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REDUCED HERBICIDE INPUTS FOR CORN AND SOYBEAN PRODUCTION

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ABSTRACT

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Farming practices such as late planting, rotary hoeing and cultivation may control weeds when herbicide applications are reduced. Research in 1990 and 1991 examined the effect of planting date, rotary hoeing and cultivation on soybean and corn yield when preemergence or postemergence herbicide inputs were reduced.

Rotary hoeing did not reduce mid-season weed populations or influence soybean or corn yield. The greatest increase in corn yield from mechanical weed control occurred with the first cultivation. Banded preemergence or postemergence herbicide treatments followed by one cultivation produced yields comparable to a broadcast herbicide program without cultivation in corn. Broadcast preemergence herbicide treatments in corn with no cultivation gave the highest net return in 1990, while banded preemergence or postemergence herbicide application followed by cultivation had the highest net returns in 1991.

Soybean yield decreased as a result of late planting which was not due to an increase in weed populations. Postemergence broadcast herbicide treatments resulted in greater soybean yield than preemergence herbicide treatments in 1990 and 1991. Banded preemergence or postemergence herbicide treatments with two cultivations failed to adequately reduce weed competition in 1990; however, 1991 yields were comparable to broadcast herbicide applications. The highest net return in 1990 was from postemergence broadcast treatments with one cultivation. In 1991, neither cultivation alone nor herbicide alone consistently provided maximum net return above weed control cost. Consistent net returns generally followed the use of both herbicide and cultivation.

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LITERATURE REVIEW

Reduced Herbicide Inputs for Corn and Soybean Production

Corn and soybean producers can control weeds culturally, chemically, and mechanically. Most growers use a combination of these three control practices, e.g., crop rotation, herbicide application and cultivation. Soybeans are a nitrogen-fixing legume crop which do not require nitrogen fertilizer inputs. However, over 50% of Michigan soybean growers still use starter fertilizer, often containing nitrogen, when planting soybeans. Corn, on the other hand, is a non-leguminous crop which, because of its inability to fix nitrogen, requires nitrogen to obtain optimum yields. Starter fertilizer may improve early crop vigor, but it may also increase the emergence and competitiveness of weeds in the crop row (Vengris et al., 1953; Okafor and De Datta, 1976; Dotzenko et al., 1969; Banks et al., 1976).

Planting date is a major factor influencing weed control. Planting later in the spring may reduce the number of weeds because many may germinate, emerge, and be controlled by tillage prior to planting. However, later planting may have a detrimental effect on corn and soybean yield because optimal planting date for both corn (Erdmann et al., 1981), and soybeans (Hesterman et al., 1987; Helsel et al., 1981), is prior to May 15, and peak weed germination is before mid May when soil temperature reaches 60 F.

LISA (low input sustainable agriculture) has become an important topic in the 1990s at the farm community, agribusiness, and legislative levels. Definitions of LISA vary depending upon the speaker and message, but use of "synthetic pesticides and fertilizers" are two areas usually addressed. Low input suggests the reduction of total chemical inputs into the farming system. This usually means that other practices must be adopted to control weeds. Such practices include rotary hoeing, cultivation, herbicide banding, reduced rates, and/or postemergence herbicide application. Labor inputs must be increased to obtain adequate weed control when these practices are implemented. The economics of low chemical-high management input systems should be evaluated so that growers, reducing pesticide and fertilizer input costs, understand the potential increase in labor and fuel expense.

Early planting of soybean provides maximum seed yield (Henson and Carr, 1946; Osler and Carter, 1954; Weiss et al., 1950). However, other factors may confound this assumption (Merch, 1980). Emergence of soybean planted in early May may take considerably longer due to the cool soil temperatures. Soybeans planted early that emerge in five days with warmer soil temperatures have the potential for greater yield than those planted seven or 14 days later (Merch, 1979).

By altering the planting date, other factors may become important when examining yield differences. Other factors such as late vs. early varieties, planting rate, and row spacing may affect soybean yield (Abel, 1961; Leonard et al., 1976; Torrie and Briggs, 1955; Hartwig and Pendleton, 1973; Osler and Carter, 1954; Merch, 1979; Weiss et al., 1950)

Osler and Carter (1954) stated that early soybean varieties should be planted later and later varieties should be planted earlier. The vegetative growth of the later variety would be less hampered than that of the earlier variety. Small yield differences occurred in other research (Torrie and Briggs, 1955), between two early varieties, Flambeau and Mandarin 507, planted on varying dates. Late varieties planted after May 20 resulted in decreased yields. Weiss et al. (1950) found these same results when comparing different planting dates. Abel (1961) found that maximum seed yields could be obtained by planting late varieties in May. Early varieties should be planted early in a drought year to give some protection against complete failure but at the expense of maximum yield should the season be favorable (Matson, 1964). Under favorable moisture conditions, May plantings exceeded all others. Cooper (1971) found that yield reduction would begin after May 20 if there was no lodging.

When lodging became a problem because of high planting rates, significance of yield due to planting date would be reduced and the advantage of planting early would be lost. Merch's work suggests that row width effects on yield are related to those of planting date. He found a much greater decline in yield experienced with later planting dates at the 10-inch row width than at the 20-inch width. Mixed results were found with the 30-inch row spacing.

Influence of Soybean Planting Date on Weed Control

Planting date may influence weed density and competitiveness. Velvetleaf population was significantly greater in soybeans planted in May compared to those planted in June (Horn and Burnside, 1985). Velvetleaf seedlings emerging with soybeans in mid May were twice as competitive as those emerging with soybeans planted in late June (Oliver, 1979). Velvetleaf density of 1 plant/12 in of row reduced soybean yield 27% in the early planting and 14% in the late planting. This was possibly due to the short day photoperiod response of velvetleaf and not different velvetleaf densities. Date of planting affected the emergence of both soybean and jimsonweed (Weaver, 1986). Reduction in both crop and weed emergence was observed in later plantings due to drier soil conditions and seed bed preparation removing the early flush of weeds.

Influence of Fertilizer on Soybean Yield

The soybean is a legume and, when well nodulated, is capable of fixing some, but not all the nitrogen required for optimal yield (Allos and Bartholomew, 1959; Bhangoo and Albritton, 1976; Dahl, 1981; Harper, 1974). However, fertilizer nitrogen response by soybean has been quite inconsistent (Harper, 1974). Nitrogen at 178 lbs/acre gave the greatest seed yield for both the non-nodulating and nodulating isolines, and no yield differences were detected between the two lines at 0 or 178 lb/acre of nitrogen (Harper, 1974). Similarly, yield of 'Lee' soybean isolines increased when nitrogen was applied, regardless of nodulation (Bhangoo and Albritton, 1976).

Dahl (1981) reported that 178 lb/acre of nitrogen increased yield when soybean was planted early but had no significant affect on yield when soybean was planted at a later date. One variety, 'Harcor', yields did not increase from the applied nitrogen. No yield increase was seen because lodging occurred and this lodging was the result of the extra nitrogen added.

Soil pH may also influence soybean response to nitrogen. Grain yield increased from 335 to 1213 lb/acre when nitrogen was added at rates up to 179 lb/acre (Parker and Harris, 1977), when soybeans were planted on soils with a low pH. Low pH inhibits symbiotic nitrogen fixation which results in a positive yield response to soybean when fertilized (Parker and Harris, 1977).

Soil moisture and residual soil nitrogen also impact soybean response to nitrogen fertilizer. Nitrogen fertilizer at 50 lb/acre and at 100 lb/acre significantly increased the grain yield under varying moisture levels in 1974 while there was significant increase in 1976 only with the low moisture level (Al-Ithawi et al., 1980). The differential response for the two years could be explained by the different levels of residual nitrogen found in the soil. In 1974 there were 74 lb/acre of residual nitrogen measured in the soil, but in 1976 there were 133 lb/acre. Increased residual nitrogen in 1976 could lessen the response to additional nitrogen which, in turn, may only give an increased yield response in the low moisture regime.

Increases in seed yield and/or seed protein percentage in nodulating lines suggest that symbiotic fixation failed to supply amounts of nitrogen essential for maximum seed yield and/or protein percentage (Ham et al., 1975). Nodulation does not occur until approximately 9 days after planting, and nitrogen fixation does not begin until 2 weeks later (Bergersen, 1958). Thus, during this early period of growth, supplemental nitrogen may be necessary.

However, other research indicates that there is no response of soybean to fertilizer nitrogen (Welch et al., 1973; Beard and Hoover, 1971; Lyons and Earley, 1952; Mederski et al., 1958; Wagner, 1962).

Beard and Hoover (1971) found although soybean on zero nitrogen plots were yellow-green in the early stages of growth, no significant difference in yield occurred due to nitrogen rate or timing. Welch et al. (1973), conducted a number of studies with organic and inorganic N at ten field locations in Illinois over a period of several years, using different rates, timing and methods of nitrogen application. Significant yield increases were found in only 3 of 133 instances, and these occurred at high, uneconomical N rates. These authors concluded that nitrogen was not the factor limiting soybean yield. In early research, with adequate rainfall, moderate temperatures, and 30 to 40 days additional growing season, there was little to no response to added nitrogen (Lyons and Earley, 1952). In 1947, conditions were hot and dry, and nodule number was reduced 35% in the control plots compared to the control plots in 1949. With the reduction of nodule numbers, a significant yield increase was obtained when nitrogen was applied. This experiment explains some of the variation in response of soybean to nitrogen fertilizer. Rainfall and temperature influence soybean yield response to nitrogen fertilizer which apparently influences symbiotic nitrogen fixation. According to Lyons and Early (1952), under optimum conditions there is little response to fertilizer. Mederski et al. (1958) found that the increase in soybean yield from nitrogen applied to non-irrigated soils was not significant and did not compensate for the cost of the applied nitrogen. Research by Wagner (1962) indicated that the application of nitrogen fertilizer did not result in a significant yield increase for the well nodulated 'Clark' soybean but rather a depression in yield from the plow down treatment of 240 pounds of nitrogen. This depression was due to salt injury to young plants from the fertilizer.

Experiments were conducted in Michigan to determine the effects of inoculant type and rate, row spacing and nitrogen fertilizer application on nodulation and grain yield of first year soybeans (Hesterman and Isleib, 1986). Nitrogen fertilizer did not affect plant height or grain yield at one location but significant effects of nitrogen fertilizer on height and grain yield occurred at another location. An economic analysis was conducted to determine the cost benefit of added nitrogen fertilizer. A soybean price at $6.00/bu and a 6.9 bu/acre yield increase were required to pay for 120 lbs/acre of nitrogen fertilizer if the fertilizer price was less than $0.35 per lb of actual nitrogen. It was not determined if one could benefit from less than 120 lbs of nitrogen fertilizer.

In general, one must conclude that studies involving nitrogen fertilization are affected by many cultural and environmental factors such as: rainfall, temperature, sunlight, humidity, planting date, row spacing, cultivar selection and tillage methods.

Fertilizer Effects on Weed Growth

Vengris et al. (1955) addressed the subject of nutrient uptake by weeds relative to crops. In these experiments, Vengris grew redroot pigweed, crabgrass, barnyardgrass, and corn all in pure stands and as a mixture of the 3 weed species and corn together. In the corn-with weeds plots, weed species were evenly mixed and placed in a 15 inch band over the corn row. All plots were cultivated but the 15 inch band was left undisturbed. Nutrient analysis was done a month after plant emergence and again at harvest. The weeds were harvested when 50-60% of the seeds were matured and the corn was harvested in the dough stage. Vengris concluded that certain species, especially redroot pigweed, responded greatly to phosphate fertilization. In 1953, redroot pigweed and lambsquarters plants on low phosphate plots were weak and failed to grow. Also, weeds will strongly compete with crops even when high rates of fertilizer are applied.

The studies of Gray et al. (1953), support the findings of Vengris (1955). In greenhouse experiments, Kentucky bluegrass and bentgrass were grown in pots to determine the uptake of potassium by the two when grown separately and to study the competition for potassium when Ladino clover was grown with the grasses. They found that the grasses maintained a higher level of potassium uptake then did the clover.

Lucas et al. (1942), presented data in which the uptake of potassium by weeds was greater than that of red clover.

Vengris et al. (1953), examined chemical composition of redroot pigweed, lambsquarters, smartweed, common purslane, galinsoga, ragweed, and crabgrass in corn fields located in the Connecticut River Valley. He found that weeds are great competitors for all plant elements and accumulate more N, P, K, Ca, and Mg than does corn. Vengris also found this trend to be true in onions and potatoes. Because weeds are such serious competitors, they are able to accumulate considerable amounts of nutrients at the expense of the crop, especially when these elements are not adequately supplied by the soil. Although phosphorus levels in weeds seem to be high even when there are low levels of available phosphorus. This indicates that weeds are able to utilize forms which are not readily available to most crops (Vengris, et al. 1953).

When applying nitrogen to upland rice fields, the purple nutsedge benefitted more than the rice (Okafor and De Datta, 1976). The rice and the purple nutsedge competed extensively for moisture and this competition was much more serious with increased nitrogen. As nitrogen increased, the density of the purple nutsedge also increased, reducing the light that could reach the rice. This in turn reduced upland rice yields.

Dotzenko et al. (1969), measured the effects of nitrogen fertilizer on weed seedling populations. The time and rate of application of N had a significant effect on the amount of weed seed produced. In all instances, increased nitrogen fertilizer increased the number of weed seedlings for all weed species measured.

Banks et al. (1976), studied the effect of continuous fertilization in wheat for 47 years to evaluate the effects of fertility on weed types and populations. Generally, the lowest total numbers of weeds were observed on plots which had not been fertilized. Highest total weed numbers were found on plots which had received N, P, K, and lime. Most species followed this trend except for evening primrose, carpetweed, and henbit. As we have seen, plants growing near one another can interact competitively for nutrients. Increasing nutrients does not appear to be a substitute for the reduction of the weed canopy. Vengris et al. (1955), thought this may be due to the luxury consumption of nutrients by some weeds or that the fertility factor was influencing growth factors which in turn are influencing root or canopy development. By increasing root or canopy development, the competitive ability of a plant is increased.

Rotary Hoeing/Timing/Weed Control

The rotary hoe was first patented in 1839 by Moses G. Cass. At that time, the rotary hoe was referred to as a revolving harrow. Not until nearly one hundred years later did this implement become widely used because of the increased soybean acreage in the corn belt. Not until 1915 was the hoe actually credited for being a cultivation tool for weed removal in soybeans. Of course, this idea brought about studies to examine the hoes ability to control weeds.

As soon as germinated weed seeds can be found, the harrow, weeder, or rotary hoe should be used vigorously, without the consideration of stage of growth the soybean is in (American Soybean Assoc, 1928). Weeds that have just germinated are often spoken of as being in the "white" or "curl" stage. It was found in this study that if weeds get beyond this stage, the rotary hoe or "rolling harrow" may be less effective. Does this rotary hoe injure the soybean? According to the American Soybean Association, if the rotary hoeing is done when soybeans are in the crook stage a 10-15% stand reduction may occur. However, planting a higher rate of soybean seed/acre will overcome this problem.

Very little data are available on the operational speed or soil conditions at which the rotary hoe can be used to satisfactorily reduce weed stands. Annual broadleaf and grass seedlings can be controlled by using a rotary hoe at high speeds. Rea (1954), found that rotary hoeing once at 15-18 mph would give 65-70% control of broadleafs and grasses and two or more rotary hoeings would give 85-90% control without the use of chemicals. All rotary hoeing was done after the weeds had emerged and soil surfaces were dry. All weeds were beyond the white stage.

Lovely et al. (1958), conducted an experiment to determine the effectiveness of the rotary hoe under various soil moisture conditions and at different soybean and weed growth stages. "Timely" rotary hoeing was performed when weeds were germinated but had not yet emerged and repeated at five day intervals. By using this timely application, weed stands could be reduced by 70-80% but with a 10% reduction in soybean stands. Due to the ability of the soybean to compensate, yields were only slightly reduced as compared to the plots which were weed free. Lovely, found that if this timely application of rotary hoe was delayed until weeds had emerged, one could expect a 50% reduction in both weed control and soybean yields. Rotary hoeing when soil moisture was high gave similar results to that of the untimely rotary hoeing, which was conducted after weeds had already emerged.

Rotary hoeing when weeds are in the white stage and less than 1/4 inch tall gives best results (Peters, 1959). Unlike Lovely, Peters found that maximum effectiveness of the hoe could be obtained after the weeds had emerged. Rotary hoeing under different soil moisture levels did not significantly influence soybean yield.

In the early 1960's chemicals became a part of life on the farm. How would these chemicals be influenced by cultivation practices or how would cultivation practices be influenced by these new weed killers. Knake (1965) performed a study to try to answer this question by looking at the effects of rotary hoeing on the performance of preemergence herbicides. The rotary hoeing was done when soybeans were 2 to 3 inches high, corn was 4 to 5 inches, and weeds were 1 inch tall. It was determined that rotary hoeing did not significantly reduce the effectiveness of any herbicides in either corn or soybeans. In most cases, the hoe gave improved weed control especially when drier conditions were encountered.

In 1970, a study was conducted by (Moomaw and Robison) in corn to look at the effectiveness of tillage variables. Rotary hoeing significantly affected weed yields at the end of the 1970 growing season. Average weed yields for rotary hoed and non rotary hoed plots were 303 and 660 lb/acre, respectively. This amounted to a 52% yield reduction of weeds following rotary hoeing. Why the rotary hoe was not effective in 1971 was not mentioned, but by looking at the data one can see that corn yields are much higher in 1971 which may be indicating greater rainfall. This increased rainfall may have deleteriously affected the ability of the rotary hoe to control weeds because of either rotary hoeing under moist conditions or rainfall causing new flushes of weeds to emerge.

Mechanical weed control in combination with reduced preemergence herbicide rates is a sound approach to minimize chemical use while maintaining adequate weed control. This assumes that weed pressure is not excessive and that rotary hoeing and cultivations are done on time (Doll et al., 1990).

Cultivation in Corn

Burnside (1970) found that the most effective way of controlling wild cane in corn was with a combination of herbicides plus cultivation. In 1966, wild cane yields were reduced as cultivations of corn increased from none to three cultivations. However, corn yields were not increased by a third cultivation. In 1967, yields of wild cane were not reduced by cultivation. This was due to the delay in cultivation caused by excessive rains. Cultivation did not take place until the cane had reached a height of 12 inches.

Cultivation significantly reduced weed yields at crop harvest by 84% and 79% in 1970 and 1971 (Moomaw and Robison, 1973). Cultivation effectiveness declined slightly with greater weed growth. Cultivation of row middles reduced the average end of season weed yields by 80%.

In 1968 Buchholtz and Doersch found that 1 cultivation resulted in an average 6% increase in corn yield on herbicide treated plots but witnessed no advantage with 2 cultivations. Similar results were reported by Meggit (1960).

A study was conducted to look at the economic comparison of mechanical and chemical weed control (Armstrong et al., 1968). When only cost was considered, two cultivations was the least expensive weed control method but atrazine banded with 1 cultivation gave the highest net return when all factors were imposed (Armstrong et al., 1968).

"Best management weed control trials" were done at Arlington and Lancaster Research Stations in 1989 (Doll et al. 1990). The objective of this research was to compare single weed management strategies to integrated approaches. Treatments included a full rate of preemergence herbicide (atrazine and metolachlor) and also reduced rates. Plots were cultivated 3, 5, and 7 weeks after planting. Weed species included giant foxtail, common lambsquarters and redroot pigweed. Weed control from the herbicide alone was greater at Lancaster than at Arlington. Only at Arlington did subsequent mechanical measures enhance weed control and crop yield when the full rate of preemergence herbicide was applied. Mechanical control by itself was insufficient in obtaining comparable corn yields.

Cultivation in Soybeans

Peters et al. (1959) found that where an effective herbicide was followed by two cultivations soybean yields were adequate. When no herbicides were used, a third cultivation increased soybean yields in 1956 but not in 1957.

Peters et al. (1961), found that 1 or 2 cultivations were generally needed to give adequate soybean yields. No increase in soybean yield was witnessed from a third cultivation. These increases in soybean yield were due to improved weed control. This indicates that herbicides used in this experiment seldom gave weed-free environments.

Dowler and Parker (1975) found that 1 or 2 cultivations were better than none. He also discovered that cultivations can be effective in increasing soybean yield when herbicide rate or effectiveness had been reduced.

In 1965, Peters et al. studied the interrelations of row spacings, cultivations, and herbicides for weed control in soybeans. He found that when chloramben and PCP were applied, soybeans in 20 and 24 inch rows usually only needed 1 cultivation. Soybeans produced in narrow rows always equalled and sometimes produced higher yields that did the wide rows.

Field studies were conducted to look at the response of itchgrass in soybean to selected herbicides and postplanting cultivation. In 1980 it was discovered that early cultivation stimulated growth of itchgrass. If this cultivation was not followed by another cultivation later in the season, itchgrass plants would compete with soybean before canopy closure. When cultivation was repeated near canopy closure of the soybean, itchgrass which had emerged after the first cultivation would be taken out. Itchgrass germinating at this time would not pose a threat because of soybean canopy closure.

Moomaw and Robinson (1973) showed that cultivating 7, 14, and 21 inch bands gave acceptable weed control and that the effectiveness of cultivating declined as weed densities increased. A 7 inch band of atrazine and propachlor with supplemental cultivation provided effective weed control and maintained corn yield equal to wider herbicide bands or broadcast treatments.

In soybean, soybeans treated with a one-half rate of alachlor and linuron and cultivated once or twice yielded the same as where a full rate of alachlor and linuron was applied alone or with one cultivation (Gebhardt, 1981). Soybeans treated with a one-half rate of alachlor and linuron plots yielded more than where chloramben was applied at a full rate and followed by two cultivations.

Trials were conducted at Arlington and Lancaster Research Stations in 1989 to look at "best management practices." Here, Doll et al. (1989) found that banded applications followed by mechanical control resulted in good weed control, especially when cultivated once or twice.

Sometimes, banding does not adequately control weeds, especially when weather conditions are poor. Plots sprayed overall produced more soybeans than those having banded treatments (Peters, 1961). This was due to abundant rainfall which delayed cultivation. Because of the delay, weeds became too large to remove by means of cultivation. So weather can become detrimental in a banding situation.

LISA

LISA (Low-Input/Sustainable Agriculture) is a USDA program designed to help farmers use resources more efficiently. The goal of LISA is to increase farm profitability while conserving natural resources and protecting the environment. Farmer resources include crop rotations, crop and livestock diversification, soil and water conserving practices, mechanical cultivation, and biological pest controls. Under the LISA program, farmers still may use some synthetic fertilizers and chemicals but substitute on-farm resources and scientific know how for others.

Research becomes essential to provide farmers with this scientific knowledge and a wide choice of cost effective farming systems that minimize the use of purchased inputs while also minimizing environmental risk. This research emphasizes a number of practices, such as more extensive use of leguminous green manure crops, planting of cover and trap crops, use of animal manures, and decreased use of fertilizers and pesticides.

The use of leguminous cover crops can minimize soil moisture and wind erosion losses while at the same time provide a source of nitrogen to the crop. Mitchell and Teel (1977) found that spring oats and hairy vetch could supply up to 88% of the total N that the corn used. Mulches also reduced soil temperature in the 1.0 to 4.0 in. zone. This resulted in greater root development near the soil surface under mulches and improved nutrient uptake.

Some work has been done comparing dead mulches with living mulches. Hall et al. (1984), found that "living mulches" were more effective in decreasing soil erosion than corn stover residues on the surfaces. These "living mulches" did not significantly reduce corn grain yields when adequate suppression of the mulch was obtained with herbicide treatments. "Living mulches" can also provide weed control by establishing ground cover early in the growing season before weeds are able to establish themselves (Hartwig, 1977).

Echtenkamp and Moomaw (1989) witnessed that chewings fescue and ladino clover maintained a living mulch and controlled weed growth but also competed with corn for water when rainfall was below normal. Successful suppression of the "living mulch" was not established in the experiment.

Interference

The two most common forms of interference between crops and weeds are competition and allelopathy. Competition is defined as the mutually adverse effects of an organism which utilizes a resource in short supply (Radosevich and Holt, 1986). These resources may be water, nutrients, oxygen, carbon dioxide and light (Rice, 1984). Allelopathy is different from competition in that, its effect depends on a chemical compound being added to the soil and not the depletion of some factor from the environment which is required by some other plant sharing the same habitat.

There are two types of competition: intraspecific and interspecific competition (Radosevich, 1984). Intraspecific competition is the negative interaction between two plants of the same species. Interspecific competition is the adverse interference among plants of different species.

The interference between weeds and crops have been extensively studied. Studies that involve corn and soybeans and specific weed species are of interest.

Common Lambsquarters Interference in Soybean

Common lambsquarters is the predominant weed in soybeans in the United States (Wisk and Cole, 1966). It can be found from sea level to 2.25 miles and from lat 70 N to lat 50 S (Holm et al., 1977). It commonly grows near local concentrations of nitrogen or organic matter (Everist, 1979). Common lambsquarters is an annual capable of growing from 2 to 5 feet tall. An average sized plant can produce 72,450 seeds in the fall (Stevens, 1932). During long days, common lambsquarters produces a greater percentage of black seeds, which are dormant. On short days, nondormant seeds are produced. Production of dormant and non dormant seeds enable the plant to germinate over a wider range of environmental factors thus, ensuring its survival (Cumming, 1963).

For most weed species, the critical weed-free period in soybean has been reported to be between 2 and 4 weeks after planting (Coble and Ritter, 1978; Coble et al., 1981; Knake and Slife, 1965).

The influence of relative planting date on the growth of common cocklebur (*Xanthium strumarium*), common ragweed (*Ambrosia artemisiifolia*), sicklepod (*Cassia obtusifolia*) and redroot pigweed (*Amaranthus retroflexus*) grown in competition with soybean was studied in the greenhouse (Shurtleff and Coble, 1985). They concluded that soybean had the highest root:shoot ratio of any plant. The root:shoot ratio of common ragweed, common cocklebur, common lambsquarters and sicklepod were intermediate while redroot pigweed was the lowest. Soybean dry matter was reduced the most when the weeds were planted two weeks prior to soybean. This suggests that these species compete well with soybean provided that their root systems are established prior to soybean.

A similar study was conducted with field experiments to look at the competitive ability of the weed species (Surleff and Coble, 19852). They observed that common lambsquarters at a density of 16 weeds per 33 foot of row reduced soybean yield by 15%. All other weed species reduced soybean yield less, except for redroot pigweed. Yet, common lambsquarters had the smallest leaf area and shoot dry weight of the five species.

Harrison (1990) analyzed the effects of common lambsquarters populations and interference duration on weed growth and soybean yield. It was predicted that with a 5% yield loss in soybean, common lambsquarters density would need to be 2 plants per 2.2 foot of row for 7 weeks. Common lambsquarters seed production was highly correlated with plant dry weight.

Time of removal with common lambsquarters in soybean has also been studied. Crook and Renner (1990) found that common lambsquarters could remain 10 weeks following soybean emergence before a 20% yield reduction occurred. In this instance, weeds were removed by hand. When using a postemergence herbicide, application would need to be prior to 5 weeks after soybean emergence in order to obtain similar results.

Competition for light is a major factor that adversely affects crops. Stoller and Myers (1989) looked at the response of soybean and four broadleaf weeds to reduced irradiances. They found that common lambsquarters had the highest light saturated photosynthesis rate of the four C_3 species. It was also observed that common lambsquarters did not adapt to shading as well as some of the other species, but because of its tall growth habit it avoids being shaded by the soybean canopy. Thus, it really doesn't need to be shade tolerant.

Common Ragweed Interference in Soybean

Common ragweed is an annual reproducing by seed. It is commonly found throughout North America and is most common in the Eastern and North Central States (Agricultural Research Service, 1970). It becomes a troublesome weed in poorly managed pastures, cultivated fields and gardens. It is also found in waste areas, idle land and roadsides (State of Nebraska). Although not generally considered a difficult weed to control, common ragweed is listed as one of the 10 most common weeds found in soybean fields in several southeastern states (Palmer, 1979).

The influence of common ragweed interference on soybean yield has been studied. Coble et al., (1981) determined that the damage-threshold population of common ragweed in the soybean row was four weeds/33 foot of row. This resulted in a 8% yield loss which was equal to 113 lb/acre. This means that each common ragweed plant/33 foot of row would reduce soybean yield an average of 29 lb/acre. In late research, Shurtleff and Coble (1985) found that a density of 16 common ragweed/33 foot of row reduced soybean yields by 12%. Soybean height was not affected by competition from common ragweed, but leaf area reductions of soybean corresponded fairly well with soybean yield reductions. Shurtleff and Coble, (1985) demonstrated the benefits of at least a 2 week weed-free period for common ragweed in soybean in the greenhouse. It was also found that if soybeans remained weed free for four weeks after soybean emergence and moisture was adequate optimum soybean yields occurred.

Giant Foxtail Interference in Corn

Giant foxtail is a summer annual reproducing by seed. It is troublesome on low, bottomland cultivated fields, and is a serious weed in Illinois and Missouri. It is thought to have been introduced from China, probably in the seeds of Chinese millet in (1931) (United States Department of Agriculture, 1970).

Corn yield reductions resulting from mature foxtail infestations averaged 14, 10 and 5 bushels per acre, with applications of 0, 70 and 140 pounds of elemental nitrogen per acre, respectively (Staniforth, 1957). As resources became less limiting, competition declined. Corn yields increased 2 to 3 times more than foxtail when nitrogen was added. In 1961, Nieto and Staniforth (1961) again looked at corn-foxtail competition under various production conditions. These works substantiated those of the earlier study. Corn yield reductions resulting from mature foxtail infestations averaged 20, 14 and 10 bushels per acre with 0, 70 and 140 pounds of elemental nitrogen per acre, respectively. They concluded that foxtail competition resulted not only from individual factors, such as soil moisture, soil nitrogen, corn plant populations and foxtail infestations, but also by the interaction of the four.

Research determined the competitiveness of corn and giant foxtail under different populations of giant foxtail in the row (Knake and Slife, 1962). The treatments consisted of 54, 12, 6, 3, 1, 1/2 and no foxtail per foot of corn row. With the highest density of foxtail, yield reductions averaged 25%. There was little to no significant effect on moisture of grain, height of crop or shelling percentage of the corn. Beckett et al. (1988) witnessed a 18% yield reduction in corn with 4 giant foxtail clumps per foot of row.

The time at which the giant foxtail becomes established in the corn is important. Knake and Slife (1965) discovered that foxtail that began growing at the same time as corn and was left until maturity reduced corn yields by 13%. Foxtail that was seeded three weeks or later after the crop was planted did not reduce corn yields, although, the dry matter of the foxtail was still substantial.

When giant foxtail was removed at 3, 6, 9 and 12 inches tall and at maturity, 1, 2, 5, 7 and 18 bushels per acre yield reductions in corn occurred (Knake and Slife, 1969). Competition of giant foxtail delayed tassel emergence but had little effect on grain moisture at harvest.

Lambsquarters Interference in Corn

Lambsquarters interference reduced corn grain yields significantly at weed densities above 4.3 plants per ft^2 in 1976 and 10 plants per ft^2 in 1977 (Sibuga and Bandeen, 1980). Common lambsquarters reduced corn yield by decreasing ear length and kernel size (Sibuga and Bandeen, 1980).

Season long interference of common lambsquarters in corn decreased yields curvilinearly with increasing weed density, resulting in a maximum yield loss of 12% at 4.9 plants/33 foot of row in 1985. In 1986 and 1987, significant yield loss was not seen. This may have been due to the insect infestation on the weed thus, reducing its competitive ability (Beckett et al., 1988).

Economics of Weed Management Decisions

Farmers rely on various methods of weed control such as mechanical, chemical or various combinations of the two. These means of control are often rated on their effectiveness. Unfortunately, effectiveness of a weed control measure is not usually an economically sound practice for selecting weed control options.

Economic research compared mechanical vs. chemical weed control. Armstrong et al., (1968) examined the effects of cost, yield, timeliness and alternative uses of labor in corn. Yields ranged from 83 bu per acre for two cultivations to 96 bu per acre with the highest cost from chemical plus mechanical weed control methods. However, when considering only yield and cost, mechanical methods had a slight advantage over chemical weed control methods. Penalizing mechanical methods because of delay or timeliness gave chemical methods a $3.00 per acre advantage. Alternative uses of labor only moderately affected net income.

Herbicide plus cultivation gave the most reliable and economic means of controlling weeds in cotton (Snipes et al., 1984). This type of study has also been done in peanuts. Wilcut et al., (1987) found that neither cultivations alone nor herbicide alone consistently provided maximum net return. Consistent maximum net returns generally followed the use of both herbicide and cultivations. This is in agreement with Bridges et al., (1984).

Lybecker et al. (1984), did a economic analysis of two management systems for two cropping rotations. System 1 involved a system typically used on irrigated farms that was not expected to rapidly reduce the weed seed potential of soil. System 2 was designed to use herbicides intensively to reduce the large weed seed reservoir that existed. The average return above variable cost was higher for system 1 than for system 2 under both cropping systems. Under higher herbicide costs, system 1 benefitted even more. Again in 1988, Lybecker et al. found that conventional tillage plus minimum levels of herbicide gave the highest adjusted gross returns.

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MECHANICAL WEED CONTROL PRACTICES FOR REDUCED PREEMERGENCE AND POSTEMERGENCE HERBICIDE USE IN CORN

JASON JOHN WOODS

Low input suggests the reduction of total chemical input into the farming system. Weed control practices such as rotary hoeing and cultivation may be necessary to control weeds when herbicide applications are reduced. Research in 1990 and 1991 examined the effect of rotary hoeing and cultivation when herbicide inputs were reduced. Main plots consisted of cultivating 0, 1, or 2 times and rotary hoe treatments. In 1990, one rotary hoe treatment was applied at an early timing. In 1991, a second rotary hoe timing was added to investigate the effect of a late rotary hoe timing on weed control. Imposed on the main plots were three herbicide treatments: 1) no herbicide; 2) broadcast preemergence application of metolachlor [2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methylethyl)acetamide] at 2.0 lb/acre and atrazine [6-chloro-*N*-ethyl-*N'*-(1-methylethyl)-1,3,5-triazine-2,4-diamine] at 1.0 lb/acre; and 3) a preemergence banded herbicide application of metolachlor plus atrazine (10 inch band directly over the corn row). In a second study main plots consisted of 0, 1 or 2 cultivations, and imposed on the main plot were three postemergence herbicide treatments: 1) no herbicide; 2) a broadcast postemergence application of bromoxynil [3,5-dibromo-4-hydroxybenzonitrile], at 0.38 lb/acre, nicosulfuron [2-[[(4,6-dimethoxypyrimidin-2-yl) aminocarbonyl]aminosulfonyl]-*N*,*N*-dimethyl-3-pyridinecarboxamide], at 0.031 lb/acre and nonionic surfactant at 0.25% (v/v), and 3) a postemergence banded application (10 inches directly over the corn row) of bromoxynil and nicosulfuron. Dominant weed species were giant foxtail, redroot pigweed, common lambsquarters and velvetleaf. Rotary hoeing had no effect on late season weed density or corn yield. Cultivation alone controlled weeds and

improved corn yield compared to no chemical or mechanical weed control but did not obtain yields comparable with systems including herbicide. The greatest increase in yield from mechanical weed control occurred with the first cultivation. Banded preemergence or postemergence herbicide treatments followed by one cultivation produced yields comparable to a broadcast herbicide program without cultivation. When yield and cost were considered in comparing weed control options, banding preemergence herbicides followed by one mechanical cultivation did not have an economic return as high as the broadcast preemergence herbicide treatment with no cultivation in 1990. However, in 1991, banded preemergence application with cultivation had an economic advantage compared to the broadcast preemergence herbicide treatment with no mechanical cultivation. In the postemergence study, banded herbicide application followed by two mechanical cultivations gave the highest net return.

INTRODUCTION

Public awareness of food and environmental issues has increased rapidly in recent years. Pesticides have become a target of public debate over the need to reduce pesticide use in the environment. Weed control systems where herbicides are applied in conjunction with mechanical weed control could be implemented to reduce herbicide use. The rotary hoe and cultivator are useful implements for mechanical weed control in corn. Meggitt (1960) compared a broadcast herbicide application to a 12 or 24 inch banded herbicide application. Two cultivations were required for weed control and corn yield when herbicides were banded, regardless of band width. Broadcast herbicide treatments also required two cultivations for optimum corn yield. Knake et al. (1965) reported that rotary hoeing improved both grass and broadleaf weed control. The improved weed control was due to the direct action of the hoe on the removal of weeds rather than the improved performance of the herbicide from the hoe.

In no case did rotary hoeing decrease herbicide effectiveness. Moomaw and Robison (1973) reported that a 7-in band of atrazine plus propachlor with supplementary cultivation was effective in controlling weed growth and maintaining corn yield as were wider herbicide bands or a broadcast treatment. Corn treated with a broadcast herbicide and no cultivation produced significantly less grain than the handweeded check in both years of the experiment. Rotary hoeing reduced early season weed yields 82 and 38%, in 1970 and 1971, respectively.

"Best management weed control trials" were conducted in Wisconsin in 1989. Doll et al. (1990) concluded that mechanical weed control in conjunction with reduced rates of preemergence herbicides was a sound approach to minimize chemical use while maintaining adequate weed control. Weed pressure in this research was not excessive and rotary hoeing and cultivations were timely. Gunsolus (1990) found that rotary hoeing effectively controlled weeds that had germinated but was not an effective method of weed control in no-till fields. This was particularly true in fields with more than 20 to 30% crop residue, or in any situation where weeds germinated from depths greater than 2 inches. Cultivation contributed to higher yields by reducing weed competition, with the greatest impact coming from the first cultivation. Mulder and Doll (1991) reported that weed control, corn yield and economic returns were greater where herbicides and mechanical weed control practices were combined as compared to only mechanical weed control practices.

Studies were initiated at Michigan State University to examine integrated weed control systems for corn which utilized combinations of rotary hoe, cultivation and herbicide application. Weed populations within each integrated weed control system and corn yield were measured.

MATERIALS AND METHODS

Preemergence Study

Field research was conducted at the Michigan State University Crop and Soil Science Research Farm at East Lansing MI, in 1990 and 1991. The soil was a Capac loam (fine-loamy, mixed, mesic Aeric Ochraqualfs) with a 3.4% organic matter and a soil pH of 6.4 and 7.1, in 1990 and 1991, respectively. In 1990, the plot area was fall chisel plowed. In 1991, the plot was spring chisel plowed due to excessive rain the previous fall. Secondary tillage included spring disking and field cultivation. In 1990, 270 lb/acre of a 46-0-0 (N-$P_2 0_5$-$K_2 0$) analysis fertilizer and 100 lb/acre of a 0-0-60 analysis fertilizer was broadcast prior to field cultivation. Three hundred lb/acre of 6-24-24 was applied as a banded treatment, two inches below and two inches beside the corn seed at planting. In 1991, 210 lb/acre of 46-0-0 was broadcast applied prior to field cultivation and 380 lb/acre of 6-24-24 was applied as a banded treatment at planting. Fertilizer application was based on soil test recommendations from Michigan State University. The entire experimental area was planted with Pioneer 3751 at a rate of 25,000 seeds/acre on May 8, 1990 and May 15 in 1991.

The experimental design was a three factor factorial arranged as a split-plot design. Individual plots were 10 by 35-ft in 1990 and 10 by 30-ft in 1991. The main plots consisted of cultivation[1] and rotary hoe[2] treatments. In 1990, one rotary hoe treatment was applied at an early timing. In 1991, a second rotary hoe treatment was added to investigate the effects of a later rotary hoe timing on weed control. In 1990 a one and a two cultivation system were included. With the one cultivation system, plots were cultivated 28 days after corn emergence. With the two cultivation system, plots were cultivated 21 days after corn

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[1]John Deere 875 minimum tillage c-shank cultivator, Deere and Co., Moline, IL 61265-1304.

[2]John Deere 400 series rotary hoe, Deere and Co., Moline, IL 61265-1304.

emergence and again, 42 days after corn emergence in 1990. In 1991, plots were cultivated 14 days after corn emergence and again 28 days after corn emergence. Dates of application and associated crop and weed heights are reported in Table 1. Imposed on the main plots were three different weed management treatments which consisted of: 1) no herbicide; 2) broadcast preemergence application and 3) preemergence banded (10 in.) herbicide application directly over the corn row. A tank-mix combination of metolachlor [2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methylethyl)acetamide] at 2.0 lb ai/acre plus atrazine [6-chloro-*N*-ethyl-*N'*-(1-methylethyl)-1,3,5-triazine-2,4-diamine] at 1.0 lb ai/acre was applied. Nozzle type, pressure, and spray volume are reported in Table 2. All herbicide applications were made with a tractor-mounted compressed air sprayer except for the 1991 banded herbicide applications where a cultivator frame mounted band sprayer was used. This system, which was not available in 1990, provided more precise placement of the herbicide band over the corn row. The system utilized a hydraulically driven centrifugal pump.

Total corn plant populations were taken in the center two rows of the plot prior to any mechanical cultivation. In 1990, quadrats (10 X 36 in) were placed over the corn row, prior to cultivation to determine weed density. After all mechanical cultivation was complete, weed densities were determined within and between the corn row with these same quadrats. Early and late weed populations were measured in 1991. Because herbicide band widths and measuring quadrat width were the same, border effects were encountered in 1990. To overcome this effect, quadrat width was reduced from 10 to 8-in. but total area was kept the same.

Corn yield was determined by harvesting the center two rows with a combine. Grain moisture was recorded, and yields were adjusted to 15.5% moisture.

Table 1. Weed control operations and associated air temperatures and plant heights.

1990	Date	Air Temp	Height			
			ZEAMX[a]	SETFA[a]	AMARE[a]	CHEAL[a]
		(°F)	(in)			
Metolachlor (2.0 lb/acre)+ Atrazine (1.0 lb/acre)	May 11	41	--	--	--	--
Rotary Hoe	May 15	63	--	--	--	--
1 Cultivation	June 16	82	14	2	2	2
2 Cultivation: 1st	June 6	66	7	3	2	2
2 Cultivation: 2nd	June 26	81	23	1	1	1

1991	Date	Air Temp	Height			
			ZEAMX	SETFA	AMARE	ABUTH[a]
		(°F)	(in)			
Metolachlor (2.0 lb/acre)+ Atrazine (1.0 lb/acre)	May 17	88	--	--	--	--
1st Rotary Hoe	May 21	79	--	--	--	--
2nd Rotary Hoe	May 29	90	6	2	1	1
1st Cultivation	June 4	81	10	4	2	3
2nd Cultivation	June 18	82	24	2	1	2

[a]Abbreviations: ABUTH, velvetleaf (*Abutilon theophrasti*); AMARE, redroot pigweed (*Amaranthus retroflexus*); CHEAL, common lambsquarters (*Chenopodium album*); SETFA, giant foxtail (*Setaria faberii*); and ZEAMX, corn (*Zea mays*)

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Table 2: Spray equipment and information.

	1990		1991	
	Band	Broadcast	Band	Broadcast
Nozzles	4002E[a]	8003[a]	8003E[a]	8003
Pressure (psi)	36	36	30	36
Spray Volume (gpa)	31	22	35	22

[a]4002E = 40° even flat fan nozzle delivering 0.2 gpm; 8003 = 80° tapered flat fan nozzle delivering 0.3 gpm; 8003E = 80° even flat fan nozzle delivering 0.3 gpm.

Postemergence Study

Field research was conducted at the Michigan State University Crop and Soil Science Research Farm at East Lansing MI, in 1991. The soil was a Capac (fine-loamy, mixed, mesic Aeric Ochraqualfs) with a soil pH of 7.1 and 3.4% organic matter. The plot area was chisel plowed, disked, and field cultivated in the spring. Prior to spring field cultivation, 210 lb/acre of 46-0-0 was broadcast applied and 380 lb/acre of 6-24-24 was applied in the corn row at planting. Fertilizer application was based on soil test recommendations from Michigan State University. All plots were planted with Pioneer 3751 on May 15 at a seeding rate of 25,000 plants/acre.

The experimental design was a two factor factorial arranged as a split-plot. Individual plots were 10 by 30-ft. The main plots consisted of either 0, 1, or 2 cultivations. The first cultivation was June 7 and the second cultivation June 21. Imposed on the main plots were three herbicide treatments which consisted of: 1) no herbicide; 2) broadcast postemergence herbicide application and 3) banded (10 in.) postemergence herbicides applied directly over the corn row. A tank-mix combination of bromoxynil, [3,5-dibromo-4-hydroxybenzonitrile], at 0

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at 0.38 lb ai/acre, nicosulfuron, [2-[[(4,6-dimethoxypyrimidin-2-yl)aminocarbonyl] aminosulfonyl]-*N*,*N*-dimethyl-3-pyridinecarboxamide], at 0.031 lb ai/acre, and NIS[3] at 0.25% v/v was applied. Dates of herbicide application appear in Table 3. Nozzle type, pressure, and spray volume are reported in Table 4.

Broadcast postemergence herbicide applications were made with a tractor-mounted compressed air sprayer. The banded postemergence treatments were made with a cultivator frame mounted band sprayer, which utilized a hydraulically driven centrifugal pump. Corn populations were measured in the center two rows of each plot. Quadrats (8 X 45 in.) were placed over the corn row, prior to cultivation to determine weed density. After all mechanical cultivation was complete, weed densities were measured within and between the corn row with these same quadrats. The center two rows of corn were harvested with a combine, grain moisture was recorded, and yields adjusted to 15.5% moisture. Data for rainfall are shown in Table 5. The statistical package used was MSTAT[4] (Microcomputer statistical program).

The economic analysis was based on variable input costs and net return. Variable input costs[5] include: tillage, herbicide, fuel, and labor. A $2.00 and $2.50/bu corn price was assumed. Net returns above weed control costs were computed by multiplying corn prices by yield and subtracting total variable input costs. Variable costs do not include costs associated with land or management such as taxes, depreciation, interest, trucking expense or drying costs.

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[3]X-77- Nonionic-type spreader and activator. Valent U.S.A. Corp., 1333 N. California Blvd., P.O. Box 8025, Walnut Creek, CA 94596-8025.

[4]MSTAT (Microcomputer statistical program), East Lansing, MI.

[5] Cost values were taken from Ext. Bul. E-2131. "Custom Work Rates in Michigan". Michigan State University, 1988.

Table 3: Weed control operations and associated air temperatures and plant heights, 1991.

	Date	Air Temp	Height			
			ZEAMX[a]	SETFA[a]	AMARE[a]	ABUTH[a]
		(°F)	(in)			
Bromoxynil (0.38 lb/acre) Nicosulfuron (0.031 lb/acre) NIS[b] (0.25% v/v)	June 3	70	10	5	1	3
1st Cultivation	June 7	79	14	6	5	5
2nd Cultivation	June 21	88	30	2	1	1

[a]Abbreviations: ABUTH, velvetleaf (*Abutilon theophrasti*); AMARE, redroot pigweed (*Amaranthus retroflexus*); SETFA, giant foxtail (*Setaria faberii*); and ZEAMX, corn (*Zea mays*).

[b]X-77, Nonionic-type spreader and activator.

Table 4: Spray equipment and application information, 1991

	Band	Broadcast
Nozzles	80015E[a]	8003[a]
Pressure (psi)	30	30
Spray Volume (gpa)	35	22

[a]80015E = 80° even flat fan nozzle delivering .15 gpm; 8003 = 80° tapered flat fan nozzle delivering 0.3 gpm.

Table 5: Rainfall in relationship to planting date.

DAYS AFTER PLANTING	1990	1991
	---------- inches ----------	
-7 - 0	1.7	4.0
0 - 7	3.2	1.7
8 - 14	2.2	3.0
15 - 30	3.0	3.6
31 - 60	2.4	2.7
61 - 90	3.2	0.8

RESULTS AND DISCUSSION

Preemergence Study

Effect of Rotary Hoeing, 1990 and 1991

Crop Response. Corn populations did not significantly differ among herbicide or cultivation treatments in 1990. However, an early rotary hoeing reduced corn stand by 11% (data not presented). Shallower planting depths and good penetration from the hoe, removed some newly emerging corn plants.

In 1991, there was no difference in corn population in any weed management treatment (data not presented). Unlike 1990, field conditions were poor and the corn was planted at 2 1/2 inches to ensure adequate moisture and seed-soil contact.

Weed Response. Rotary hoeing when weeds had germinated but not yet emerged removed shallow germinating weeds but had little to no effect on deeply rooted broadleaves. Mid-season weed counts indicated no reduction in weed populations from rotary hoeing in either 1990 or 1991 (data not presented). Due to the intense weed populations, weeds removed from the rotary hoe were quickly replaced by a second flush of weeds. Under conditions with less weed pressure, rotary hoeing may be more effective by controlling a single flush of small emerging weeds (Doll et al., 1990). Weed populations were therefore averaged over rotary hoe treatments since no differences in weed populations were observed among rotary hoe treatments.

Effect of Herbicide and Cultivation on Weed Population and Corn Yield

Weed Populations in The Corn Row, 1990. Untreated plots had a weed population of 65 plants/ft^2 in the corn row (Figure 1a). This population was reduced by 12% with one cultivation. This small reduction was a result of the cultivator throwing soil into the corn

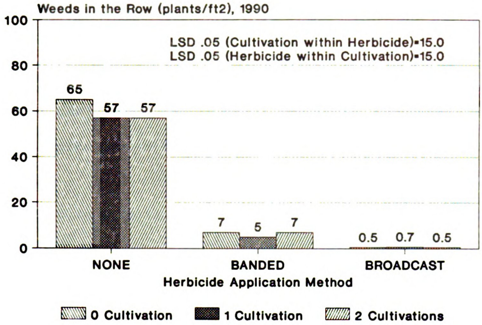

Figure 1a. Weeds in the corn row as affected by preemergence herbicide and cultivation, 1990.

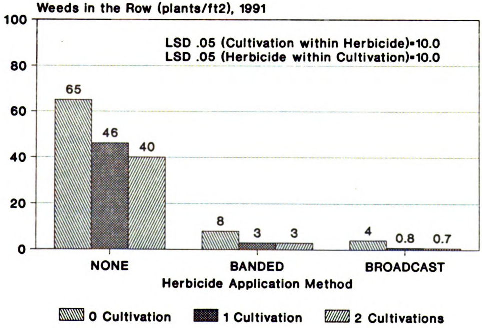

Figure 1b. Weeds in the corn row as affected by preemergence herbicide and cultivation, 1991.

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row, thus covering some of the small emerging weeds. No further reduction in weed population occurred following a second cultivation. When a 10 inch band of herbicide was applied, weed populations were reduced by 90%. Cultivation of the banded herbicide treatments did not improve control of weeds in the row. Weed populations in the corn row were not significantly different in the broadcast herbicide treatments as compared to the banded herbicide treatments. This would be expected, since both the band and broadcast herbicide treatments received the same amount of herbicide in the corn row.

Weed Populations in The Corn Row, 1991. Plots receiving no herbicide or cultivation had 65 plants/ft^2 in the corn row (Figure 1b). Cultivating once improved weed control in the row by 30%. This same reduction from the first cultivation occurred in 1990 possibly due to soil being thrown into the corn row, thus covering up small weeds. No significant reduction in weed population was seen from a second cultivation. Banded herbicide treatments without cultivation significantly reduced weed populations to 8 plants/ft^2 (Figure 1b). Cultivation of the banded herbicide treatments did not improve control of weeds in the row. Weed populations in the corn row were not significantly different in the broadcast herbicide treatments as compared to the banded herbicide treatments. Supplemental cultivation in the broadcast herbicide treatments did not significantly reduce weed populations. Weed populations in the corn row in 1991 were very similar to those in 1990.

Weed Populations Between The Corn Row, 1990. Weed populations between the corn row were reduced 90% following one cultivation (Figure 2a). A second cultivation reduced weed populations to 2 plants/ft^2. Therefore, the greatest reduction in weeds from mechanical control occurred with the first cultivation with a much smaller effect from the second cultivation. Banded herbicide treatments had weed populations between the corn row similar

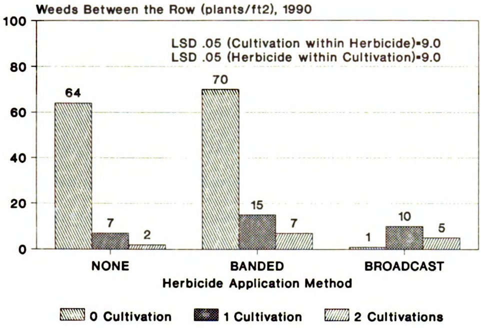

Figure 2a. Weeds between the corn row as affected by preemergence herbicide and cultivation, 1990.

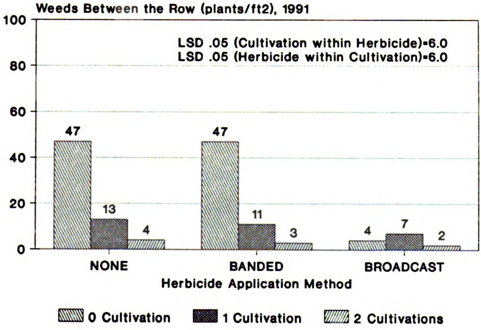

Figure 2b. Weeds between the corn row as affected by preemergence herbicide and cultivation, 1991.

to the untreated plots. Cultivating the banded herbicide treatment reduced weed populations from 70 to 15 plants/ft^2; an 80% reduction in weed numbers (Figure 2a). A second cultivation further reduced the number of weeds between the corn row to 7 plants/ft^2. Broadcast herbicide treatments alone reduced the weed population between the corn row to 1 plant/ft^2, a 98% reduction when compared to the untreated plots (Figure 2a). However, when broadcast herbicide treatments were cultivated once, weed populations increased to 10 plants/ft^2. It is probable that this is due to the disruption of the herbicide layer by the cultivator, allowing weed escapes. Some of these weeds emerging from the first cultivation were then removed by the second cultivation where weed populations were reduced to 5 plants/ft^2 in these plots.

Weed Populations Between The Corn Row, 1991. Corn which received no cultivation or herbicide had 47 plants/ft^2 between the corn row (Figure 2b). One cultivation reduced weed populations 72%. A second cultivation reduced weed populations from 13 to 4 plants/ft^2. In 1990, the first cultivation was more effective in removing weeds than it was in 1991, and thus a reduction in weed population from the second cultivation did not occur in 1990. When banded herbicide treatments were cultivated one time, weed populations were reduced from 47 to 11 plants/ft^2, amounting to a 77% reduction (Figure 2b). A second cultivation further reduced weed populations to 3 plants/ft^2. A similar trend occurred with a second cultivation in 1990. Banded herbicide treatments with supplemental cultivation provided weed control between the row equivalent to broadcast herbicide treatments that received supplemental cultivation. Two cultivations removed weeds between the corn row as effectively as treatments that received broadcast herbicide. Thus two cultivations can control weeds between the corn row as effectively as a broadcast herbicide treatment with no supplemental cultivation, but not weeds within the corn row.

Corn Yield, 1990. Corn receiving no herbicide or cultivation produced a grain yield of 46 bu/acre (Figure 3a). Corn yield increased to 101 bu/acre following a single cultivation, doubling the yield over the untreated plot. Corn yield did not significantly increase by an additional cultivation. We can compare these corn yields to weed populations in and between the corn row. The most substantial decrease in weed population in or between the corn row was also a result of the first cultivation (Figure 2a). There was no significant effect from a second cultivation on weed populations in or between the corn row or corn yield.

Corn receiving a banded herbicide treatment without cultivation produced a grain yield of 124 bu/acre (Figure 3a). Corn grain yield was increased to 159 bu/acre through the addition of one cultivation. The number of weeds between the corn row was also significantly reduced from this first cultivation (Figure 2a). Corn yield was not significantly increased from a second cultivation which corresponds to weed populations in and between the corn row not being reduced. Broadcast herbicide treatments without supplemental cultivation produced a yield of 173 bu/acre. Yield was not increased from supplemental cultivation. It was necessary to cultivate twice when banding the herbicide in order to obtain yields comparable to the broadcast treatments.

Corn Yield, 1991. In 1991, corn receiving no herbicide or cultivation produced a grain yield of 97 bu/acre (Figure 3b). Corn yield increased to 153 bu/acre following one cultivation. Weed populations in and between the corn row decreased following one cultivation and thus corn yields increased significantly. Weed populations between the row in treatments cultivated a second time decreased compared to that of one cultivation, however, no corresponding corn yield increase occurred.

Banded herbicide treatments with no supplemental cultivation yielded 117 bu/acre (Figure 3b). One supplemental cultivation lowered weed populations between the corn row (Figure

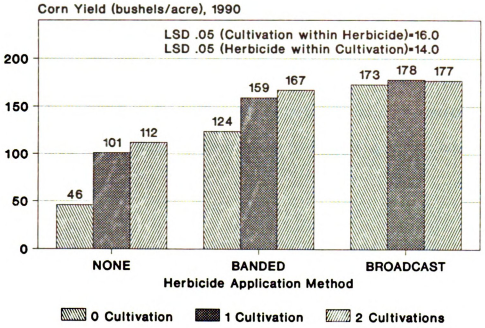

Figure 3a. Corn yield as affected by preemergence herbicide and cultivation, 1990.

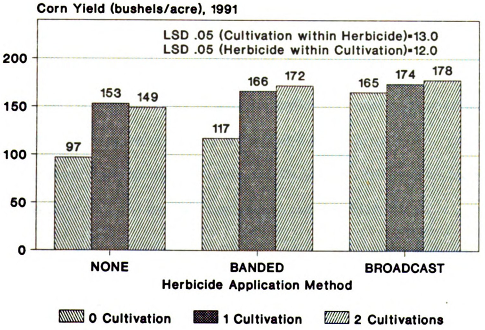

Figure 3b. Corn yield as affected by preemergence herbicide and cultivation, 1991.

2b) and yield increased to 166 bu/acre. Weed populations between the row were reduced from a second cultivation (Figure 2b) but increases in yield were not observed (Figure 3b). Broadcast herbicide treatments without cultivation yielded 165 bu/acre. This yield was similar to the banded herbicide treatments with one or two cultivations. Two cultivations of broadcast herbicide treatments increased corn yield compared to the broadcast herbicide treatment alone. Weed populations did not differ in these broadcast treatments (Figure 2b), and thus yield increases related to cultivation may be due to an agronomic factor other than weed control.

Economics, 1990. Net returns were computed using a $2.00 and $2.50/bu corn price (Table 6). A $2.00/bu corn price will be used for discussion unless otherwise indicated. Corn without herbicides or cultivation produced a net return of $92.00/acre. Treatments receiving one cultivation had a net return of $197.50/acre. A second cultivation slightly increased yield, which compensated for the added expense of the second cultivation. Corn receiving a banded herbicide treatment without cultivation averaged a net return of $238.08/acre, giving a higher net return than any of the mechanical treatments alone. Banded herbicide treatments receiving one cultivation gave a net return of $303.58/acre. A second cultivation boosted net returns to $315.08/acre. A broadcast herbicide application without subsequent cultivation resulted in a higher net return than any of the banded herbicide treatments. One cultivation further increased yields, giving a net return of $329.34/acre. Yield was not increased from the second cultivation, and thus net returns were lowered to $322.84/acre.

Table 6. Corn yields and net returns above weed control costs with preemergence herbicide, 1990.

					Returns[a]			
		Variable Costs		Corn	$2.00/Bu		$2.50/Bu	
Herbicide[b]	Cultivation	Mechanical	Herbicide	Yield[c]	Total	Net	Total	Net
		---------- ($/A) ----------		(Bu/A)				
None	0	0	0	46	92.00	92.00	115.00	115.00
	1	4.50	0	101	202.00	197.50	252.50	248.00
	2	9.00	0	112	224.00	215.00	280.00	271.00
Band	0	3.80	6.12	124	248.00	238.08	310.00	300.08
	1	8.30	6.12	159	318.00	303.58	397.50	383.08
	2	12.80	6.12	167	334.00	315.08	417.50	398.58
Broadcast	0	3.80	18.36	173	346.00	323.84	432.50	410.34
	1	8.30	18.36	178	356.00	329.34	445.00	418.34
	2	12.80	18.36	177	354.00	322.84	442.50	411.34

[a]Net returns above weed control cost = (yield * corn price) - (mechanical cost + herbicide cost).

[b]Herbicide program consisted of metolachlor (2.0 lb ai/acre) + atrazine (1.0 lb ai/acre) applied preemergence.

[c]Corn yield averaged over rotary hoe treatments and calculated at 15.5% moisture.

Economics, 1991. Corn without herbicides or cultivation produced a net return[6] of $194.00/acre (Table 7). One cultivation increased yield significantly, giving a net return of $301.50/acre. A second cultivation did not improve corn yield and as a result, net returns fell to $289.00/acre. In 1990 this second cultivation increased net returns when compared to one cultivation. Banded herbicide treatments without supplemental cultivation gave a net return of $224.00/acre. One cultivation boosted yields significantly, giving a net return of $317.58/acre. Net returns were further increased from a second cultivation. Broadcast herbicide treatments without any cultivation gave a net return of $307.84/acre, therefore banded herbicide treatments with one or two cultivations gave a higher net return than broadcast herbicide treatments without supplemental cultivation. This was not the case in 1990. Net returns were increased from a cultivation in the broadcast treatments, however banded herbicide treatments with two supplemental cultivations still had a higher net return. Broadcast herbicide treatments with two cultivations had a higher yield than banded herbicide treatments with two cultivations. However net returns were greater in the banded herbicide treatments with cultivations because cost was reduced from using less herbicide. In 1991, banded herbicide treatments with two cultivations gave the highest net returns.

Postemergence Study, 1991

Effect of Herbicide and Cultivation on Weed Population and Corn Yield

Weed Populations in The Corn Row, 1991. Corn which received no cultivation or herbicide had 76 weeds/ft^2 in the corn row (Figure 4). One cultivation reduced weed populations 11%. In this study, the first cultivation was done four days later compared to the preemergence study. Weeds were thus larger and more difficult to remove in the row with the first

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[6]net returns=net returns above weed control costs

Table 7. Corn yield and net returns above weed control costs with preemergence herbicide, 1991.

		Variable Costs		Corn	Returns[a]			
					$2.00/Bu		$2.50/Bu	
Herbicide[b]	Cultivation	Mechanical	Herbicide	Yield[c]	Total	Net	Total	Net
		---------- ($/A) ----------		(Bu/A)				
None	0	0	0	97	194.00	194.00	242.50	242.50
	1	4.50	0	153	306.00	301.50	382.50	378.00
	2	9.00	0	149	298.00	289.00	372.50	363.50
Band	0	3.80	6.12	117	234.00	224.00	292.50	282.58
	1	8.30	6.12	166	332.00	317.58	415.00	400.58
	2	12.80	6.12	172	344.00	325.08	430.00	411.08
Broadcast	0	3.80	18.36	165	330.00	307.84	412.50	390.34
	1	8.30	18.36	174	348.00	321.34	435.00	408.34
	2	12.80	18.36	178	356.00	324.84	445.00	413.84

[a]Net returns above weed control costs = (yield * corn price) - (mechanical cost + herbicide cost).

[b]Herbicide program consisted of metolachlor (2.0 lb ai/acre) + atrazine (1.0 lb ai/acre) applied preemergence.

[c]Corn yield averaged over rotary hoe treatments and calculated at 15.5% moisture.

cultivation. However, the second cultivation reduced weed populations in the row by 51% (Figure 4). Banded herbicide treatments alone had weed populations of 2 plants/ft^2, a 96% reduction when compared to no herbicides or cultivation. Cultivating the banded herbicide treatments either one or two times did not significantly reduce weed populations in the corn row as compared to the band treatments alone. This was also seen in the preemergence study in both years of research. Banded herbicide treatments controlled weeds in the row as affectively as broadcast herbicide treatments either alone or with subsequent cultivation.

Weed Populations Between The Corn Row, 1991. Corn which received no cultivation or herbicide had 53 weeds/ft^2 between the corn row (Figure 5). One cultivation reduced weed populations 79%. No further reduction in the number of weeds between the corn row was seen from cultivating a second time. Banded herbicide treatments that were not cultivated had 75 plants/ft^2 between the corn row. One cultivation reduced weed populations 81%. No significant reduction was seen from a second cultivation. Weed populations in the broadcast herbicide treatments were very low and did not differ, regardless of the cultivation. These results are similar to those reported in the preemergence study in 1991.

Corn Yield, 1991. Corn which received no cultivation or herbicide yielded 54 bu/acre (Figure 6). Treatments that were cultivated once yielded 102 bu/acre. No significant increase in corn yield occurred following the second cultivation. Trends in weed populations are inversely related to corn yield for these three treatments. Banded herbicide treatments that were not cultivated yielded 137 bu/acre. One cultivation reduced these weed populations (Figure 5) and corn yield increased to 170 bu/acre. Band treatments that were cultivated twice yielded 180 bu/acre however, this 10 bu/acre increase was not statistically significant. Broadcast herbicide treatments without cultivation yielded 171 bu/acre, and supplemental

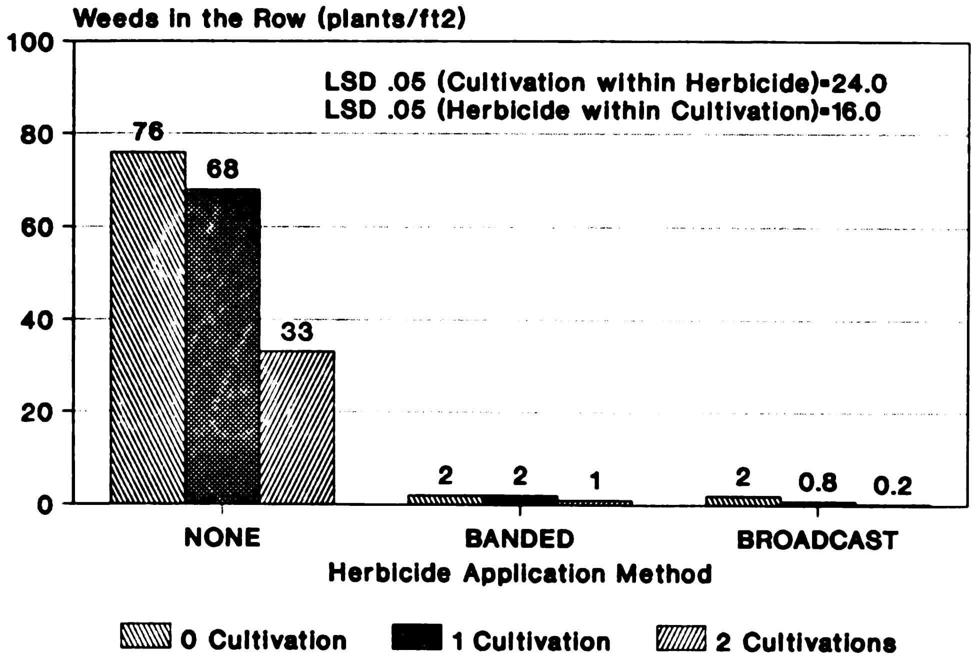

Figure 4. Weeds in the corn row as affected by postemergence herbicide and cultivation, 1991

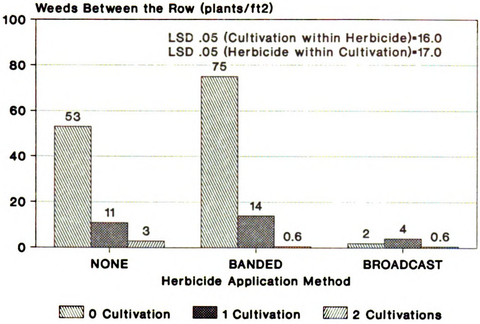

Figure 5. Weeds between the corn row as affected by postemergence herbicide and cultivation, 1991.

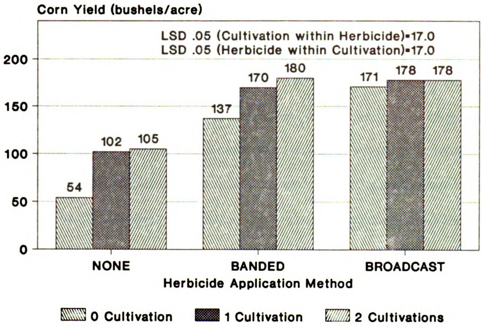

Figure 6. Corn yield as affected by postemergence herbicide and cultivation, 1991.

cultivation did not significantly improve yield. Banded treatments with one or two cultivations yielded as much or more as any of the broadcast herbicide treatments.

Economics, 1991. Corn without herbicide or cultivation produced a net return of $108.00/acre (Table 8). One cultivation boosted yields and doubled net returns to $199.50/acre. Very little increase in net return was provided from cultivating a second time. All weed control systems that included herbicides resulted in a greater net return than those without herbicides, regardless of cultivation treatment. Banded postemergence herbicide treatments without supplemental cultivation averaged a net return of $260.88/acre. Cultivating these banded herbicide treatments one time significantly increased yield, giving a net return of $322.38/acre. A second cultivation provided only a small increase in yield, however this increase was more than enough to pay for the added expense of the second cultivation, giving a net return of $337.88/acre. Broadcast postemergence herbicide treatments without cultivation yielded the same as banded postemergence herbicide treatments receiving one cultivation. However banded postemergence herbicide treatments with one cultivation gave a higher net return because of the reduced herbicide cost. Broadcast postemergence treatments with two cultivations yielded the same as broadcast herbicide treatments with one cultivation but the added expense from the second cultivation reduced net returns. Banded postemergence treatments with two cultivations provided the highest net returns in the postemergence study.

Table 8. Corn yield and net returns above weed control costs with postemergence herbicide, 1991.

					Returns[a]			
		Variable Costs		Corn	$2.00/Bu		$2.50/Bu	
Herbicide[b]	Cultivation	Mechanical	Herbicide	Yield[c]	Total	Net	Total	Net
		---------- ($/A) ----------		(Bu/A)				
None	0	0	0	54	108.00	108.00	135.00	135.00
	1	4.50	0	102	204.00	199.50	255.00	250.50
	2	9.00	0	105	210.00	201.00	262.50	253.50
Band	0	3.80	9.32	137	274.00	260.88	342.50	329.38
	1	8.30	9.32	170	340.00	322.38	425.00	407.38
	2	12.80	9.32	180	360.00	337.88	450.00	427.88
Broadcast	0	3.80	27.49	171	342.00	310.71	427.50	396.21
	1	8.30	27.49	178	356.00	320.21	445.00	409.21
	2	12.80	27.49	178	356.00	315.71	445.00	404.71

[a]Net returns = (yield * corn price) - (mechanical cost + herbicide cost).

[b]Herbicide program consisted of bromoxynil (0.38 Lb ai/acre) + nicosulfuron (0.031 lb ai/acre) + nonionic surfactant (0.25% v/v) applied postemergence.

[c]Corn yield averaged over rotary hoe treatments and calculated at 15.5% moisture.

Discussion. Cultivation alone controlled weeds and improved corn yield but did not provide yields as high as systems where herbicides were utilized. The greatest increase in yield from mechanical weed control occurred with the first cultivation, however the yields in banded herbicide treatments were always increased from a second cultivation. Banded herbicide treatments receiving one cultivation provided yields comparable to broadcast herbicide treatments without cultivation. Banded treatments receiving two cultivations provided yields that were equal to that of broadcast treatments with one or two cultivations. In the preemergence study in 1990 broadcast treatments with one cultivation gave the highest net return. In 1991, preemergence and postemergence banded herbicide treatments receiving two cultivations gave the highest net return.

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CHANGING WEED MANAGEMENT PRACTICES IN SOYBEANS

Low input suggests the reduction of total chemical input into the farming system. Other practices must be adopted to control weeds, including rotary hoeing and cultivation. This study determined the impact of reduced herbicide and fertilizer inputs on weed species emergence and control in soybeans and resulting soybean yield. The experiment was designed as a split-block. The main plots in 1990 were: 1) early May planting, no starter fertilizer; and 2) early May planting with 198 lb/acre of 6-24-24 as starter fertilizer. In 1991 a late May planting date with no starter fertilizer was added as a third main plot. On each of these main plots, 17 weed control strategies were imposed. In 1990, adding starter fertilizer did not increase weed populations or soybean yield. Rotary hoeing did not reduce mid-season weed populations or influence soybean yield in either year. Weed populations in the control were similar in broadcast preemergence and broadcast postemergence herbicide treatments in 1990, but greater in preemergence treatments in 1991. A single cultivation increased soybean yield for both preemergence and postemergence broadcast treatments each year. Postemergence broadcast herbicide treatments resulted in greater soybean yield than preemergence herbicide treatments in 1990, but not in 1991. Banded postemergence and soil-applied treatments failed to give adequate weed control in 1990 or 1991 even when rotary hoed and cultivated twice. Yet, one quarter of a standard postemergence herbicide treatment banded and applied twice or a full rate banded once resulted in acceptable soybean yield when cultivated twice in 1991. The highest net return in 1990 was from postemergence broadcast treatments with one cultivation. With the early planting in 1991, treatments receiving reduced rates of herbicide with cultivation produced net returns equivalent to treatments receiving full rate herbicide with cultivation. In the late planted soybeans, this same trend was observed however, treatments receiving only two cultivations had net returns equivalent to all the treatments except where a broadcast preemergence or postemergence herbicide treatment without cultivation was applied.

INTRODUCTION

Soybean producers can control weeds culturally, chemically, and mechanically. Most growers use a combination of these three control practices, e.g., crop rotation, herbicide application and cultivation. Soybeans are a nitrogen-fixing legume crop which do not require nitrogen fertilizer inputs. However, over 50% of Michigan soybean growers still use starter fertilizer containing 10-15 lbs of nitrogen when planting soybeans. Starter fertilizer may improve early crop vigor, but it may also increase the emergence and competitiveness of weeds in the crop row (Vengris et al., 1953; Okafor and De Datta, 1976; Dotzenko et al., 1969; Banks et al., 1976).

Planting date is a major factor influencing weed control. Planting later in the spring may reduce the number of weeds because peak weed germination is before mid May when soil temperature reaches 60 F and many weeds may germinate, emerge, and be controlled by tillage prior to planting. However, later planting may have a detrimental effect soybean yield because optimal planting date for soybeans is prior to May 15 (Hesterman et al., 1987; Helsel et al., 1981).

LISA (low input sustainable agriculture) has become an important topic in the 1990s at the farm community, agribusiness, and legislative levels. Definitions of LISA vary depending upon the speaker and message, but use of "synthetic pesticides and fertilizers" are two areas usually addressed. Low input suggests the reduction of total chemical inputs into the farming system. This usually means that other practices must be adopted to control weeds. Such practices include rotary hoeing, cultivation, herbicide banding, reduced herbicide rates, and/or postemergence herbicide application. Labor inputs must be increased to obtain adequate weed control when these practices are implemented. The economics of low chemical-high management input systems should be evaluated to determine the balance between reduced pesticide and fertilizer input costs, and the potential increase in labor and fuel expense.

MATERIALS AND METHODS

Field research was conducted at the Michigan State University Crop and Soil Science Research Farm at East Lansing Mi, in 1990 and 1991. The soil was a Capac (fine-loamy, mixed, mesic Aeric Ochraqualfs) with an organic matter content of 2.6 and 3.8 and a soil pH of 7.3 and 7.8 in 1990 and 1991, respectively. In 1990 and 1991, the research site was chisel plowed in the fall and then disked and field cultivated in the spring. The entire experimental area was planted to 'Elgin 87' at a rate of 156,000 seeds/acre.

The experimental design was a factorial arranged as a split-plot. In 1990, the main plots consisted of: no starter fertilizer and starter fertilizer (6-24-24) ($N-P_20_5-K_20$) applied at planting at a rate of 198 lb/acre. In 1991 a May 30 planting date with no starter was added to investigate the effects of a late planting on weed control and soybean yield. The late planted field area was field cultivated on May 8, 15 and 29 to remove emerged weeds prior to planting. Each of these main plots were then divided into 17 weed management systems. Individual plots were 10 by 38-ft in 1990 and 10 by 35-ft in 1991.

Preemergence band and broadcast herbicide applications consisted of a tank-mix combination of metolachlor [2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2 methoxy-1-methylethyl) acetamide] at 2.0 lb ai/acre, linuron [*N'*-(3,4-dichlorophyl)-*N*-methoxy-*N*-methylurea] at 0.38 lb ai/acre and metribuzin [4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5(4*H*)-one] at 0.18 lb ai/acre. Treatments were applied immediately after planting. Application equipment information can be found in Table 1.

Table 1: Application Equipment

Appl. Time	Sprayer Type	Speed MPH	Nozzle Type	Nozzle Size	Nozzle Height (in)	Boom Width (in)	GPA	Carrier	PSI
Pre	Comp. Air	3.2	Flat Fan	8003	20	100	22	H_20	30
Pre Band	Comp. Air	3.2	Even ff	40015	12	120	22	H_20	30
E-Post	Comp. Air	3.2	Even ff	40015	12	120	22	H_20	30
Post	Comp. Air	3.2	Flat fan	8003	20	100	29	H_20	50
Post Band	Comp. Air	3.2	Even ff	40015	16	120	29	H_20	50

Early rotary hoe treatments were applied when weeds had germinated but not yet emerged (white stage). Selected treatments were late rotary hoed when weeds were cotyledon to one leaf. Treatments were rotary hoed at 8 mph.

Early postemergence herbicide applications were banded at 1/4 of the standard postemergence application rate. A tank-mix combination of bentazon [3-(1-methylethyl)-(1*H*)-2,1,3-benzothiadiazin-4(3*H*)-one 2,2-dioxide] at 0.19 lb ai/acre, acifluorfen[5-[2-chloro-4-(trifluoromethyl)phenoxy]-2-nitrobenzoic acid] at 0.060 lb ai/acre and crop oil concentrate[7] at 1.0 pt/acre was applied.

Postemergence herbicide applications at the standard timing consisted of a tank mix of bentazon at 0.75 lb ai/acre, acifluorfen at 0.25 lb ai/acre and crop oil concentrate at 1.0 pt/acre. Weed and crop stages at the time of application can be found in Table 2. Predominant weed species in 1990 included common ragweed (*Ambrosia artemisiifolia* L.), and common lambsquarters (*Chenopodium album* L.), and in 1991 redroot pigweed (*Amaranthus retroflexus* L.), and velvetleaf (*Abutilon theophrasti* Medicus) (Table 3).

Selected treatments were first cultivated[8] when weeds were approximately at the four leaf stage. Soybean plots were then cultivated a second time, 14 days after the first cultivation.

Total soybean plant populations were taken in the center two rows of each plot prior to any mechanical cultivation. In 1990, quadrats (10 by 36-in) were placed over the soybean row prior to cultivation to determine the density of weeds present in the row. After all mechanical cultivation was complete, weed densities were determined within and between the soybean row with these same quadrats. Early and late weed populations were also taken in

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[7]Crop Oil Concentrate. Herbimax, petroleum hydrocarbons (83%) - light paraffinic distillate, odorless alaphatic petroleum solvent, surfactant (17%) - mono and diesters of omega hydroxypoly oxyethylene, Loveland Industries, Loveland, IO.

[8]John Deere 875 minimum tillage c-shank cultivator, Deere and Co., Moline, IL 61265-1304.

Table 2: Weed Control Operations and Plant Growth Stage[a]

Table 2: Weed Control Operations and Plant Growth Stage[a]

	Time of Herbicide Application[b]			Rotary Hoe		Cultivation	
	Pre	E-Post	Post	Early	Late	1st	2nd
May 8, 1990							
Dap[c]	1	23	34	6	21	38	52
Crop Stage	-	VC	V2	VE	VC	V3	V5
Weed Stage	-	2 lf	5 lf	white	coty	4 lf	coty
May 9, 1991							
Dap	-	11	20	4	11	26	40
Crop Stage	-	VC	V2	-	VC	V3	V6
Weed Stage	-	1 lf	4 lf	white	coty	5 lf	coty
May 30, 1991							
Dap	-	14	20	5	14	27	42
Crop Stage	-	VC	V2	VE	VC	V5	V6
Weed Stage	-	1 lf	5 lf	white	coty	6 lf	coty

[a]Abbreviations: coty=cotyledon; VC=cotyledon; VE=emergence; V(n)=number of nodes on the main stem; white=germinated but not emerged.

[b]Pre=preemergence herbicide applciation, E-Post=early postemergence herbicide application, and Post=postemergence herbicide application.

[c]Dap=days after planting

Table 3: Weed populations in untreated plots.

	IN THE ROW		BETWEEN THE ROW	
	1990	1991	1990	1991
C. LAMBSQUARTERS	11	-	15	2
C. RAGWEED	9	-	6	-
REDROOT PIGWEED	-	32	-	33
VELVETLEAF	-	2	-	3
TOTAL	20	34	21	38

1991. Because herbicide band widths and measuring quadrat widths were the same, border effects were encountered in 1990. To overcome this effect, quadrat width was reduced from 10 to 8 in. in 1991 but quadrat length was increased by 8 inches to keep total area the same. The center two row of the soybeans were harvested with a plot combine. Grain moisture was recorded and yields were adjusted to 14% moisture. Rainfall data can be found in Table 4. The statistical package used was MSTAT[9].

The economic analysis was based on variable input costs[10] and net return. Variable input costs include: tillage, herbicide, fuel, and labor. A $5.50/bu soybean price was assumed. Net returns above weed control costs were computed by multiplying the price/bu of soybeans by yield and subtracting total variable input costs. Variable cost include only those costs that changed from one treatment to another and do not include cost associated with land or management such as taxes, depreciation, and interest.

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[9]MSTAT (Microcomputer statistical program), Michigan State University., East Lansing, Mi.

[10]Cost values were taken from Ext. Bul. E-2131. "Custom Work Rates in Michigan". Michigan State University, 1988.

Table 4: Rainfall

Table 4: Rainfall Intervals

days after planting	1990	1991	
	May 8 planting	May 9 planting	May 30 planting
	(in)	(in)	(in)
-7 - 0	0.8	0.1	0.9
0 - 7	0.4	0.1	0.8
8 - 14	2.0	0.3	1.5
15 - 30	0.2	1.7	1.0
31 - 60	2.1	4.5	2.5
61 - 90	3.3	1.8	3.9

RESULTS AND DISCUSSION

There was no significant effect of starter fertilizer on weed populations or soybean yield in 1990 or 1991. Soil fertility levels were high in each year of research. Thus, weed populations and soybean yields will be averaged over the fertilized and non fertilized plot areas.

There were significant year by weed management treatment and planting date by weed management treatment interactions. Therefore, data will be presented separately for 1990 and 1991 and for early and late planted soybean weed management treatments in 1991.

Soybean Response. Early rotary hoeing reduced soybean plant populations by 9% in 1990 and 1991 (data not presented). Lovely et al. (1950) found similar results with a timely rotary hoeing reducing soybean population by 10%. Rotary hoeing late, when weeds were cotyledon to one leaf, reduced soybean plant populations by 3 and 6% in 1990 and 1991, respectively (data not presented).

Weed populations. Control plots averaged 20 and 34 weeds/ft^2 in 1990 and 1991 respectively (Table 3). Broadcast preemergence herbicide treatments without any supplemental cultivation averaged 1.3 weeds/ft^2 in the soybean row in 1990 and 0.6 weeds/ft^2 in 1991 and late planted soybean plots averaged 1.4 weeds/ft^2. Thus a 94 and 98% reduction in weed population occurred from broadcast preemergence herbicides in 1990, 1991, and late planted in 1991 (Figure 1). The number of weeds in the soybean row did not decrease in 1990 or 1991 when broadcast preemergence treatments were rotary hoed and cultivated, or only cultivated (Figure 1). Weed populations in the late planted soybeans did not differ from weed populations in the early planted soybeans in 1991.

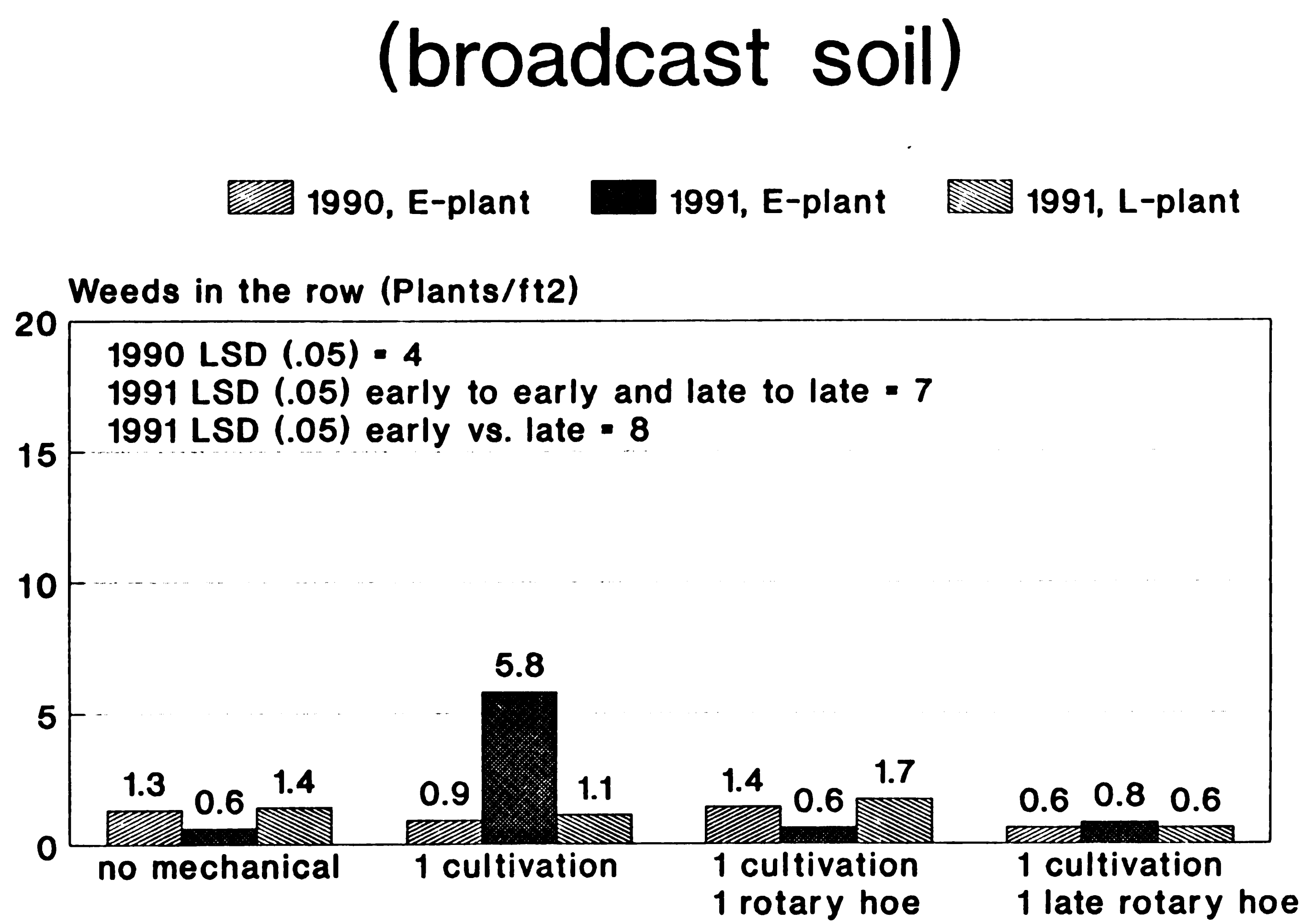

Figure 1. Weed populations in the soybean row as affected by broadcast postemergence herbicide, cultivation, and rotary hoe.

Similar comparisons can be made with broadcast postemergence herbicide treatments (Figure 2). Broadcast postemergence treatments without supplemental cultivation averaged 3.7 weeds/ft^2 in the row in 1990, 5.6 weeds/ft^2 in the early planted soybeans in 1991, and 2.3 weeds/ft^2 in late planted soybeans. Weed populations in the soybean row were not reduced by cultivating or rotary hoeing in 1990 or 1991.

Broadcast soil applied treatments averaged 0.95 weeds/ft^2 between the row in 1990, and 2.1 and 2.5 weeds/ft^2 for early and late planted soybeans in 1991, respectively (Figure 3). Weed populations between the row in the control plots averaged 21 weeds/ft^2 in 1990 and 38 and 12 weeds/ft^2 in the early and late planted soybeans in 1991, respectively. A small increase in the number of weeds was witnessed from supplemental cultivation in 1991, but not in 1990. Weed populations between the row in the late planted soybeans in 1991 were not reduced compared to weed populations in the early planted soybeans.

Figure 4 shows the number of weeds present between the soybean row following broadcast postemergence treatments. Broadcast postemergence treatments averaged 3.4 weeds/ft^2 in 1990 and 5.3 and 1.6 weeds/ft^2 for early and late planted soybeans respectively, 1991. This reduction in weed population from planting later however, was not significant. No reduction in weed population was seen from cultivation or rotary hoeing in 1990. However, in 1991 supplemental cultivation increased the number of weeds between the soybean row in the early planted soybeans. Possibly the first cultivation stimulated new weed seedling germination and emergence. In the late planted soybeans, field cultivation before planting may have reduced weed populations such that germination was not induced following cultivation, or alternatively, soil temperatures or moisture conditions following cultivation may not have been condusive for weed germination.

Figure 5 compares the number of weeds in the soybean row for banded versus broadcast preemergence and postemergence treatments. Weed populations in the soybean row following

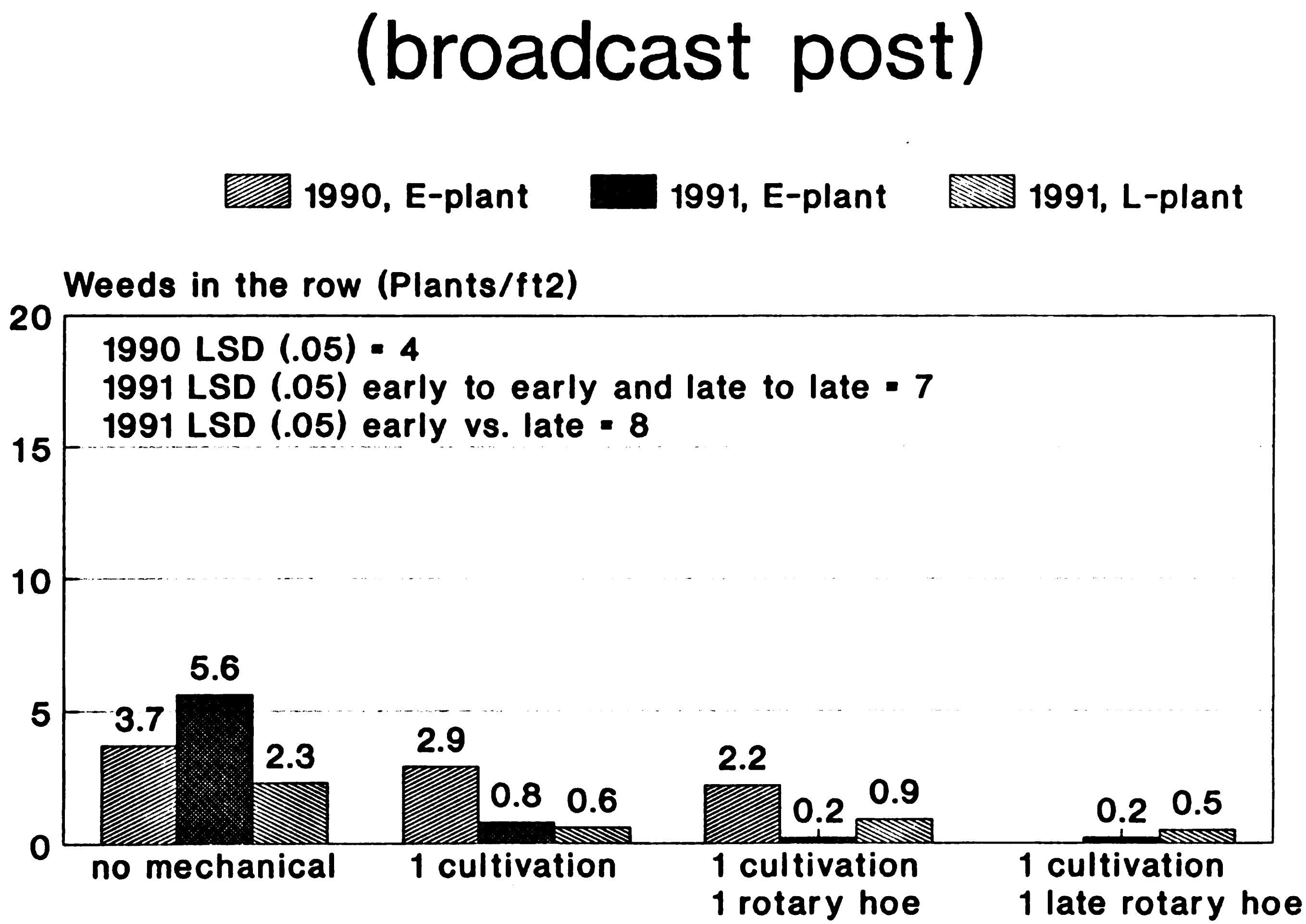

Figure 2 Weed populations in the soybean row as affected by broadcast postemergence herbicide, cultivation, and rotary hoe.

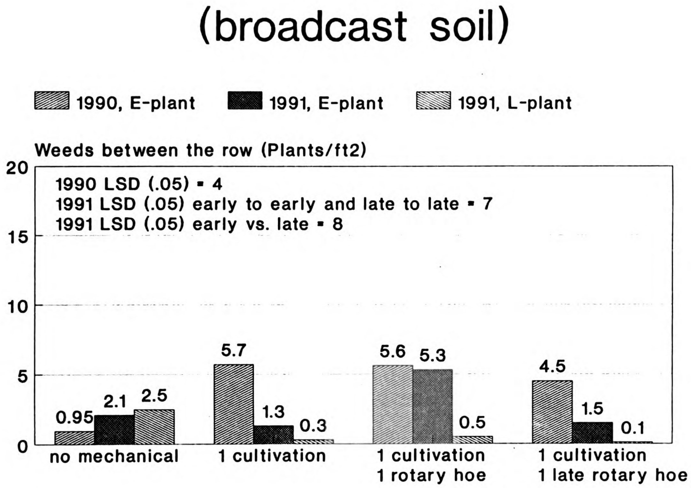

Figure 3 Weed populations between the soybean row as affected by broadcast preemergence herbicide, cultivation, and rotary hoe.

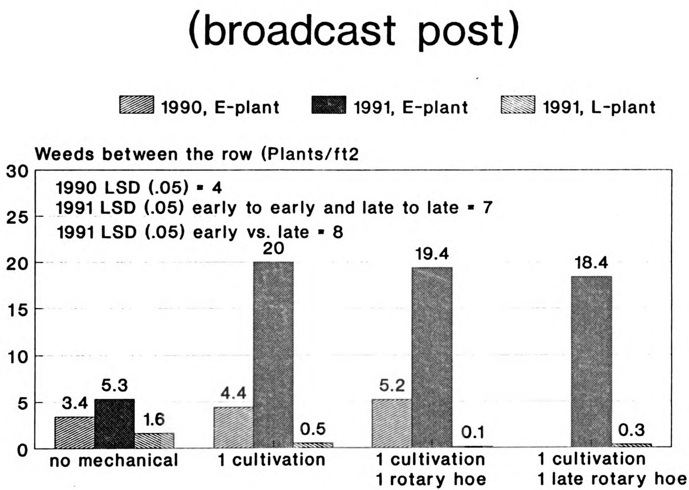

Figure 4 Weed populations between the soybean row as affected by broadcast postemergence herbicide, cultivation, and rotary hoe.

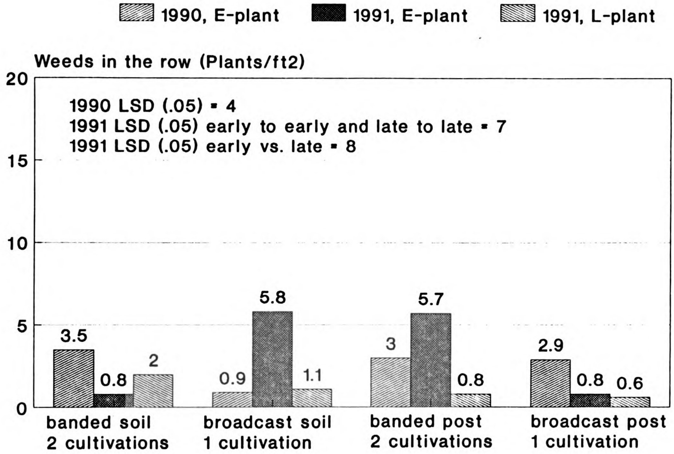

Figure 5 Weed populations in the soybean row as affected by banded and broadcast preemergence and postemergence herbicide and cultivation.

final cultivation did not differ in 1990, regardless if the herbicides were applied preemergence or postemergence, banded or broadcast. In 1991, these same trends occurred in both the early and late planted soybeans.

We can look at the number of weeds in the soybean row following application of postemergence herbicides at reduced rates (Figure 6). Weed populations in these treatments were similar to treatments that received a full rate in both 1990 and 1991, regardless of planting date.

Figure 7 compares the number of weeds between the soybean row for banded versus broadcast preemergence and postemergence treatments. Weed populations between the soybean row following final cultivation were similar, regardless if the herbicides were applied preemergence or postemergence, and banded or applied broadcast in 1990. However, in 1991, broadcast postemergence treatments followed by one cultivation had a substantially higher number of weeds between the soybean row. Possibly a single cultivation resulted in a new flush of weeds that germinated and a second cultivation was required to remove these weeds from between the soybean row. This was not seen in the preemergence treatments because of the residual soil activity from the herbicide. Weed populations in broadcast postemergence herbicide treatments with one cultivation were reduced in the late planted soybeans which may be due to tillage prior to planting, or unfavorable conditions for weed seed germination following cultivation.

Finally, we can look at the number of weeds between the soybean row following applications of postemergence herbicides at reduced rates (Figure 8). Weed populations did not differ from those treatments that received the full rate in both 1990 and 1991, regardless of the planting date. Thus, from the weed population data, one could conclude that 25% of the standard postemergence herbicide application rate, applied either early or late, provided weed suppression similar to that of the standard postemergence herbicide application rate.

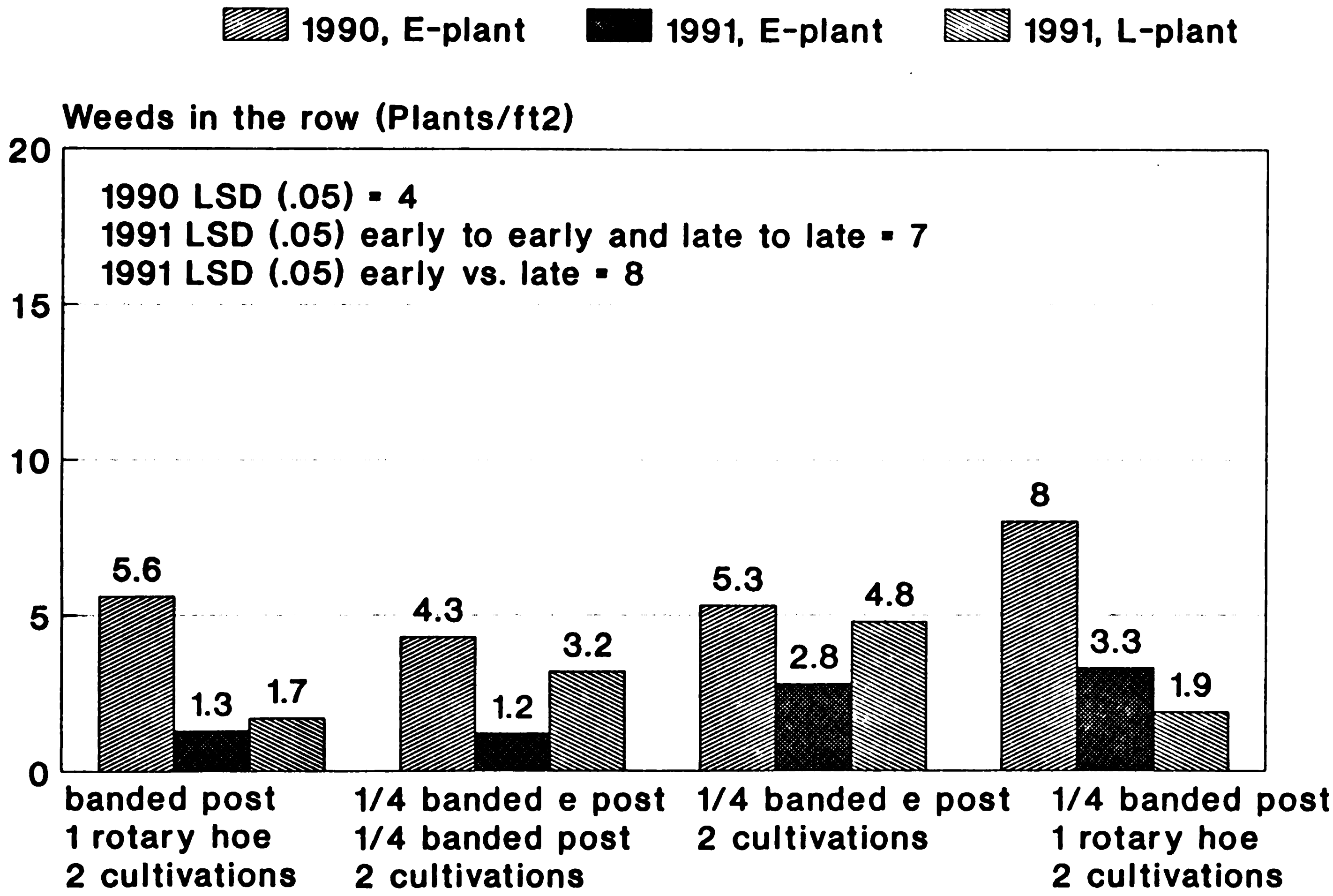

Figure 6 Weed populations in the soybean row as affected by standard and reduced rate postemergence banded herbicide, cultivation, and rotary hoe.

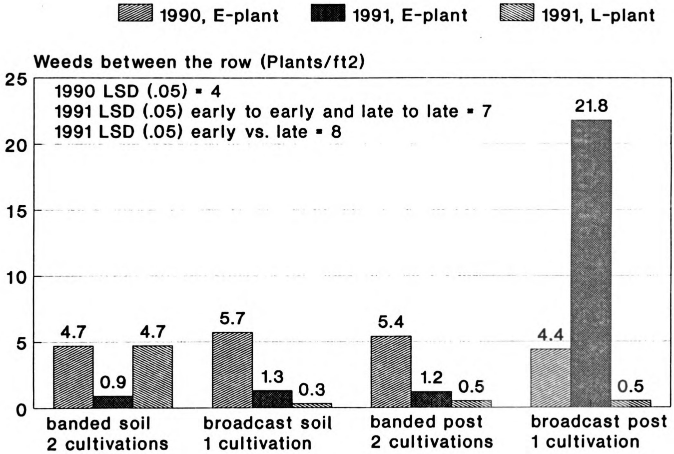

Figure 7 Weed populations between the soybean row as affected by banded and broadcast preemergence and postemergence herbicide and cultivation.

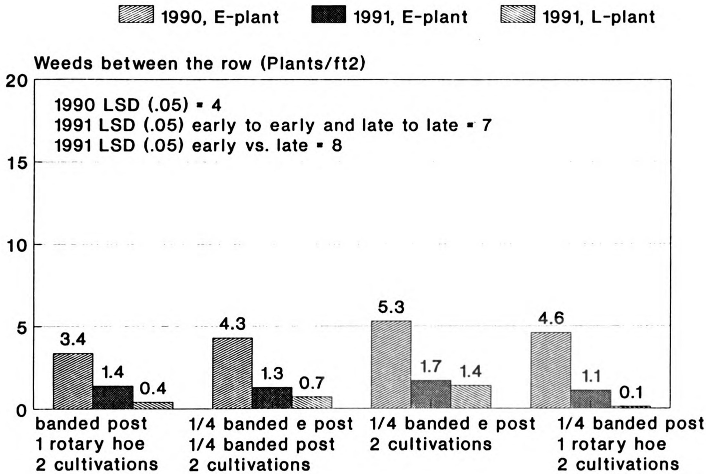

Figure 8 Weed populations between the soybean row as affected by standard and reduced rate postemergence banded herbicide, cultivation, and rotary hoe.

Soybean yield. Broadcast preemergence herbicide treatments without cultivation yielded 9 bu/acre in 1990 (Figure 9). One supplemental cultivation increased yield to 29 bu/acre however, handweeded control plots yielded 40 bu/acre. In 1991, early planted soybeans receiving broadcast preemergence treatments without cultivation yielded 49 bu/acre as compared to the late planted, which yielded 30 bu/acre. One supplemental cultivation increased yield to 58 bu/acre in the early planted soybeans and 50 bu/acre in the late planted soybeans. Thus, significant reductions in yield in these treatments were observed in the late planting. Rotary hoeing however, did not increase yield in 1990 or 1991.

Yield of broadcast postemergence treatments in 1990 increased from 18 bu/acre to 34 bu/acre when cultivated (Figure 10). Similar trends occurred in 1991 in the early planted soybeans, with yield increasing from 57 to 64 bu/acre following cultivation of the broadcast postemergence treatment. Late planted soybean yields increased from 43 to 54 bu/acre following cultivation of the broadcast postemergence herbicide treatment. Rotary hoeing of postemergence herbicide treatments did not increase yield compared to cultivation alone in either 1990 or 1991 (Figure 10). Broadcast postemergence treatments which were planted later yielded significantly less than those planted early in 1991.

Banded preemergence treatments with two cultivations yielded 11 bu/acre while broadcast preemergence treatments with one cultivation yielded 29 bu/acre in 1990 (Figure 11). Banded postemergence treatments with two cultivations yielded 23 bu/acre as compared to the broadcast postemergence treatments with one cultivation which yielded 34 bu/acre in 1990. In 1991 there was no difference in yield between these four weed management systems in either the early or late planted soybeans. However a significant yield reduction was observed in all cases from planting later. Thus, in only one of the two years did soybean yield in banded herbicide treatments equal that of the broadcast herbicide systems.

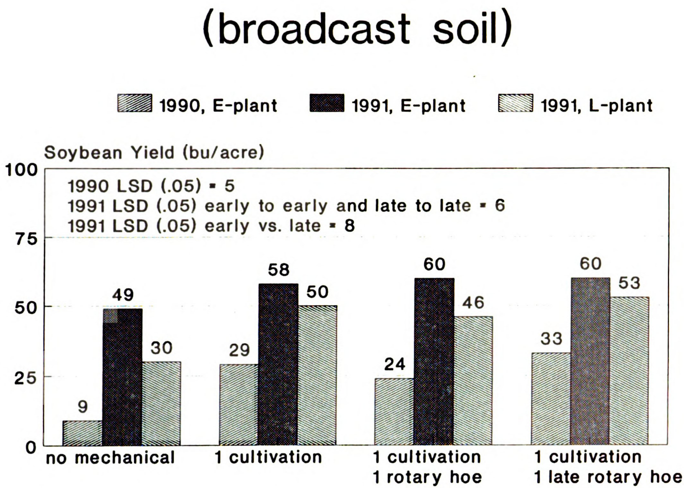

Figure 9 Soybean yield as affected by broadcast preemergence herbicide, cultivation, and rotary hoe.

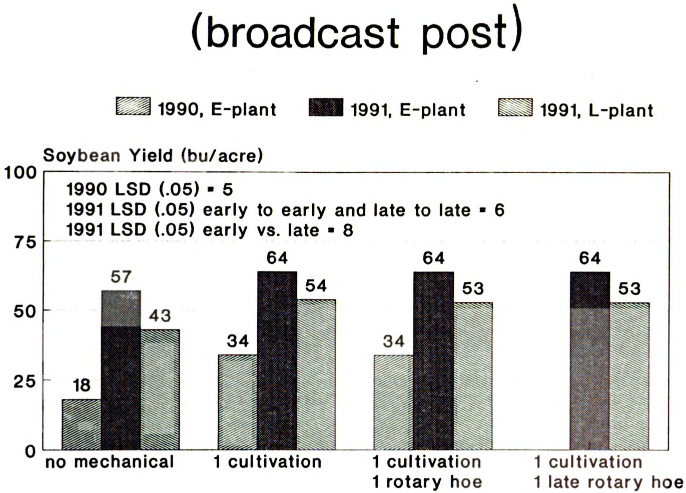

Figure 10 Soybean yield as affected by broadcast postemergence herbicide, cultivation, and rotary hoe.

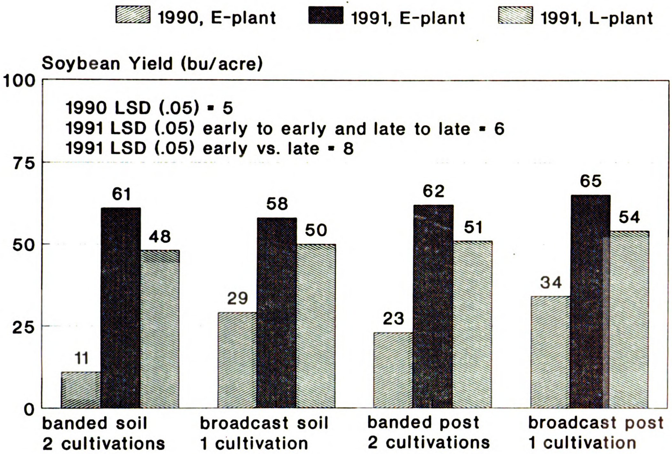

Figure 11 Soybean yield as affected by banded and broadcast preemergence and postemergence herbicide and cultivation.

Banded postemergence treatments followed by one rotary hoeing and two cultivations yielded 13 bu/acre in 1990, while treatments of 1/4 of the full rate applied early and again at the standard time yielded 24 bu/acre (Figure 12). In the early planted soybeans, in 1991, 1/4 of the standard rate applied early or at the standard time had yields comparable to the split treatments. In the late planted soybeans, banded postemergence treatments with one rotary hoe and two cultivations yielded 52 bu/acre, while treatments of 1/4 of the application rate applied early and again at the standard time yielded 48 bu/acre. Thus in one of two years, reduced postemergence herbicide applications at reduced rates resulted in soybean yield comparable to that of the handweeded control (71 bu/acre in 1991).

Discussion. Poor weed control between the soybean row was not reflected in reduced yield, particularly in the early planted soybeans in 1991. One reason for this may be that weed counts sample only a small area of the plot, thus increasing sample error, while yields encompass one-half of the plot (center two soybean rows). Another reason may be that weeds were only counted and weed weights or biomass were not measured. Weed biomass may be a better indicator of weed 'pressure' that reduces soybean yield since weed size greatly influences the competitive ability of weeds.

Cultivation significantly increased the number of weeds between the row in broadcast preemergence treatments in 1990 but not in 1991. Conversely, cultivation increased the number of weeds between the row in broadcast postemergence treatments in 1991 but not in 1990. Cultivation may have disturbed the preemergence herbicide layer in 1990 thus, resulting in increased weed numbers. Alternatively, weed spectrums varied from 1990 to 1991 with the dominant weed specie in 1990 common lambsquarters and in 1991, redroot pigweed. Common lambsquarters is less likely to germinate under warm soil temperatures while redroot pigweed will continue to germinate under high soil temperatures at the time of

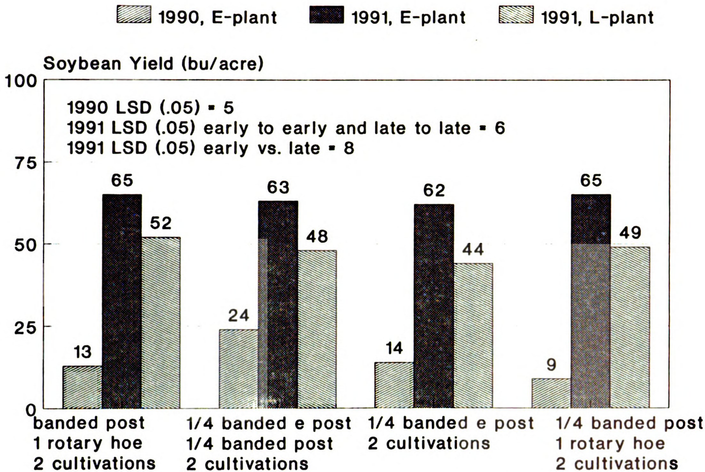

Figure 12 Soybean yield as affected by standard and reduced rate postemergence banded herbicide, cultivation, and rotary hoe.

cultivation. Postemergence herbicide treatments provide no residual soil activity and thus redroot pigweed germinated following cultivation of postemergence herbicide treatments in 1991.

Yields were reduced in every instance in the late planted compared to early planted soybeans. Handweeded control plots yielded 67 bu/acre when early planted and 55 bu/acre when late planted, a decrease of 18%. Untreated plots yielded 35 bu/acre when early planted and 24 bu/acre when late planted, a decrease of 31%. This indicates that weeds were more competitive in the late planted soybeans even though there were fewer weeds present. Therefore reduced yield in the late planted soybeans was not only a result of the late planting itself but also of greater competitiveness of the weeds.

Weed populations were greater in 1991 compared to 1990, yet weeds appeared to be less competitive. Oliver (1979) found that velvetleaf seedlings emerging with soybeans in mid May were twice as competitive as those emerging with soybeans planted in late June which differed from our findings. This could be due to a change in weed species composition, but is more likely a reflection of soybeans ability to compete with weeds under conditions of adequate moisture and high temperature. This points out the difficulty in establishing weed thresholds in soybean at which yield will be reduced. Crook and Renner (1990) found common lambsquarters reduced yield 15% more in a year of drought compared to a year of adequate moisture. Neither 1990 or 1991 were draughty, but soybean yields across the state were much greater in 1991, reflecting better growing conditions.

Economics. A $5.50/bu soybean price was assumed in both 1990 and 1991. In 1990, broadcast preemergence treatments without cultivation gave a net return[11] of $17.84/acre (Table 5). Broadcast preemergence treatments with one cultivation yielded substantially higher thus, giving a net return of $123.34/acre. Preemergence band treatments did not adequately control weeds and thus net returns were only $38.41/acre. Two cultivations alone gave a net return of $2.00/acre. Postemergence broadcast treatments without cultivation gave a net return of $75.56/acre, while cultivation increased net return to $159.06/acre (Table 6). Banded postemergence treatments receiving two cultivations gave a significantly lower net return of $107.15/acre. Net returns were further reduced in treatments receiving 1/4 of the standard postemergence herbicide rate in a band with two cultivations In 1990, broadcast postemergence treatments with one cultivation gave the highest net return, followed by broadcast preemergence treatments with one cultivation.

In 1991, the broadcast preemergence herbicide treatments yielded fairly high in the early planting, giving a net return of $237.84/acre and $282.84/acre for no and one cultivation respectively (Table 7). Unlike 1990, preemergence band treatments with two cultivations gave a net return of $307.91/acre, while two cultivations alone gave a net return of $293.50/acre. Broadcast preemergence treatments without cultivation yielded significantly less when planted on May 30 and the net return was only $133.34/acre. No decrease in yield occurred in the late planted soybeans when a preemergence herbicide band was followed by two cultivations as compared to broadcast preemergence treatments with one cultivation, resulting in net returns equivalent to treatments receiving a broadcast herbicide with one cultivation. Two cultivations alone provided net returns in the late planted soybeans that were

[11]net return=net return above weed control cost

Table 5. Soybean yields and net returns above weed control costs with preemergence herbicide, 1990.

Preemergence[b]	Variable Costs		Soybean	Returns[a] $5.50/Bu	
	Mechanical	Herbicide	Yield	Total	Net
	---------- ($/A) ----------		(Bu/A)		
Broadcast	3.80	27.86	9	49.50	17.84
Broadcast + 1 cultivation	8.30	27.86	29	159.50	123.34
Band + 2 cultivations	12.80	9.29	11	60.50	38.41
2 cultivations alone	9.00	0	2	11.00	2.00
LSD (.05)			5		28.16

[a]Net returns above weed control costs = (yield * soybean price) - (mechanical cost + herbicide cost).

[b]Herbicide program consisted of metolachlor (2.0 lb ai/acre) + linuron (0.38 lb ai/acre) + metribuzin (0.18 lb ai/acre) applied preemergence.

Table 6. Soybean yields and net returns above weed control costs with postemergence herbicide, 1990.

Postemergence[b]	Variable Costs		Soybean	Returns[a] $5.50/Bu	
	Mechanical	Herbicide	Yield	Total	Net
	---------- ($/A) ----------		(Bu/A)		
Broadcast	3.80	19.64	18	99.00	75.56
Broadcast + 1 cultivation	8.30	19.64	34	187.00	159.06
Band + 2 cultivations	12.80	6.55	23	126.50	107.15
1/4 band[b] + 2 cultivations	12.80	1.82	9	49.50	34.88
2 cultivations alone	9.00	0	2	11.00	2.00
LSD (.05)			5		28.16

[a]Net returns above weed control costs = (yield * soybean price) - (mechanical cost + herbicide cost).

[b]Herbicide program consisted of bentazon (0.75 lb ai/acre) + acifluorfen (0.25 lb ai/acre) + crop oil concentrate (1 pt/acre) applied postemergence; 1/4 band = one quarter the standard postemergence rate applied in a band.

Table 7. Soybean yields and net returns above weed control costs with preemergence herbicide, 1991.

Preemergence[b]	Variable Costs		Soybean Yield		Returns[a]			
					Early planting		Late planting	
	Mechanical	Herbicide	Early Planting	Late Planting	Total	Net	Total	Net
	---------- ($/A) ----------		-------- (Bu/A) --------		---------------------- ($/A) ----------------------			
Broadcast	3.80	27.86	49	30	269.50	237.84	165.00	133.34
Broadcast + 1 cultivation	8.30	27.86	58	50	319.00	282.84	275.00	238.84
Band + 2 cultivations	12.80	9.29	60	48	330.00	307.91	264.00	241.91
2 cultivations alone	9.00	0	55	46	302.50	293.50	253.00	244.00
LSD (.05)			6	6		32.54		32.54

[a]Net returns above weed control costs = (yield * soybean price) - (mechanical cost + herbicide cost).

[b]Herbicide program consist of metolachlor (2.0 lb ai/acre) + linuron (0.38 lb ai/acre) + metribuzin (0.18 lb ai/acre) applied preemergence.

equivalent to treatments receiving broadcast herbicide with cultivation or banded herbicide treatments receiving two cultivations.

Broadcast postemergence treatments with no cultivation gave a net return of \$290.06/acre, while cultivation increased net return to \$324.06/acre (Table 8). Banded postemergence treatments followed by two cultivations gave a net return of \$316.15/acre. One quarter rate postemergence band treatments with two cultivations gave a net return of \$333.58/acre, and treatments that were cultivated twice gave a net return of \$293.50/acre. In the early planted soybeans in 1991, the treatments yielding the highest net return were: 1/4 rate postemergence band treatments with two cultivations, broadcast postemergence treatments with one cultivation, and postemergence banded treatments with two cultivations (Table 8). Treatments receiving 1/4 of the standard rate band with two cultivations gave a significantly higher net return/acre than treatments receiving a broadcast postemergence herbicide without cultivation or treatments receiving only two cultivations. In the late planted soybeans, all postemergence treatments gave equivalent net returns except where a broadcast herbicide treatment was applied alone and in this treatment, net returns were significantly lower (Table 8). In both 1990 and 1991, annual grass pressure in the fields were quite light and the addition of a postemergence grass herbicide was not necessary. In fields that required a postemergence grass herbicide, weed control cost/acre would increase \$10-\$15/acre which would change the net returns and possibly the economic advantage of a postemergence herbicide program.

Table 8. Soybean yields and net returns above weed control costs with postemergence herbicide, 1991.

					Returns[a]			
	Variable Costs		Soybean Yield		Early Planting		Late Planting	
Postemergence[b]	Mechanical	Herbicide	Early Planting	Late Planting	Total	Net	Total	Net
	($/A)		(Bu/A)		($/A)			
Broadcast	3.80	19.64	57	43	313.50	290.06	236.50	213.06
Broadcast + 1 cultivation	8.30	19.64	64	54	352.00	324.06	297.00	269.06
Band + 2 cultivations	12.80	6.55	61	51	335.50	316.15	280.50	261.15
1/4 band + 2 cultivations	16.60	1.82	64	49	352.00	333.58	269.50	251.08
2 cultivations alone	9.00	0	55	46	302.50	293.50	253.00	244.00
LSD (.05)			6	6		32.54		32.54

[a]Net returns above weed control costs = (yield * soybean price) - (mechanical cost + herbicide cost).

[b]Herbicide program consisted of bentazon (0.75 lb ai/acre) + acifluorfen (0.25 lb ai/acre) + crop oil concentrate (1 pt/acre) applied postemergence; 1/4 band = one quarter of the standard postemergence rate applied in a band.

CONCLUSIONS

Starter fertilizer and rotary hoeing had no affect on weed population or soybean yield in 1990 or 1991. Cultivation did not reduce weed populations between the row where herbicides had been broadcast but soybean yield increased in 1990 and 1991. Banding herbicides with two cultivations provided yields equivalent to broadcast herbicide treatments with one cultivation in 1991 only. Split applications of reduced rates of postemergence herbicides did not provide effective weed control in either 1990 or 1991. However, 1991 soybean yields did not reflect this. The highest net return in 1990 was from postemergence broadcast treatments with one cultivation. With the early planting in 1991, treatments receiving reduced rates of herbicide with cultivation produced net returns equivalent to treatments receiving full rate herbicide with cultivation. In the late planted soybeans, this same trend was observed however, treatments receiving only two cultivations had net returns equivalent to all the treatments except where a broadcast preemergence or postemergence herbicide treatment without cultivation was applied.

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