 = .77

SANDY LOAM

SS = 1085

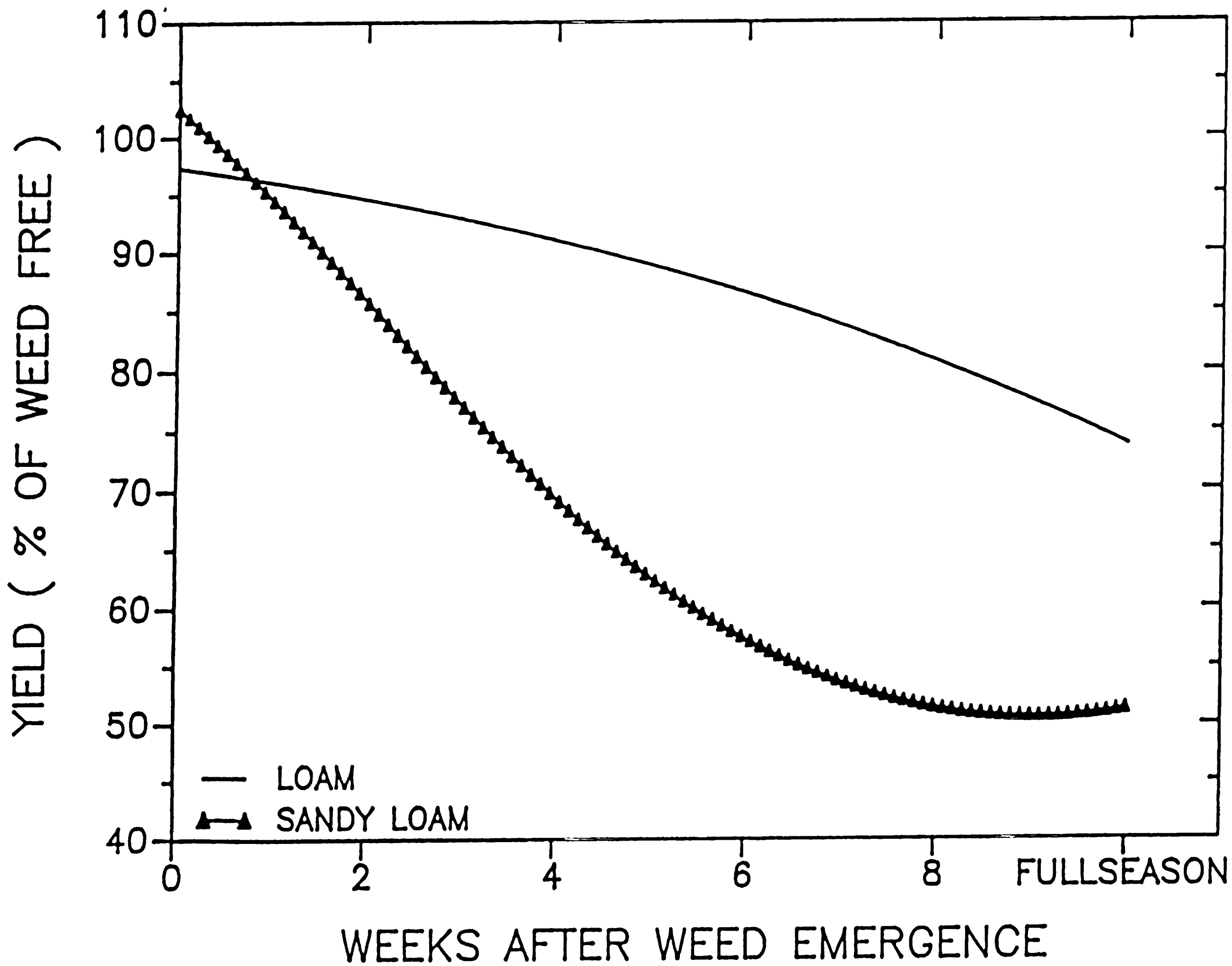
R^2 = .89

soybean yield response occurred at natural weed populations 515 plants/M^2 (sandy loam) and 491 plants/M^2 (loam) (Figure 4). The sandy loam curve resulted in a more rapid decrease in yield with increasing weed duration as compared to the loam curve. This curve for loam and sandy loam, at natural weed populations, represented the greatest yield reduction potential to soybean for 1983. Similar to 1983, 1984 (dry season) non-linear soybean yield reduction potentials when annual grass interference were on sandy loam soils as compared to loam soils. At all weed densities 14, 28, and 56 plants/M^2 greater soybean yield reductions were observed at all duration periods (Figure 5, 6, 7). The natural population curves in 1984 (Figure 8), represented the greatest soybean yield reduction, similar to 1983. On loam soils, even though the natural population weed densities were 70 plants/M^2 in 1984 compared to 491 plants/M^2 in 1983, soybean yield decreases occurred earlier and more rapidly in 1984 (Figures 4 and 8). On sandy loam soils comparing 1983 and 1984 natural populations similar soybean yield response curves were obtained (Figures 4 and 8).

CONCLUSIONS

These data suggest under high moisture seasons, that weed densities of 14, 28, 56 plants/M^2, weeds should be removed prior to 6 weeks after weed emergence on loam soils and prior to 4 weeks after weed emergence on sandy loam soils. Natural populations of weeds should be removed prior to 2 weeks after

Figure 4. Influence of annual grass interference on soybean yield in 1983. Annual grass natural population.



LOAM

SS = 1241

R^2 = .62

SANDY LOAM

SS = 1346

R^2 = .90

Figure 5. Influence of annual grass interference on soybean yield in 1984. Annual grass population was 14 plants/M^2.

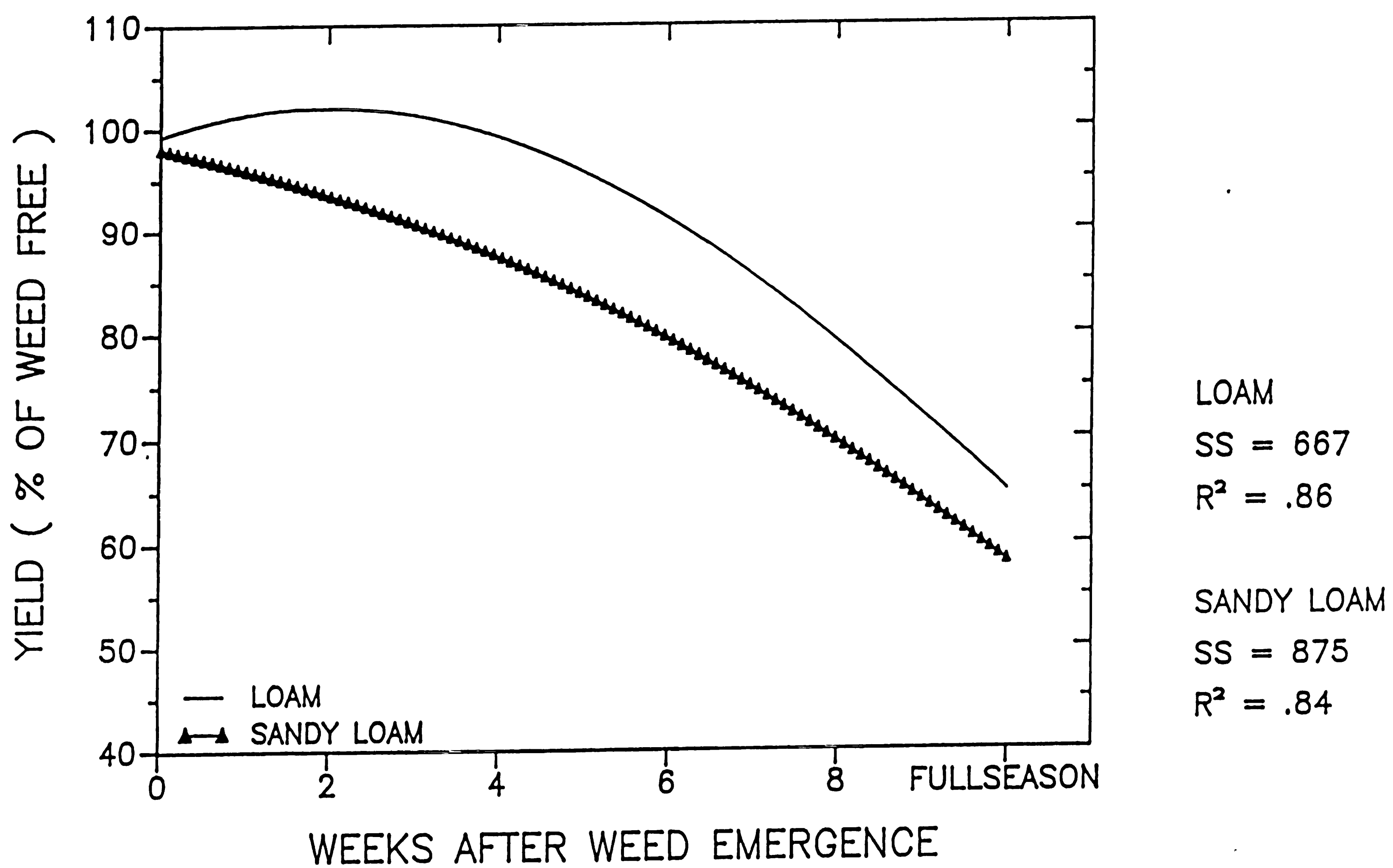
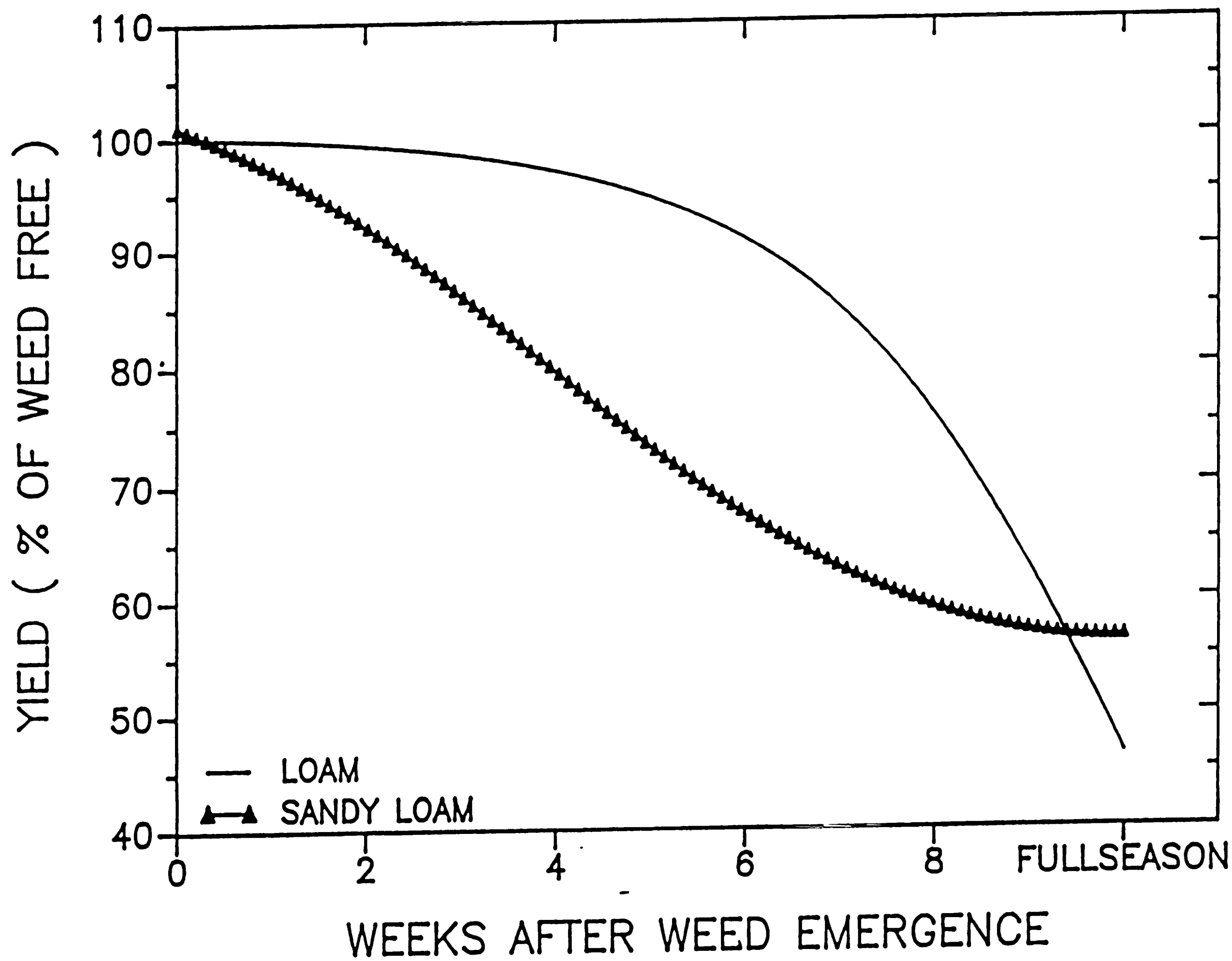

110
100
90
80
70
60
50
40
0
2
4
6
8
FULLSEASON
YIELD (% OF WEED FREE)
WEEKS AFTER WEED EMERGENCE
LOAM
SANDY LOAM
LOAM
SS = 667
R² = .86
SANDY LOAM
SS = 875
R² = .84

Figure 6. Influence of annual grass interference on soybean yield in 1984. Annual grass population was 28 plants/M^2.



LOAM

SS = 752

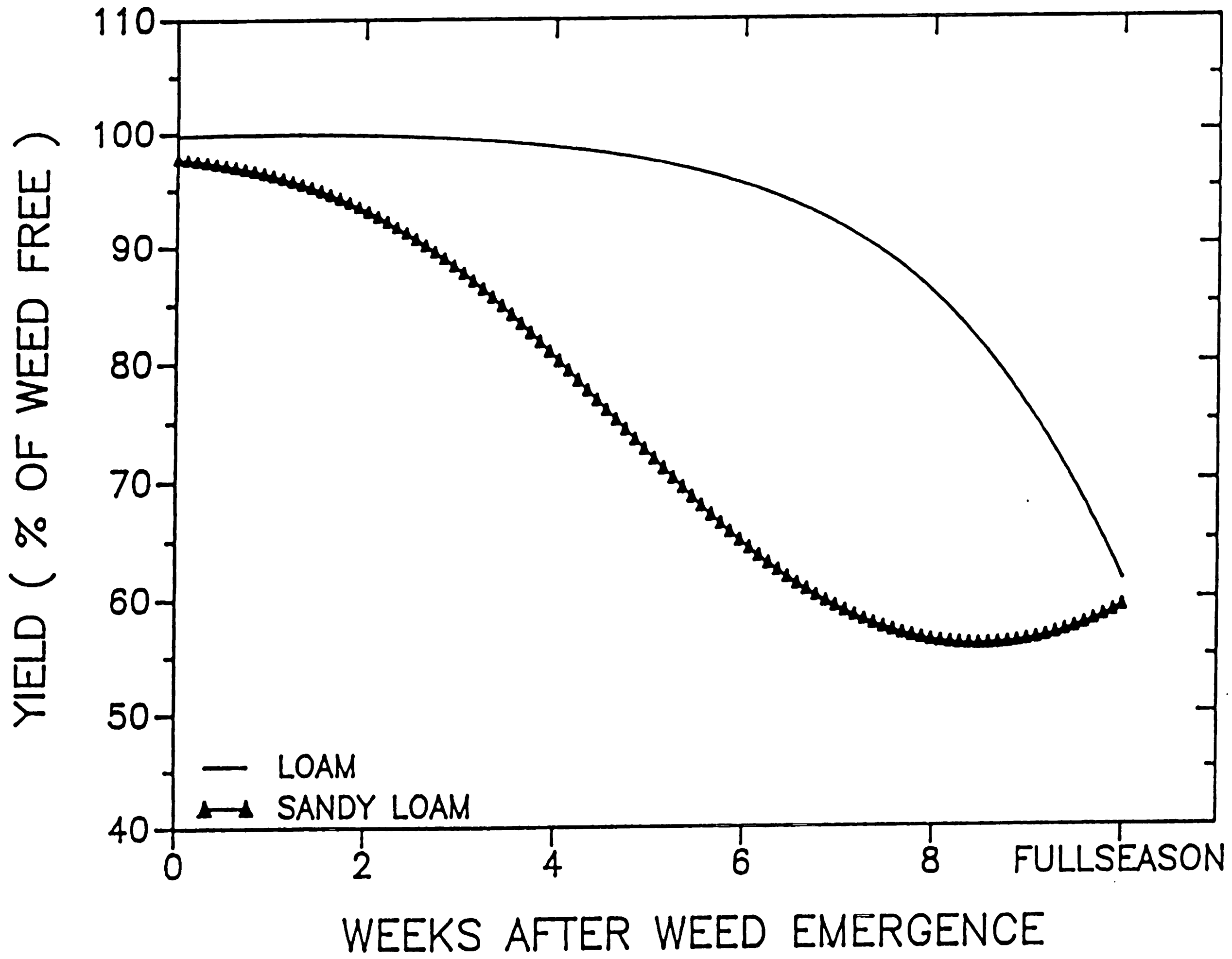
R^2 = .92

SANDY LOAM

SS = 771

R^2 = .89

Figure 7. Influence of annual grass interference on soybean yield in 1984. Annual grass population was 56 plants/M^2.



LOAM

SS = 578

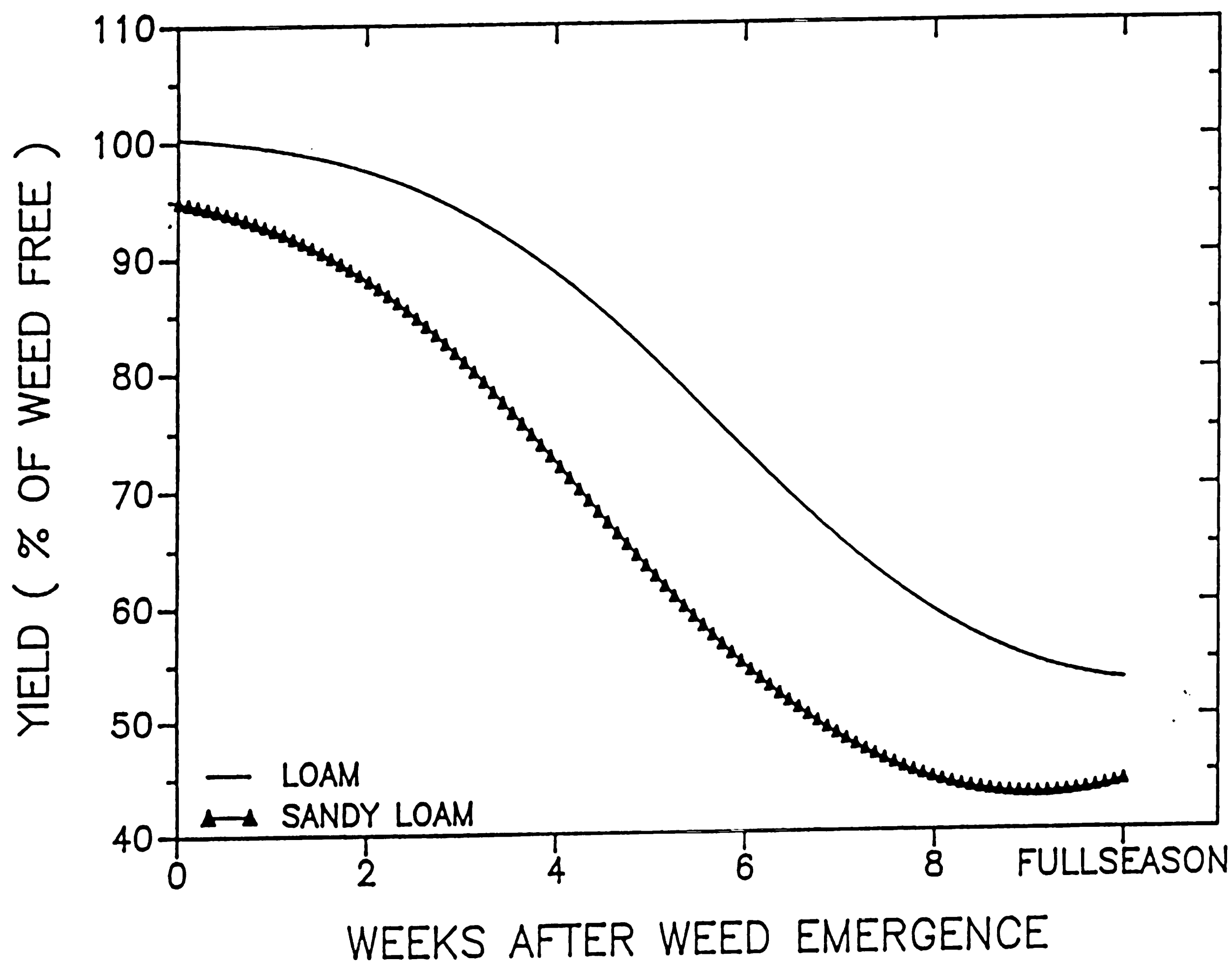
R^2 = .89

SANDY LOAM

SS = 1164

R^2 = .85

Figure 8. Influence of annual grass interference on soybean yield in 1984. Annual grass natural population.



LOAM
SS = 2450
R^2 = .82

SANDY LOAM
SS = 3597
R^2 = .80

weed emergence on sandy loam soils, and prior to 4 weeks on loam soils. Low precipitation during the growing season enhances annual grass interference to soybean on both loam and sandy loam soils. This occurred at all densities, with exception to the natural population and sandy loam soil, where yield reduction curves were similar.

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CHAPTER 4

APPLYING ECONOMICS TO WEED INTERFERENCE DATA

ABSTRACT

In 1983 and 1984 research was conducted to determine the influence of annual grass density and duration on soybean [Glycine max (L.) Merr.] yield. Soybean yield responses to annual grass interference based on percent of the weed free environment were plotted against time for densities 5, 10, 20, 20 plants/ft^2 using a non-linear regression model. Based on these soybean yield response curves, tables were developed on a computer spreadsheet, which predict economic return from postemergence grass herbicide applications at several points during the growing season. Grower inputs, expected soybean yield goal (bu/A), expected soybean price ($/bu) and herbicide application cost ($/A) can be entered and changed on this program to predict net profit or loss. Four tables were developed representing sandy loam soil with high moisture, sandy loam soil with low moisture, loam soil with high moisture and loam soil with low moisture. Thus, economic return can be evaluated by soil type and environmental conditions.

The process developed for predicting economic return from postemergence herbicide applications can be applied to any weed species or mixed weed population where adequate weed interference data exist.

INTRODUCTION

Weeds are an annual pest in soybean production in Michigan and throughout the United States. Knake (4) reported that unlike insects, diseases and nematodes, weeds will occur in cultivated row crops every year at population threshold levels that will cause severe crop losses unless controlled. Chandler et al. (2) reported annual losses due to weeds in soybean in the Lake States (Minnesota, Wisconsin and Michigan) to be 142 million dollars. Since weeds are predictable pests which occur annually and since losses due to weeds are high, research is needed for the development of Integrated Weed Management Systems (IWMS). Shaw reported (7) these systems utilize cultural, mechanical, biological, ecological and chemical methods in a directed agroecosystem approach. Blair and Parochetti (1) reported the use of widespread, weed-science Integrated Pest Management (IPM) strategies require damage thresholds for weeds to be established in various cropping situations. To the authors knowledge, little or insufficient data exists currently for the prediction of damage threshold levels for weeds in row crops.

In the State of Michigan and throughout the United States, active scouting, and Integrated Pest Management (IPM) programs exist. At Michigan State University, computer program models are used to predict the economic benefit of insecticide applications for European corn borer (*Pyrausta nubilalis* Hubner.) (5) on corn (*Zea mays* L.), and alfalfa weevil (*Hypera postica* Gyllenhal.) (6)

on alfalfa (Medicago sativa L.). However, in Michigan, data obtained from scouts indicate approximately 80% of all pests observed are weeds in field crops. Currently, no models exist in Michigan to predict the economic return from post emergence herbicide applications in field crops. In North Carolina, however, weed interference data has been used to help growers to predict the economics of post emergence herbicide applications for weeds in soybeans. Coble (3) has developed competitive indexes for 34 weed species in North Carolina. He reports growers can scout their fields and determine their potential yield loss and the economics of postemergence herbicide treatments from multi-weed species in the field. These data, however, need to be replicated in other states prior to implementation by growers outside of North Carolina as weed species prevalent differ from one region of the country to another.

The development of selective grass postemergence herbicides in soybeans offers growers the ability to implement (IPM) weed management strategies. For this reason, Michigan State University conducted experiments to evaluate annual grass weed interference in soybean.

The objectives of this research were a) to develop a computer program model for county extension agents, private consultants, agribusiness, and growers for annual grass weed interference on soybean; b) to allow users to predict the economic return from an application of selective postemergence grass herbicides throughout the growing season at different annual grass population densities, soil type, and soil moisture conditions.

MATERIALS AND METHODS

In 1983 and 1984, research was conducted to determine the influence of annual grass density and duration on soybean yield. The experimental procedure and data analysis are presented in Chapter 3 of this thesis. Soybean yield responses to annual grass interference based on percent of the weed free environment were plotted over time for weed densities of 5, 10, 20, and 20 plants/ft^2 using a commercial non-linear regression software package.[1] Based on these yield response curves, tables were developed which predict economic return from post emergence herbicide applications at several durations during the growing season. The equation used to predict net profit or loss was: Net economic return = [[yield with treatment (bu/A) - yield without treatment (bu/A)] x soybean price ($/bu)] - herbicide application cost ($/A). The user has the ability to enter and change three variables, 1) yield goal (bu/A), 2) soybean price ($/A) and 3) herbicide application cost ($/A).

A system template version 1.0 for IBM PC and IBM PC compatible computers were used to enter the data. The program uses a MS DOS 2.1 drive and a spreadsheet system disk.[2]

[1]PlotIT. 1985. Computer Resource Services. 4352 Doncaster, Holt, Michigan 48842.

[2]Lotus 1-2-3 Systems Disk.(c) 1983. Lotus Development Corporation, 161 First Street, Cambridge, MA. 02142.

RESULTS AND DISCUSSION

Using non-linear regression curves, soybean yield (% of weed-free control yield) were predicted for weed density, duration , soil type, and moisture conditions. Soybean yields in all situations were reduced at all weed densities with increasing duration (Table 1). The predicted soybean yield (% yield of weed-free control soybean) on sandy loam soil with adequate moisture at full season duration was 46, 49, 47, and 51% at weed densities of 5, 10, 20, >20 plants/ft^2, respectively. In contrast, soybean yield prediction on loam soil with high moisture at full season weed duration was 80, 80, 74, and 72% at 5, 10, 20, >20 plants/ft^2 weed densities, respectively. Therefore, these data suggest during growing seasons with high soil moisture, annual grass interference was greater on sandy loam soils as compared to loam soils. Under low soil moisture conditions, the predicted soybean yield on sandy loam soil was 58, 56, 58, and 44% of soybean yield as weed-free control at weed densities 5, 10, 20, >20 plants/ft^2, respectively, at full season weed duration. On loam soil with low moisture soybean yield was 65, 47, 62, and 53% at weed densities of 5, 10, 20, >20 plants/ft^2, respectively, at full season weed duration. Similar to data from high soil moisture conditions, these data suggest generally, under low moisture, annual grass interference was greater on sandy loam soil compared to loam soil. The comparison of sandy loam soil, under different soil moisture conditions,

Table 1. Predicted soybean yield values as influenced by annual grass density and duration.

Soil Type	Soil Moisture	Period after weed emergence	Soybean yield[a] Weeds per foot of row 5	10	20	>20
		(wk)	(%)			
Sandy loam	High	1	100	100	100	95
		2	100	100	100	85
		3	98	97	98	77
		4	93	92	93	69
		5	87	87	86	63
		6	79	80	80	57
		7	71	73	73	53
		8	63	65	64	51
		Full Season	46	49	47	51
Sandy loam	Low	1	97	97	96	92
		2	94	92	93	87
		3	91	86	87	81
		4	88	79	80	72
		5	84	74	72	63
		6	79	68	64	55
		7	75	64	59	48
		8	69	59	57	44
		Full Season	58	56	58	44
Loam	High	1	100	100	100	96
		2	100	100	100	95
		3	100	100	99	93
		4	100	100	98	91
		5	98	99	98	88
		6	96	97	96	86
		7	92	94	94	83
		8	87	91	91	81
		Full Season	80	80	74	72
Loam	Low	1	100	100	100	100
		2	100	100	100	97
		3	100	98	99	93
		4	100	97	98	88
		5	97	94	97	81
		6	91	91	94	72
		7	85	84	91	65
		8	79	76	85	59
		Full Season	65	47	62	53

[a]Percent of weed free control

generally resulted in greater soybean yield reductions at full season weed durations and high soil moisture. In contrast, weed interference on soybean yield was greater during dry seasons on loam soils and full season weed durations at all weed densities.

The data were then used to predict economic return from postemergence grass herbicide applications. Generally, the longer a grower waits after weed emergence, the lower the net economic return, regardless of herbicide effectiveness (Table 2). The grower inputs were a) expected yield 40 bu/A, b) soybean price 6 $/A, and c) herbicide application cost 25 $/A. On a sandy loam soil with high moisture, herbicide application was profitable at 8 week duration for weed densities 5, 10, and 20 plants/ft^2 and at 5 week duration for >20 plants/ft^2 weed density. In contrast, herbicide application on sandy loam soil with low moisture was profitable at weed densities 10, 20, and >20 plants/ft^2 at 6, 5, and 6 weeks after weed emergence, respectively. At weed density 5 plants/ft^2, however, economic return from a herbicide occurred even at 8 weeks after weed emergence. On loam soil with high moisture, herbicide application was profitable at 8 weeks after weed emergence at weed densities 10 and 20 plants/ft^2 and at 7 weeks after weed emergence for 5 and >20 plants/ft^2 weed densities. Low soil moisture on loam soil resulted in profitable herbicide application at 8 weeks after weed emergence for weed densities 5, 10, and 20 plants/ft^2 and at 7 weeks after weed emergence for >20 plants/ft^2 weed density.

With the expected yield goal changed to 25 bu/A, differences

Table 2. Influence of weed density and duration on economic return from post-emergence grass herbicide application for different soil type and moisture conditions[a].

Soil Type	Soil Moisture	Period after weed emergence	Economic return: Weeds per foot of row 5	10	20	>20
		(wk)	($/A)			
Sandy loam	High	1	105	97	102	81
		2	105	97	102	57
		3	100	90	97	37
		4	88	78	85	18
		5	73	66	69	4
		6	54	49	54	-11
		7	35	33	37	-20
		8	16	13	16	-25
Sandy loam	Low	1	69	73	66	90
		2	61	61	59	78
		3	54	47	45	64
		4	47	30	28	42
		5	37	18	9	21
		6	25	4	-11	1
		7	16	-6	-23	-15
		8	1	-18	-27	-25
Loam	High	1	23	23	37	33
		2	23	23	37	30
		3	23	23	35	25
		4	23	23	33	21
		5	18	21	33	13
		6	13	16	28	9
		7	4	9	23	1
		8	-8	1	16	-3
Loam	Low	1	59	102	66	88
		2	59	102	66	81
		3	59	97	64	71
		4	59	95	61	59
		5	52	88	59	42
		6	37	81	52	21
		7	23	64	45	4
		8	8	45	30	-11

[a]Expected yield goal 40 Bu/A
Expected soybean price 6 $/Bu
Herbicide application cost 25 $/A

Table 3. Influence of weed density and duration on economic return from post-emergence grass herbicide application for different soil type and moisture conditions[a].

Soil Type	Soil Moisture	Period after weed emergence	Economic return: Weeds per foot of row 5	10	20	>20
		(wk)	($/A)			
Sandy loam	High	1	56	52	54	41
		2	56	52	54	26
		3	53	47	52	14
		4	46	40	44	2
		5	36	32	34	-7
		6	24	22	24	-16
		7	12	11	14	-22
		8	0	-1	0	-25
Sandy loam	Low	1	34	36	32	47
		2	29	29	28	40
		3	24	20	18	30
		4	20	10	8	17
		5	14	2	-4	4
		6	6	-7	-16	-9
		7	0	-13	-24	-19
		8	-8	-20	-26	-25
Loam	High	1	5	5	14	11
		2	5	5	14	10
		3	5	5	12	6
		4	5	5	11	4
		5	2	4	11	-1
		6	-1	0	8	-4
		7	-7	-4	5	-8
		8	-14	-8	0	-12
Loam	Low	1	28	54	32	46
		2	28	54	32	41
		3	28	52	30	35
		4	28	50	29	28
		5	23	46	28	17
		6	14	41	23	4
		7	5	30	18	-7
		8	-4	18	10	-16

[a]Expected yield goal 25 Bu/A
Expected soybean price 6 $/Bu
Herbicide application cost 25 $/A

resulted in the economic return from herbicide application (Table 3). Under all moisture and soil conditions, economic return was lower as compared to 40 bu/A expected yield goal (Table 2).

A lower expected soybean price $5.50/bu (Table 4) resulted in greater economic return from early herbicide application as compared to a decrease in soybean yield (Table 3). Economic return potential at expected soybean price $5.50/bu were decreased, however similar trends resulted when compared to soybean price $6.00/bu (Table 2).

In contrast, the greatest economic return/A resulted when herbicide application costs were reduced to 20 $/A (Table 5). These data could allow a grower to compare the difference in economic return/A from hiring a commercial applicator as compared to using his own equipment. Economic loss, however, resulted at the same weed infestation duration periods even though economic return potential was higher under reduced application costs.

CONCLUSIONS

The predictive model developed for evaluation of post emergence herbicide application can be applied to any weed species or mixed weed population where adequate weed interference data exist. This research supports and other weed research has demonstrated that early post emergence herbicide applications can reduce weed interference and increase profitability. However, this procedure allows growers the opportunity for evaluation of economic return or loss associated with soybean yield, price,

Table 4. Influence of weed density and duration on economic return from post-emergence grass herbicide application for different soil type and moisture conditions[a].

Soil Type	Soil Moisture	Period after weed emergence	Economic return: Weeds per foot of row 5	10	20	>20
		(wk)	($/A)			
Sandy loam	High	1	94	87	97	72
		2	94	87	92	50
		3	89	81	87	32
		4	78	70	76	15
		5	65	59	61	1
		6	48	43	48	-12
		7	30	28	32	-21
		8	12	10	12	-25
Sandy loam	Low	1	61	65	59	81
		2	54	54	52	70
		3	48	41	39	56
		4	41	26	23	37
		5	32	15	6	17
		6	21	1	-12	-1
		7	12	-7	-23	-16
		8	-1	-18	-27	-25
Loam	High	1	19	19	32	28
		2	19	19	32	26
		3	19	19	30	21
		4	19	19	28	17
		5	15	17	28	10
		6	10	12	23	6
		7	1	6	19	-1
		8	-10	-1	12	-5
Loam	Low	1	52	92	59	78
		2	52	92	59	72
		3	52	87	56	63
		4	52	85	54	52
		5	45	78	52	37
		6	32	72	45	17
		7	19	56	39	1
		8	6	39	26	-12

[a]Expected yield goal 40 Bu/A
Expected soybean price 5.50 $/Bu
Herbicide application cost 25 $/A

Table 5. Influence of weed density and duration on economic return from post-emergence grass herbicide application for different soil type and moisture conditions[a].

Soil Type	Soil Moisture	Period after weed emergence	Economic return: Weeds per foot of row 5	10	20	>20
		(wk)	($/A)			
Sandy loam	High	1	110	102	107	86
		2	110	102	107	62
		3	105	95	102	42
		4	93	83	90	23
		5	78	71	74	9
		6	59	54	59	-6
		7	40	38	42	-15
		8	21	18	21	-20
Sandy loam	Low	1	77	78	71	95
		2	66	66	64	83
		3	59	52	50	69
		4	52	35	33	47
		5	42	23	14	26
		6	30	9	-6	6
		7	21	-1	-18	-10
		8	6	-13	-22	-20
Loam	High	1	28	28	42	38
		2	28	28	42	35
		3	28	28	40	30
		4	28	28	38	26
		5	23	26	38	18
		6	18	21	33	14
		7	9	14	28	6
		8	-3	6	21	2
Loam	Low	1	64	107	71	93
		2	64	107	71	86
		3	64	102	69	76
		4	64	100	66	64
		5	57	93	64	47
		6	42	86	57	26
		7	28	69	50	9
		8	14	50	35	-6

[a]Expected yield goal 40 Bu/A
Expected soybean price 6 $/Bu
Herbicide application cost 20 $/A

application costs and later season applications (a common situation faced by many soybean producers). Limitations to these data are as follows, a) weed density is often variable throughout a field, b) most weed interference data assume simultaneous crop and weed emergence, and c) this analysis considers crop yield in the year of application only and does not address potential harvesting problems or the potential impact of weed seed production on subsequent crops.

Research is needed to evaluate the interference of other weed species in row crops. Although this procedure has some limitations, the principles and predictive model discussed here should enhance growers abilities to utilize economics in their weed control decisions. This method can act as a foundation for the incorporation of further interference data in the future.

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