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SUGAR BEET (*Beta vulgaris*) PRODUCTION FOLLOWING CORN (*Zea mays*) AND SOYBEAN (*Glycine max*) STRIP-CROPPING

By

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ABSTRACT

SUGAR BEET (*Beta vulgaris*) PRODUCTION FOLLOWING CORN (*Zea mays*) AND SOYBEANS (*Glycine max*) STRIP-CROPPING

by

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In the Saginaw Valley wind erosion is a serious concern due to the flat lakebed soils. Planting corn and soybeans in strips followed by mulch tillage may reduce wind erosion and protect sugar beet seedlings planted the following year. Field research was conducted in 1996 and 1997 to evaluate the effectiveness of five herbicide combinations for control of broadleaf weeds and annual grasses in corn and soybean strip-cropping. The use of mulch tillage after the strip-cropping for protection of young sugar beet seedlings from wind erosion and the effectiveness of three broadleaf herbicide combinations for weed control in sugar beets was also studied. Corn was planted in six 30-inch rows and cultivated once. Soybeans were drilled in twenty-six 7-inch rows and were not cultivated. Weed density decreased in corn and soybeans when herbicides were applied PRE followed by POST or when POST herbicides were applied twice as a split application. Weed density in the untreated control was greater in soybean compared with corn in both years. Residue cover after sugar beet planting was 12% and 35% following soybean and corn, respectively before cultivation. Weed densities were greater in sugar beets planted in soybean residue. Weed densities were reduced by at least 86% in sugar beets by all three of the broadleaf herbicide combinations. Sugar beets following soybean had lower plant populations, yield, sugar, and recoverable white sugar per acre compared with sugar beets following corn.

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CHAPTER 1

REVIEW OF LITERATURE

INTRODUCTION

Sugar beets (*Beta vulgaris*) have been grown in Michigan since 1880 (Christenson, 1998). However, due to the flat lakebed soils, vast open spaces, and fall moldboard plowing, severe wind erosion has become a threat to the sugar beet industry. Crops such as sugar beets are susceptible to abrasion from soil particles in the spring (personal communication with R. Roslund, Monitor Sugar Company). The unprotected flat lakebed soils will become compacted following a heavy rain and sugar beet seedlings will be unable to emerge. The compacted soils also allow for the movement of soil particles on the soil surface in high winds. These sand particles can abrade young sugar beet seedlings.

HISTORY OF SUGAR BEET PRODUCTION

Sugar beet production began with the German chemist Andres Marggraf in 1747. He discovered that sucrose could be extracted from the sugar beet root and converted into a crystalline form (Fischer, 1995). Sugar beet production was introduced in the United States in the early 1800's. In 1830 the first sugar beet society was organized (Fischer, 1995). Sugar beets were first introduced in White Pigeon, Michigan where the first factory was established in 1838 (Fisher, 1995). However due to a lack of technology the factory closed its doors soon after they opened. It was not until 1880 that a successful factory was built.

The production of sugar beets required many laborers. The labor came from German immigrants and laborers from Mexico. With the advances in new technology, labor requirements are a lot less today (Fischer, 1995).

In Michigan, sugarbeets rank sixth behind corn (*Zea mays* L.), hay, soybeans (*Glycine max* L. (Merr)), wheat (*Triticum aestivum* L.) and dry beans (*Plaseolus vulgaris L.*) with respect to the number of acres grown (Christenson, 1998). Sugarbeet growers in Michigan received approximately $136 million in 1990 for the sugarbeet crop, representing 3% of the gross farm income in the state (Christenson, 1998). Sugarbeets contribute $434 million to the Michigan economy (Christenson, 1998). Sugarbeets are grown primarily in the Saginaw Valley and the thumb of Michigan. In this region, sugarbeets account for 20% of the gross farm income.

The sugarbeet industry in one year will invest $95 million to produce 187,000 acres of sugarbeets. In 1998, 2,880 farmers produced 187,000 acres of sugarbeets in Michigan. Five factories employed 2,032 workers to process the beets. In the United States consumers pay 32% less for sugar than sugar bought in foreign countries (Landell Mills, 1994).

EROSION

Soil erosion is the greatest threat to agriculture in the United States. Erosion rates have surpassed the replacement costs on farm fields (Fawcett, 1995). The following is a quote from an early Connecticut settler in 1747. The quote illustrates that soil erosion is not something new but has influenced farming and land clearing here longer than we know. "When our forefathers settled here, they entered a land which probably never had been ploughed since the creation; the land being new they depended on the natural fertility of the ground which served their purpose very well and when they had worn out one piece of land they cleared another. Our land being thus worn out, I suppose this to be one reason why so many are inclined to move to new places that they may raise wheat" (Bidwell, 1925). Finding ways to reduce soil erosion and conserve moisture are becoming more popular with conservation tillage (Fawcett, 1995).

Traditional farming practices included the use of legumes in order to provide nitrogen for the crops and limit soil erosion by providing cover during the non-cropping season. Using intensive tillage primarily for weed control resulted in severe erosion when grain crops were grown (Fawcett, 1995). Nearly half of the original topsoil had eroded away following the first 100 years of farming in Iowa (Fawcett, 1995).

TILLAGE

Conservation tillage is an economical way to reduce soil erosion. The crop residue protects the soil surface from erosion caused by wind and rain. The amount of protection is based on the percent cover of the soil surface. For instance, if a field has 75% cover then 75% of the soil will be protected from erosion (Fawcett, 1995). Conservation tillage also has environmental benefits. Soil organic matter will increase near the soil surface along with microbial populations. Phosphatase and dehydrogenase enzyme activities, soil moisture, and organic carbon and nitrogen in the near surface of no-till soil is also significantly higher than in conventional tillage (Doran, 1980). Such increases in microbial activity have been associated with increased rates of pesticide degradation with conservation tillage (Fawcett, 1995).

Moldboard plowing buries weed seeds and grains, which are an important source of food for insects and animals. Mulch tillage leaves more seeds available for insects and animals to eat. Conservation tillage also enhances wildlife nesting (Fawcett, 1995).

Conservation tillage combined with strip-cropping in corn and soybeans can reduce water runoff and wind erosion. Sugar beets can be protected from wind abrasion following corn and soybean strips when combined with conservation tillage. By controlling wheel traffic in the strips, compaction will be reduced and water runoff will be less likely to occur (Natural Resources Conservation Service website).

Sugar beet stands were greater in reduced tillage systems than in conventional plowed systems (Sojka et al., 1980). Root yield was not significantly lower in the reduced tillage compared to the conventional tillage system. The ground level wind speed was lower and soil temperatures were warmer in reduced tillage compared to conventional tillage in the early spring in Fargo, North Dakota (Sojka et al., 1980). Sugar beets grown in a reduced tillage study over a 3-year period in two locations were more profitable compared to conventional tillage in Michigan (LeCureux, 1996).

STRIP-CROPPING

Strip-cropping is planting two crops of the same planter width in alternating strips across a field. The concept of planting two crops in the same field is not new to agriculture. However, with the use of large machinery and large farms it was impractical for farmers to practice strip-cropping. Now with lower grain prices and rising production costs, farmers are reevaluating strip-cropping.

Strip-cropping provides for biological diversity in a field, helps in conservation tillage, and improves crop rotation flexibility (Fortin et al., 1987). The main benefit of strip-cropping is to intercept sunlight more efficiently and maximize crop production (Iragavarapu et al., 1987). Corn yields increased 20 to 40 bushels/acre in 15-foot strips while soybeans yielded slightly less in 15-foot strips (West and Griffith, 1992). The yield advantage in the corn is due to the outside corn rows, because these rows can produce two to three ears of corn while within the blocks corn may only produce one ear per plant (Mangold, 1992). Row direction is important for maximizing yield potential (Crookston and Hill, 1979). Corn yields increased 9 to 12% in rows that were oriented north and south, while corn yields increased 2 to 7% when the rows were planted east and west (Iragavarapu et al., 1987).

The practical farmer's organization of Iowa reported a 20 to 30 bushels/acre increase in corn yield in strip-cropping when compared with corn grown in blocks. Soybean yield did not increase in the strips compared with blocks (Mangold, 1992). A farmer in Iowa experimented with corn and soybeans in strips. Corn yield was 20 to 30 bushels greater in strips while soybeans yielded 2 bushels less in strips compared with a block (Walter, 1993). In other research, strip-cropping at another farm resulted in a 29-bushel/acre increase in corn and 6 bushel/acre in soybeans compared to blocks (Reynolds, 1986). Farm profitability over a five-year period was $18 per acre greater in a strip-cropping program (Reynolds, 1986).

Strip-cropping can improve yields and profit margins, and reduce soil erosion (West and Griffith, 1992). A ton of soil eroding from a farm is valued at $12.50 of nitrogen, phosphorous, and potassium. If five tons of soil are lost per acre in one year, a farmer would lose $62.50 per acre. Strip-cropping can reduce erosion by five tons per year (Ferguson, 1993). Corn provides greater surface residue than soybean, although soybean residue still protects the soil from wind erosion (Seim, 1995). Strip-cropping can also increase diversity of plant species and may lead to an increase in wildlife populations (Mangold, 1992).

One difficulty with strip-cropping is herbicide selection (Walter, 1993). Weed control with herbicides is difficult in strip-cropping because of sprayer boom width and a concern for spray drift to the adjacent crop strip. Sunlight reaching the soil surface will increase in the corn strips because there are more outside rows compared to corn grown in blocks. With increased sunlight more weeds will germinate in the outside rows compared to the corn grown in the in blocks. Increased light penetrating the soil surface will cause more weeds to germinate and many postemergence herbicides such as 2,4-D in corn cannot be applied in strip-cropping with soybeans (Klor and Klor, 1986). With new herbicide technology strip-cropping will become easier. There are now corn and soybeans genetically modified to be tolerant to glyphosate (*N*-(phosphonomethyl) glycine) or glufosinate (butanoic acid, 2-amimo-4-(hydroxymethylphosphinyl)-monoammonium salt) (Vroom, 1998), and these tolerant varieties could be planted in strips and the same herbicide applied in both crops (Ferguson, 1993; Mangold, 1992).

Corn rootworms can become a problem when last years corn residue is adjacent to this years corn crop because corn rootworms overwinter in the fields and eggs hatch from May to June (Mangold, 1992). Root feeding by corn rootworm larvae constitutes the greatest economic threat to profitable corn production. Severe root pruning by larvae often results in lodging (plants no longer remain erect) of plants, and yields can be reduced significantly if lodging is extensive. Fields with severe larval damage also can increase harvest expenses (Gray and Steffey, 1999). Corn rootworms can become a serious problem the following year if only four thousand corn plants per acre exist. There are insecticides available to control corn rootworms (McGahen, 1989), however this increases input costs to the grower and increases pesticide exposure in the environment.

CORN AND SOYBEAN HERBICIDES

On an Iowa farm practicing strip-cropping, metolachlor was applied as a burndown and imazethapyr was applied as a postemergence herbicide to both soybeans and an imidazolinone tolerant corn variety (Zinkand, 1995). Imidazolinone tolerant corn is corn that was genetically modified to tolerate postemergence applications of imazethapyr. However, there is a forty-month rotation restriction to sugar beets following imazethapyr (Anonymous, 1998; Kells and Renner 1999). Flumetsulam/metolachlor could be applied to both corn and soybeans but there is a 26-month rotation restriction to sugarbeets. Herbicides that can be used in both corn and soybeans and have no restrictions for rotation to sugar beets include metolachlor, bentazon, and flumiclorac. Glyphosate and glufosinate could be applied with Roundup Ready™ or Liberty Link™ corn and soybeans (Kells and Renner, 1999). These varieties are genetically modified to be tolerant of postemergence applications of glyphosate and glufosinate, respectively.

A study was conducted at Southern Illinois University to compare herbicide treatments in corn. Corn treated with flumetsulam/metolachlor preplant incorporated was not injured and the yield of 135 bushels/acre did not differ from yield of the weed free control (Krausz and Kapusta, 1997). Corn treated with metolachlor preplant incorporated followed by bentazon postemergence was not injured and yielded 124 bushel/acre. In another study, corn treated with metolachlor preplant incorporated followed by bentazon postemergence had 96 to 100% weed control and no yield loss compared with the weed free control. Corn is usually tolerant to metolachlor except under cool and wet conditions (Viger et al., 1991). Factors that effect metolachlor injury to corn include high application rates, excessive moisture and sensitive varieties (Rowe et al., 1991). There was no injury to the soybeans from a metolachlor followed by bentazon treatment (Horng et al., 1983). Soybean yield was similar in both reduced tillage and conventional tillage. The preemergence and postemergence herbicide treatments had similar yields (Yenish et al.1992).

SOYBEAN ROW SPACING

Producers are using conservation tillage in solid-seeded soybeans to increase productivity and reduce erosion. Research at the OARDC Northwest branch has shown yield increases in solid-seeded soybeans compared to 30-inch row soybeans (Beuerlein and Eckert, 1987). The early canopy closure with solid seeded soybeans will help with late season weed control. Weed control in reduced tillage is limited to postemergence and preemergence treatments (Buhler et al., 1990).

TILLAGE INFLUENCES ON WEED MANAGEMENT

Tillage and rotation of crops will influence weed seed in the soil (Ball, 1992). Primary tillage influences the distribution of weed seed in the soil tillage layer (Ball, 1992). There is more weed seed left near the surface in fields that were chisel plowed rather than moldboard plowing. Reduced tillage required increased weed management to control weeds (Ball, 1992).

Crop rotation also influences weed seed numbers in the soil. The crop rotation dictates the time of tillage and herbicide type used (Ball, 1992). Over a several year period, the most dominant factor influencing species composition in the seedbank and weed flora was cropping sequence. Crop sequences dictate both time and type of tillage operations and herbicides used (Sagar and Mortimer, 1976).

Secondary tillage such as row cultivation during the growing season also has an influence on seedbank numbers and species composition. In a 3-yr study of irrigated row crops, cultivation eliminated weeds between the row, which reduced seed production and influenced seedbank number (Sagar and Mortimer, 1976). Cultivation during the growing season reduced weed seed numbers between the rows in soybeans and in corn, but there was no increase in weed control (Ball, 1992). No tillage or reduced tillage may increase the potential for growth of certain weed species due to weed seed accumulation at or near the firm soil surface and lack of control of existing weeds at planting (Buhler, 1992).

WEED COMPETITION

Common lambsquarters is very competitive in sugarbeets and less competitive in other crops. Twenty-four common lambsquarters per 100 feet of row decreased sugar beet root yield by 48% (Schweizer, 1983). Forty-nine common lambsquarters per 30 feet of row decreased soybean yield by 12% in Michigan (Crook and Renner, 1990); while nine common lambsquarters per 30 feet of row reduced soybean yield by 33% in Ohio (Harrison, 1989). In a North Carolina study sixteen common lambsquarters per 30 feet of row reduced soybean yield by 15% (Shurtleff, 1985). In a Canadian study corn yield decreased when common lambsquarters density was greater than 10 plants per square foot (Sibuga, 1985). One common lambsquarter plant will produce 72,000 seeds (Crook and Renner, 1990). Therefore weed control in corn and soybean the year prior to sugarbeet production is critical to reduce the potential for weeds in sugarbeets.

WEED CONTROL IN SUGAR BEETS

Weed control in previous crops is essential for sugar beet production. Sugarbeet growers control weeds to eliminate yield loss from competition with weeds. Weeds also reduce sugarbeet harvesting efficiency. Thirdly, weeds in storage piles at the processing factory can spoil the sugarbeets in the pile because weeds will generate heat and mold (Bray, 1980). Sugarbeet yield losses from weeds are dependent upon the weed species and weed populations (Shribbs et. al., 1990). One redroot pigweed per four sugarbeets reduced sugarbeet yields by 24% (Wilson, 1992). Eight common lambsquarters per 30 feet of sugar beet row decreased root yield by 48% (Schweizer, 1983). A population of 170 common lambsquarters per square foot decreased sugar beet yield by 86% (Holmes et al., 1974). Weeds that emerge soon after sugar beet planting are more competitive than late emerging weeds. Weeds become most competitive when they begin to shade the crop (Wilson, 1992). Weed competition with sugar beets can be prevented if sugar beets are kept weed free for 8 weeks after planting (Wilson, 1992). Sugar beet yield loss is related to total weed biomass and not to weed population (Shribbs et al., 1990).

Weed control in sugar beets depends on various fields operations because of low crop tolerance to herbicides and a variety of weeds (Shribbs et al., 1990). Weed management practices include pre-plant herbicides, cultivation, postemergence herbicides and hand weeding (Wilson, 1994). With increased costs for hand labor and reduced tillage, growers are relying more on chemical control. Even with these investments weed interference can still reduce sugar beet root yield by 5-10% (Shribbs et al., 1990).

SUGAR BEET HERBICIDES

Sequential application of herbicides at planting and after sugar beet emergence has proven effective in early season weed control (Wilson, 1994). Other popular weed control methods have omitted the use of herbicides at planting and rely only on sequential postemergence herbicide treatments after emergence (Wilson, 1992). There are many advantages to postemergence herbicides. One advantage is weed problems can be identified before the herbicide is applied. This allows for tank mixing of herbicides to control the weeds that are present (Burtch et al., 1981). Postemergence herbicides require less time and fuel to apply than preplant incorporated herbicides (Burtch et al. 1981).

Chemical weed control can cost $125.00/acre in sugar beet production. The benefit of postemergence herbicides in sugar beets compared with hand labor can range from $77/acre to $125.00/acre. There was a $124 to $149/acre benefit with preplant incorporated herbicides compared with hand-weeded treatments. In addition, when preplant incorporated and postemergence herbicides were applied the return was $113 to $152/acre more than the hand-weeded control (Miller et at., 1989).

Ethofumesate and desmedipham plus phenmedipham are postemergence herbicides used in sugar beets (Wilson, 1994). Postemergence herbicides are banded over the row to reduce cost. The cost of postemergence herbicides can range from $20.00 to $25.00 per acre (List, 1998). Redroot pigweed and common lambsquarters at the cotyledon to second true leaf stage are controlled by ethofumesate (Duncan et al., 1981). Ethofumesate alone postemergence caused less visual injury but provided less weed control than desmedipham plus phenmedipham (Wilson, 1994). Common lambsquarters densities were lower following phenmedipham plus desmedipham compared with ethofumesate. In other research ethofumesate plus phenmedipham provided better initial and residual control than phenmedipham alone (Marshall et. al., 1987). Sugar beets are not tolerant to this application if sugarbeets are smaller than 2nd true leaf (Marshall et. al., 1987). Research conducted in 1988 and 1989 showed that injury to sugar beets caused by phenmedipham did not cause a greater yield loss compared with plots that had inadequate weed control (Prodoehl et al., 1992).

Broadleaf weed control can be improved by the use of split applications of low dosages of postemergence herbicides. Broadleaf weeds in the cotyledon to two-leaf stage can be controlled with lower rates of desmedipham with phenmedipham in split applications (Dexter, 1994). A single application of desmedipham plus phenmedipham applied at the 4 true leaf stage was less effective in controlling weeds than a split application applied in the 2-4 leaf stage (Dexter, 1994). Split applications can improve weed control. The use of low rate split applications of phenmedipham plus desmedipham resulted in less injury to sugarbeets and increased weed control compared to single application rates (Norris, 1991). However, split applications of sugar beet herbicides can cause more injury than single applications to sugar beets when given the right environmental conditions (Norris, 1991). Phytotoxicity of both phenmedipham and desmedipham increases as light and temperature increase (Prodoehl et al., 1992). Split applications at the reduced application rates are needed to protect sugarbeets from herbicide injury. Damage is more severe in the two-leaf stage of sugar beet growth (Prodoehl et al., 1992). Sugar beets at the four-leaf stage are significantly less susceptible to injury than smaller plants.

Sugar beet growers need to design their weed control programs by the types of weed problems that exist in their fields. If weed density is low, either a preplant or postemergence applied herbicide followed by hand labor provides an economical weed control program (Wilson, 1992). As weed density increases a preplant or preemergence herbicide application followed by one or two postemergence herbicide applications provides the greatest reduction in weed density (Wilson, 1992).

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Chapter 2

SUGAR BEET (*Beta vulgaris*) PRODUCTION FOLLOWING CORN (*Zea mays*) AND SOYBEAN (*Glycine max*) STRIP-CROPPING

ABSTRACT

Planting corn and soybeans in strips followed by fall mulch tillage may reduce wind erosion and protect sugar beet seedlings planted the following year. Corn and soybean strip-cropping trials were conducted in 1996 and 1997 on a commercial farm in Bay County, Michigan. Corn was planted in six thirty-inch rows with alternating strips of soybean planted in twenty-six seven-inch rows. Weed management treatments in corn and soybeans included: flumetsulam at 0.056 lb a.i./Acre plus metolachlor at 2.1 lb a.i./Acre PRE; metolachlor at 2.0 lb/Acre PRE followed by bentazon at 1.0 lb a.i./Acre POST; metolachlor at 2.0 lb/Acre followed by bentazon plus flumiclorac POST; bentazon POST; bentazon plus flumiclorac POST; bentazon E. POST and POST; bentazon E. POST followed by bentazon plus flumiclorac POST; a hand-weeded control; and an untreated control. Bentazon was applied at 1.0 lb a.i./Acre and flumiclorac at 0.41 lb a.i./Acre. Corn was cultivated once and the soybeans were not cultivated. Sugar beets were planted the year following corn and soybean strip-cropping. Crop residue was measured in the spring before and after sugar beet planting and following first cultivation. Pyrazon was applied pre emergence at 3 lb a.i./Acre to all treatments. Postemergence weed management treatments in sugarbeets included a single application of desmedipham 0.037 lb a.i./acre + phenmedipham 0.037 lb a.i./acre + ethofumesate 0.037 lb a.i./acre POST; desmedipham 0.02 lb a.i./acre + phenmedipham 0.02 lb a.i./acre + ethofumesate 0.02 lb a.i./acre applied E POST and POST; desmedipham 0.085 lb a.i./acre + phenmedipham 0.085 lb a.i./acre applied E POST and POST; hand-weeded control; and

an untreated control. Weed population in sugarbeets and sugar beet populations, root yield, percent sugar and recoverable white sugar per acre were measured to determine the influence of previous crop on sugar beet production.

Weed density in corn and soybeans was equal to that of the handweeded control when herbicides were applied PRE followed by POST or when POST herbicides were applied twice as a split application. Redroot pigweed densities decreased significantly when flumiclorac was added to the tank mixture compared to the treatments that did not contain flumiclorac. Corn and soybean yield increased when herbicides were applied PRE followed by POST or in E-POST followed by POST treatments. Bentazon followed by bentazon gave the highest corn yield in both 1996 and 1997. The soybean yield was greatest in 1998 and 1997 when flumiclorac was added to the tank mixture. Weed density in the untreated control was greater in soybean compared with corn in both years.

Residue cover in the spring after sugar beet planting was 12 and 35% following soybean and corn, respectively. Weed densities in sugar beets were greater in soybean residue, reflecting the increased weed densities the previous year. Sugar beets planted in soybean residue had lower populations, percent sugar and recoverable white sugar per acre compared with sugar beets planted in corn residue. In 1996 and 1997 sugarbeet populations, percent sugar and recoverable white sugar were significantly lower in the desmedipham + phenmedipham + ethofumesate single treatment at 0.11 lb a.i./Acre compared to the desmedipham + phenmedipham + ethofumesate split application at reduced rate of 0.06 lb a.i./Acre. Weed densities were greater following soybean. Crop residue was greater following corn and sugar beet population and recoverable white sugar per acre were greater following corn. Split applications of reduced rate of herbicide did not reduce sugarbeet stand and had recoverable white sugar per acre equal to the handweeded control.

INTRODUCTION

Bay County, Michigan has vast open spaces and flat lakebed soils. In the spring, wind erosion is a serious concern. The typical erosion rate on a Bay County field that is moldboard plowed is 10 tons per acre (personal communication, Charles Lightfoote Natural Resource Conservation Service). This is based on a three-year rotation of corn-soybeans-sugar beets. Erosion can be greatly reduced with the use of conservation tillage and strip-cropping. Conservation tillage is the reduction of soil and water loss relative to conventional tillage (Fenster, 1983). Conservation tillage in this rotation would reduce soil loss to 6.4 tons per acre per year (Anonymous, 1980).

Strip-cropping is planting two crops of the same planter width alternating across a field (Fortin et al., 1987). Field strip-cropping is laid out parallel to a field boundary (Schreb et al., 1981). The benefits of field strip-cropping are greater conservation of moisture, reduction in soil erosion, increased corn yields and earlier harvesting (Schwab et al., 1981). Alternating strips of corn and soybeans in the same field can increase net profit per acre (Griffith, 1992). Strip-cropping increased corn yields by 20% (Pendleton et al., 1963). Corn yields increase 20 to 40 bushels/acre in six row strips with six rows of soybeans alternating between (West et al., 1992). The yield increase can be attributed to the increase in sunlight penetration on the outside corn rows (Iragavarapu, 1996).

Herbicide selection is one limiting factor that prevents farmers from strip-cropping. Herbicide drift to soybeans from corn or herbicide drift from soybean to corn is a major concern. The boom width of the sprayer also presents problems when trying to spray narrow strips separately (Walter, 1993).

Herbicide options that can be applied in both corn and soybeans are limited. With the use of herbicide tolerant corn, imazethapyr can be used to both crops (Farm Journal, 1995). On an Iowa farm practicing strip-cropping, metolachlor was applied as a burndown and imazethapyr was applied as a postemergence herbicide to both soybeans and imidazolinone tolerant corn (Zinkand, 1995). Sugar beets grown in corn/soybean rotation limit herbicide options in corn and soybeans because sugar beets are very sensitive to herbicide residues in the soil and therefore impose many herbicide rotational restrictions (Kells and Renner, 1999). Sugar beets cannot be planted for 26 months following flumetsulam/metolachlor application and for 40 months following an imazethapyr application (Kells and Renner, 1999). Herbicides that can be used in both corn and soybeans and allow rotation to sugar beets include metolachlor, bentazon and flumiclorac (Kells and Renner, 1999). Glyphosate and glufosinate could be applied with Roundup Ready™ or Liberty Link™ corn and soybeans (Michigan State University, 1999). These varieties are genetically modified to be tolerant of postemergence applications of glyphosate and glufosinate, respectively. Neither herbicide would restrict rotation to sugarbeets.

Sugar beet seedlings need wind erosion protection. The wind can move soil particles and destroy young sugar beet seedlings. In 1998 sugarbeet growers for Monitor Sugar replanted 5,436 acres due to wind erosion and soil crusting (personal communication with R. Roslund, Monitor Sugar Company, 1998). Sugar beets are the most susceptible to wind erosion during establishment when the wind potential is the highest. Tillage practices that leave residue on the soil surface have the greatest potential for controlling wind erosion (Skidmore, 1968). Residue cover left on the soil surface will protect soil from wind and water erosion. Residue cover will act like an umbrella to intercept the raindrops and reduce the energy before it strikes the soil surface. The residue cover will keep the soil cooler and moister (Natural Resource Conservation Service, 1997). Strip-cropping combined with conservation tillage leaves 20 to 40% residue on the soil surface compared to 60% crop residue after corn and 10% residue after dry edible beans (personal communication with Jerry Grigar, Natural Resource Conservation Service, 1998). Conservation tillage will reduce both wind and water erosion. The quantity of erosion that occurs is largely dependent on the quantity of residue that is left on the soil surface. The moldboard plow will leave between 0 and 5 percent residue and the chisel plow will leave 75 percent residue on the soil surface (Hayes and Young, 1982). In a study in the thumb of Michigan sugar beets that were planted after the soil was chisel plowed had a population of 139 beets per 100 row foot following the mold board plow (LeCureux, 1996). In a study conducted in Fargo, North Dakota in 1994 and 1995 in sugar beets following corn residue, sugar beets planted into 11% corn residue yielded 1 ton less than sugarbeets planted into 30% residue (Sugarbeet Research and extension Report, 1995). However conservation tillage leaves weed seeds near the soil surface, which can result in more weeds than conventional tillage systems (Buhler et al. 1990). Shallow tillage decreases seed persistence in the soil and increases weed seedling emergence (Egley and Williams, 1990). Weed seed produced in the corn and soybean strip crops would be near the soil surface following conservation tillage, which could result in increased weed densities in sugarbeets the following year.

Weed control is essential in crops grown before sugar beets. There are limited herbicide programs available to control weeds in sugar beets. Sugar beets need to be weed free to prevent yield loss, improve harvesting efficiency, and improve storage when piled. The cost of chemical weed control programs for sugar beets is between $26 and $58/acre depending on the weed species and herbicide program. Postemergence sugar beet herbicides must be applied before weeds exceed two inches or weed control will be reduced (Wilson, 1992). Postemergence herbicides can be applied as a single application or twice at reduced application rates. Two applications at reduced rates (split application) provide better weed control than a single application (Wilson, 1992).

Strip cropping would be a desirable practice to increase corn yields and leave more available crop residue on the soil surface prior to planting sugar beet the following year. However, weeds must be controlled in both the corn and soybean strips to reduce the potential for weed infestations the following year.

Studies were conducted in Michigan from 1996 to 1997 to: 1) evaluate the effectiveness of five herbicide programs for weed control in corn and soybean strip-cropping, 2) evaluate crop residue prior to and after sugar beet planting, and following the first cultivation in the corn and soybean strips, 3) evaluate three weed management programs in sugar beets following corn and soybean strip-cropping, and 4) evaluate sugar beet populations, root yield, percent sugar, and recoverable white sugar per acre following corn and soybean strip-cropping.

MATERIALS AND METHODS

Corn and soybeans

Field studies were initiated in1996 and 1997 on a Tappan loam (fine-loamy, mixed, calcareous mesic Typic Halpaguolls) with 3% organic matter and pH of 7.8. The study was a two-factor factorial randomized complete block with four replications. Corn and soybean strips were the main plots and herbicide treatments were the sub plots. Plots were fifteen feet wide by seventeen feet in length, consisting of six-thirty inch rows of corn and twenty-six seven-inch rows of soybeans. Plots were strip cropped for two years in corn and soybean strips prior to planting sugarbeets. The corn and soybean strips were prepared in the spring using a Sunflower[1] combination tillage tool that included discs, sweeps, harrow, and a rolling basket. The plots were established using a John Deere[2] 7000 twelve-thirty inch row planter. The middle six seed boxes were used and the outside three rows were left off the planter. Each time the planter would turn six empty rows remained. The empty six rows were then drilled to soybeans using a Case[3] IH 5400 twenty-six by seven-inch drill. The corn variety Pioneer 3861 was planted at 30,000 seeds/acre in 1996 and 1997. Pioneer 9172 soybean was planted at 180,000 seeds/acre in 1996 and 1997. A dry fertilizer 8-10-35-2-1 (nitrogen-phosphorous-potassium-manganese-zinc) was broadcast prior to seedbed preparation. Nitrogen in the form of 28% area ammonium nitrate was applied at the time of cultivation at 60 gal/acre (180 lbs/acre of nitrogen) with a six-row Hinicker[4] 5000 cultivator to corn at the twelve-inch stage in both years.

[1] Sunflower, 1 Sunflower Drive, P.O. Box 566, Beliot, KS 67420
[2] Deere and Company, John Deere Road, Moline, IL 61265-1304
[3] J.F. Case, Hamilton, Ontario L8N 4C4
[4] Hinicker Co., P.O. Box 3407, Mankato, MN 56002-3407

Herbicide treatments were applied to the corn and soybean strips at the same time with a thirty-foot pull-type sprayer with a twenty-inch nozzle spacing using flat fan nozzles and a hydraulically driven pump. The sprayer delivered 17 gal/acre at 50 psi and the ground speed was 6.0 mph. The weed management treatments were: flumetsulam at 0.056 lb a.i/Acre plus metolachlor at 2.1 lb a.i./Acre PRE; metolachlor PRE at 2.0 lb/Acre plus bentazon POST at 1.0 lb a.i./Acre; metolachlor PRE at 2.0 lb/Acre plus bentazon at 1.0 lb/Acre plus flumiclorac at 0.041 lb a.i./Acre POST; bentazon at 1.0 lb /Acre POST; bentazon at 1.0 lb/Acre plus flumiclorac at 0.041 lb/Acre POST; bentazon at 1.0 lb/Acre E. POST and POST; bentazon at 1.0 lb/Acre E. POST followed by bentazon plus flumiclorac at 0.041 lb/Acre POST; a hand-weeded control; and an untreated control. The untreated control was cultivated. Herbimax[5] at 1 quart/acre was applied in all POST herbicide treatments.

The PRE treatments were applied immediately after planting. The E. POST herbicide treatments were applied when the corn was 4 inches tall and the soybeans were two inches tall and at the second trifoliate growth stage. The POST application was made when the corn was 8 inches tall and the soybeans were 4 inches tall and at the fifth trifoliate growth stage. Redroot pigweed and common lambsquarters were 1 inch in height with 2 leaves at the time of E. POST application in both years. At the time of the POST application these weeds were 2 inches in height with 4 leaves.

Weed densities were counted in August of both years in the corn and soybean strip-cropping experiment. In each treatment, a 15-foot by 17.5-foot area was counted. Weed pressure was low in both years (Tables 1 and 2).

Soybean plots were harvested using a Massey Ferguson[6] plot combine. The area harvested was 15 foot wide by 17.5 feet. The corn was hand harvested from a six row by 17.5 feet area. Crop yields were converted to bushels per acre at 15.5% moisture for corn and 13.0% moisture for soybeans. The soybean plots were harvested October 5, 1996 and October 10, 1997. The corn plots were harvested October 28, 1996 and October 30, 1997.

Sugar beet

Sugar beets were planted in 1996 and 1997 on a Tappan loam (fine-loamy, mixed, calcareous mesic Typic Halpaquolls). In 1996 the field had 1.8% organic matter and pH of 6.5. In 1997 a different field had a soil pH of 7.3 and 2.0% organic matter. The previous crop in both 1996 and 1997 was strip-cropped corn and soybeans. The study was a two factor factorial randomized complete block with four replications. The field site was prepared by utilizing a sunflower disc chisel with three inch twisted shovels. The site used conservation tillage. The chisel plow was pulled at 4.5 mph and was in the soil at an 8 inch depth. The seedbed in the spring was prepared once using a sunflower soil finisher that included discs, sweeps, harrow, and a rolling basket. The soil finisher was pulled at 7.0 mph and at a soil depth of 3 inches. The planter was a John Deere 7000 Twelve-30 inch row planter equipped with Yetter[7] row cleaners (two 13-inch steel wheels 1/4 inch thick with 16 interlocking fingers) were mounted on the seed unit to sweep residue and soil clods off the row. In a sugar beet following corn residue study it was

[5] Herbimax, 83% petroleum oil, 17% surfactant, Loveland Industries, Inc., P.O. Box 1289, Greeley, CO 80632

[6] Massey Ferguson (AGCO), Duluth, GA 30136

[7] Yetter Mfg. Co. Inc., P.O. Box 358, Colchester IL 62326

shown that row cleaners increased sugar beet population (Sugar beet Research and Extension Report, 1995).

The planting speed was 3.5 mph and a dry fertilizer 9-21-11-1-1-1/4 (nitrogen-phosphorous-potassium-zinc-manganese-boron) was applied in a band two inches to the side and two inches below the seed at a rate of 220 lbs/acre. Pyrazon was applied at 3 lb a.i./A in a ten-inch band over the row at planting with a hydraulically driven pump using 8003 flat fan nozzles at 35 p.s.i.

Sugar beets were cultivated four times in 1996 and 1997. The first cultivation was when the sugar beets were at the four true leaf stage in both years. A Buffalo[8] six-row cultivator was used with tunnel shields, cutaway discs and a single sweep to allow the residue to flow through the cultivator. At the 8-true leaf stage in both years nitrogen (28% urea ammonium nitrate) was applied at 75 lb N/A in 1996 and 60 lb N/A in 1997 using a Hinicker 5000 cultivator with rolling shields and a single sweep. The nitrogen rate was based on the soil nitrate test that was done two weeks prior to side-dressing both years. The third cultivation was at the 10-true leaf stage of the sugar beet using the Hinicker 5000 cultivator. The final cultivation was at canopy closure with the Hinicker 5000 cultivator.

The sugar beet experiment was a two-factor factorial randomized complete block with four replications. The main plots were strips of corn or soybean residue. The subplots were the five weed management treatments in each crop residue. Each treatment was six rows wide, and each subplot was the length of the field (900 feet). All subplots were treated with Pyrazon PRE at 3 lb a.i./Acre. All plots were cultivated 4 times. The subplot treatments consisted of desmedipham at 0.0367 lb a.i./A plus phenmedipham at

0.0367 lb a.i./A plus ethofumesate at 0.0367 lb a.i./A POST; desmedipham at 0.085 lb/A plus phenmedipham at 0.085 lb/A applied as a split application early POST and POST, desmedipham at 0.02 lb/A plus phenmedipham at 0.02 lb/A plus ethofumesate at 0.02 lb /A applied as a split application early POST and POST, a hand-weeded control, and a no POST control only. The treatments were applied using a 12-row 30-inch band sprayer applying herbicide in a ten-inch band at 6 m.p.h. There were two flat fan nozzles one on each side of each sugar beet row. A hydraulically driven pump applied 8 gal/acre at 35 p.s.i.

The sugar beet seed used in both years was MonoHybrid Company 'E-17' planted on May 4, 1996 and April 20, 1997. The soil temperature at planting in 1996 in the corn residue was 52° F and in the soybean residue 52°F. In 1997 the soil temperature in the corn and soybean residue was 48° F. Soil temperature was measured using five soil thermometers randomly placed in the corn and soybean residue and then averaging the five temperature readings for each crop residue. The rainfall for the strip-cropping and sugar beet plot in 1996 was 28.0 inches for the growing season. In 1997, the rainfall was 16.5 inches for the growing season. After planting sugar beets the rainfall for 1996 in May was 6 inches, 9 inches in June, 5.5 inches in July, .70 inches in August, and 6.8 inches in September. After planting in 1997 the rainfall for May was 2.9 inches, 4.7 inches in June, 3.6 inches in July, 3.1 inches in August and 2.2 inches in September.

Residue was measured in four areas throughout the field by counting residue along a 100 foot tape at one-foot intervals. A line transect is a field measurement technique that has been proven effective in estimating the percent of ground surface covered by plant residue. It may be used to estimate crop residue, live plant cover, and

[8] Buffalo Farm Equipment, Fleischer Mfg. Co., P.O. Box 848, Columbus, NE 60602-0848

other ground cover at any time (Natural Resources Conservation Service, 1997). It is most accurate when the residue is lying flat on the soil surface and is evenly distributed across the field. The residue cover was then calculated into a percentage by the state agronomist with the Natural Resource and Conversation service.

Sugar beet split applications were first applied when the first true leaf pairs of sugarbeets were visible in both years. The second portion of the split application and the single application of the full rate treatments were applied when the third true leaf pairs of sugarbeets were visible in both years. In 1996, the temperature was 60° F and 70° F at the time of the first and second application, respectively. In 1997, the temperature was 65° F and 75° F at the time of the first and second application, respectively.

Weed densities were counted in a 15 foot wide by 17.5 feet area in August and converted to the number of weeds per acre (Tables 4 and 5). Sugar beets were harvested on September 29, 1996 and October 1, 1997. Sugar beet population was counted in each plot after the first cultivation and at the time of harvest and was converted to number of sugar beets per 100 feet of row. The sugar beet plots were defoliated and root yield, percent sugar, and recoverable white sugar per acre were determined by hand digging the center two rows of each six-row plot, 25 feet in length. The plot yield was converted to tons/acre. Monitor Sugar Company analyzed five medium-sized sugar beets from each plot[9] for sugar beet quality. Recoverable sugar per acre was converted to pounds per acre. % Clear Juice Purity = (Pol/((RSD%*1.14525)-1.32544))*100 RWSW=((18.4%Sugar)-22)*(1-(60/(%CJP-3.5)))/.4 RWSA=RWST*Tons/Acre (Hubbell, 2001).

[9] Monitor Sugar Company, Bay City, Michigan 48706

The plot design for both experiments was a split plot design with four replications, with crop as the main plot and herbicide treatment as the subplot. Data were subjected to analysis of variance. Significant year-by-treatment interactions occurred; therefore the data are presented separately by year. Treatment means were separated using Fisher's Protected LSD at the 5% level for both the strip-cropping and sugar beet research.

RESULTS AND DISCUSSION

Corn and Soybean

Redroot pigweed and common lambsquarters densities were significantly greater in 1997 (Table 1). Rainfall in 1997 made it difficult to apply herbicide treatments at the correct weed height. All herbicide treatments significantly reduced redroot pigweed and common lambsquarters densities in corn and soybeans compared to the untreated control (Table 2). In corn and soybeans, redroot pigweed densities in the metolachlor PRE followed by bentazon plus flumiclorac POST, bentazon E. POST followed by bentazon POST and bentazon E. POST followed by bentazon/flumiclorac POST treatments were equal to the handweed control (Table 2). In corn, the treatments of metolachlor PRE followed by bentazon plus flumiclorac POST, metolachlor PRE followed by bentazon POST, and bentazon E. POST followed by bentazon POST had common lambsquarters densities equal to the handweed control (Table 2). In soybean, treatments of metolachlor PRE followed by bentazon/flumiclorac POST, bentazon E. POST followed by bentazon POST, and bentazon E. POST followed by bentazon/flumiclorac POST had common lambsquarters densities equal to the handweed control. Total weed densities in corn were lowest in the metolachlor PRE followed by bentazon/flumiclorac POST and the bentazon/flumiclorac E. POST followed by POST treatments (Table 2). These treatments had total weed densities similar to the handweed control. Total weed densities in soybean in the bentazon E. POST followed by bentazon flumiclorac POST, bentazon E. POST followed by bentazon POST, bentazon/flumiclorac POST, and metolachlor PRE followed by bentazon/flumiclorac POST treatments were similar to the handweed control. Herbicide treatments where flumiclorac was added significantly reduced weed densities compared to treatments without flumiclorac. Treatments where a PRE or E. POST was followed by a POST application had significantly lower weed densities compared to a single PRE or POST application. By using multiple applications weeds did not have time to exceed the optimum growth stage for herbicide application. Furthermore, weeds that germinated following the first herbicide application were controlled by the second herbicide application.

Weed densities influenced corn and soybean yield in 1996 and 1997 (Table 3). Corn and soybean yields were greater in all herbicide treatments compared to the untreated control (Table 3). The percent corn yield loss compared to the handweeded control ranged between 2% and 14%. The percent soybean loss ranged between 3% and 20%. In 1996, corn yield in any herbicide treatment did not equal yield in the handweeded control, while in 1997 corn yield in bentazon followed by bentazon equaled that of the handweeded control. Soybeans in 1996 and 1997 had three treatments where yield was equal to that of the handweeded control; however these were not necessarily the treatments with the lowest weed density. Corn and soybean yields were not greater in treatments with the lowest weed densities (Tables 2 and 3). Weed densities were greater in soybean in the untreated control and yield was reduced by 20% in 1996 and 18% in

1997. Corn yield loss in the untreated control was 25% in 1996 and 15% in 1997. Therefore differences in weed control in these herbicide treatments were not reflected in yield loss due to low weed densities in both years.

Sugar Beets

The sugar beet experiment had 25% more weeds in 1996 than in 1997 (Table 4). It was a cool wet spring with a dry summer in 1996. More weeds emerged in 1996 due to periodic rainfall events. These rains made it difficult to spray the weeds at the proper growth stage in sugar beets. Weed densities in sugarbeet varied by previous crop residue and weed management treatment (Table 5). All treatments reduced weed numbers significantly when compared to the no POST control (Table 5). One application of desmedipham plus phenmedipham plus ethofumesate, a split application of desmedipham plus phenmedipham plus ethofumesate, and a split application of desmedipham plus phenmedipham reduced redroot pigweed and common lambsquarters density similarly in corn residues (Table 5). In soybean residue, the desmedipham plus phenmedipham split application treatment had 33% less redroot pigweed than the desmedipham plus phenmedipham plus ethofumesate split application treatment (Table 5). Desmedipham plus phenmedipham has a weed control rating of "good" for redroot pigweed compared to ethofumesate which has only a "fair" rating for redroot pigweed control (Kells and Renner 1999). The desmedipham plus phenmedipham probably provided better redroot pigweed control because it has 17% more desmedipham plus phenmedipham compared to the desmedipham plus phenmedipham plus ethofumesate treatment at the rates applied. In a sugar beet weed control study in 1994 it was shown that phenmedipham + desmedipham gave 8 percent greater redroot pigweed control compared to phenmedipham + desmedipham + ethofumesate (Sugarbeet Research and Extension Reports, 1994). The desmedipham plus phenmedipham split treatment had fewer total weeds than the other two herbicide treatments in soybean residue, reflecting the lower number of redroot pigweeds.

Sugar Beet Stand

The sugar beet population in 1996 following the first cultivation, combined over the previous crop, was 116 per 100 row feet. In 1997, the population after first cultivation was 143 per 100 row feet. Sugar beet stand was 11% lower in 1996 compared to 1997 due to the cool, wet weather conditions that increased weed competition and injury caused by herbicide applications in 1996 (Table 6). Reduced tillage leaves crop residue on the soil surface, which creates cooler and wetter soils. In corn, soybeans, and sugar beets *Pythium,* damping off and root rot have increased with reduced tillage (Pedersen, 1999), and in sugar beets, root rot caused by *Aphanomyces* is becoming a problem. Redroot pigweed has been found to be a host for *Rhizoctonia* (Potter and Schneider, 1981), another seedling root disease. In this two-year study we planted a sugar beet variety resistant to Rhizoctonia and we did not see any insect problems or an increase in disease problems.

Sugar beet, root yield, percent sugar and recoverable white sugar were greater in 1997 (Table 6). In Michigan the average sugar beet yield percent sugar and recoverable white sugar was 24% greater in 1997 versus 1996 reflecting better growing conditions and adequate moisture in 1997 (personal communication with R. Roslund, Monitor Sugar Company, 1998).

Sugar beet stand, root yield, percent sugar and RWSA were greater in sugar beets planted into corn residue compared to soybean residue (Table 7). Sugar beet stand was 23% greater in the corn residue compared to the soybean residue. Residue remaining on the soil surface averaged 35% following corn and 12% following soybeans. The increased residue in corn protected the soil from surface compaction due to heavy rainfall, and probably limited soil crusting, which can prohibit sugar beet seedling emergence. Higher sugar beet populations produce smaller beets with a higher sugar content (personal communication with R. Roslund, Monitor Sugar Company, 1998). In a study conducted in 1994 and 1995 it was shown that increased sugar beet populations increased percent sugar by 0.30 percent (Sugarbeet Research and Extension Reports, 1995). Tonnage therefore does not increase but a higher percent sugar results in a higher RWSA (Table 7 and Figure 1).

In 1996 and 1997, the single application of desmedipham plus phenmedipham plus ethofumesate significantly reduced sugar beet stand when compared to the hand weeded control (Table 8). In 1996, the split application of desmedipham plus phenmedipham also reduced sugarbeet stand compared to the handweed control. The reason for the reduced stand with the split application of desmedipham plus phenmedipham in 1996 was that sugar beets were sprayed the first time at the two leaf stage resulting in herbicide related injury, but in 1997 the sugar beets were sprayed the first time at the three leaf stage which did not result in herbicide injury. In 1994 a single application of desmedipham + phenmedipham + ethofumesate resulted in 26% sugarbeet injury compared to a split application of desmedipham + phenmedipham + ethofumesate (Sugarbeet Research and Extension Reports, 1995).

Sugar beets treated with a split application of desmedipham plus phenmedipham plus ethofumesate treatment had significantly higher root yields in 1996 when compared to the other two herbicide treatments (Table 8). In 1997, yields in all herbicide treatments were significantly greater than yield in the no POST control. The percent sugar and RWSA were affected by herbicide treatment in both years. In 1996 the percent sugar was lower in all herbicide treatments compared to the handweed control. However in 1997 sugarbeets treated with the split application of desmedipham plus phenmedipham had a higher percent sugar and sugarbeets treated with a single application of desmedipham plus phenmedipham plus ethofumesate had a lower percent sugar than the handweed control. RWSA was reduced in the single treatment of desmedipham plus phenmedipham plus ethofumesate in both years compared to the handweed control. The split application of desmedipham plus phenmedipham also reduced RWSA in 1996.

When sugarbeets or corn follow soybean strip-cropping and mulch tillage, soil erosion is reduced by 4.1 tons per acre compared to sugarbeets following dry beans. The erosion rate is based on the length of field which was 1000 feet, field conditions where the slope is 0-1%, the crop residue on the surface, and the climate. The erosion index based on the soil types was 134. Wind erosion rates were calculated from the National Resource Conservation Technical Guide.

Implication for sugar beets

When sugar beets follow corn residue, it becomes difficult to cultivate small sugar beets. Adjustments need to be made in order for the residue to flow through the cultivator without plugging. If adverse weather conditions exist it becomes difficult to dry the soil out with the residue on the soil surface.

SUMMARY

Weeds were controlled with seven weed management programs in corn and soybean strip-cropping. Weed control was greater in plots where two herbicides or split-applied herbicides were used compared to single herbicide application. Redroot pigweed control increased with the addition of flumiclorac in corn and soybean. Corn injury increased with metolachlor/flumetsulam and flumiclorac. Corn yield was lower in plots treated with flumiclorac and metolachlor/flumetsulam. The herbicide programs in this research do not restrict rotation to sugar beets. Weed management options in strip-cropping have increased with the availability of transgenic crops such as Round up Ready™ and Liberty Link™ corn and soybeans.

Sugar beet populations were greater following corn compared to soybeans in one of two years. Corn residue improved sugar beet population in one of two years. Weeds were controlled with all three of the POST herbicide programs following Pyrazon PRE and including cultivation. A single application of desmedipham + phenmedipham + ethofumesate at 0.11 lb a.i./Acre reduced sugar beet stand percent sugar, and recoverable white sugar per acre in both years. These herbicides applied in split applications at reduced rates of 0.06 lb a.i./Acre gave better crop tolerance and increased weed control and root yield.

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Table 1. Weed densities in August of each year averaged over crop and herbicide treatment.

Year	Redroot Pigweed - number/acre-	Common Lambsquarter - number/acre-	Total - number/acre-[a]
1996	393	331	724
1997	649	556	1143
Significance	**	*	*

[a]including all weed species in the plot. Minor weed species are included.

** Significance at the 0.01 probability level.

* Significance at the 0.05 probability level.

Table 2. Weed densities within each crop and herbicide treatment averaged over years.

Herbicide Treatment	Application Method	Redroot Pigweed		Common Lambsquarters		Total Weed Count	
		In Corn	In Soybean	In Corn	In Soybean	In Corn	In Soybean
		- weeds/Acre -		- weeds/Acre -		- weeds/Acre -	
flumetsulam + metolachlor[1]	PRE	464	714	250	464	750	1179
metolachlor fb bentazon[2]	PRE followed by POST	392	538	179	339	535	821
metolachlor fb bentazon + flumiclorac[3]	PRE followed by POST	56	71	36	53	71	125
bentazon[4]	POST	607	786	464	446	1143	1429
bentazon + flumiclorac[5]	POST	604	321	214	340	750	304
bentazon fb bentazon[6]	early POST followed by POST	250	161	109	143	286	304
bentazon fb bentazon + flumiclorac[7]	early POST followed by POST	107	71	215	196	250	268
handweed Control[8]		0	0	0	0	0	0
untreated Control[9]		786	2786	982	2571	1893	5357
LSD (.05)		257	236	206	312	273	421

[1]flumetsulam 0.056/metolachlor 2.1 PRE lb ai/Acre
[2]metolachlor PRE 2.0 lb a.i./Acre bentazon POST 1.0 lb a.i./Acre
[3]metolachlor PRE 2.0 lb a.i./Acre bentazon POST 1.0 lb a.i./Acre plus flumiclorac POST 0.041 lb a.i./Acre
[4]bentazon 1.0 lb a.i./Acre POST
[5]bentazon 1.0 lb a.i./Acre plus flumiclorac 0.041 lb a.i./Acre POST
[6]bentazon 1.0 lb a.i./Acre E. POST/POST
[7]bentazon 1.0 lb a.i./Acre E. POST/bentazon plus flumiclorac 0.041 lb a.i./Acre POST
[8]handweeded control
[9]untreated control

Footnote: Total weed count includes all weed species present in corn or soybeans.

Table 3. Crop yield in each herbicide treatment expressed as a percentage of the handweeded control each year.

Herbicide Treatment	Application Method	Corn Yield 1996	Corn Yield 1997	Corn Yield 1996	Corn Yield 1997	Soybean Yield 1996	Soybean Yield 1997	Soybean Yield 1996	Soybean Yield 1997
		- bu/Acre -		- % hw control/Acre -		- bu/Acre -		- % hw control/Acre -	
flumetsulam + metolachlor[1]	PRE	138	181	84	92	49	46	98	90
metolachlor fb bentazon[3]	PRE followed by POST	155	190	94	96	47	48	94	96
metolachlor fb bentazon + flumiclorac[2]	PRE followed by POST	159	186	96	94	48	50	96	98
bentazon[4]	POST	145	188	88	95	49	47	98	92
bentazon + flumiclorac[5]	POST	156	191	95	97	49	49	98	96
bentazon fb bentazon[6]	early POST followed by POST	159	193	96	98	47	48	94	94
bentazon fb bentazon + flumiclorac[7]	early POST followed by POST	135	183	82	93	48	50	96	98
handweed Control[8]		165	197	100	100	50	51	100	100
untreated Control[9]		124	167	75	85	40	42	80	82
LSD (.05)		3	5	2	3	2	3	3	4

[1]flumetsulam 0.056/metolachlor 2.1 PRE lb ai/Acre
[2]metolachlor PRE 2.0 lb a.i./Acre bentazon POST 1.0 lb a.i./Acre plus flumiclorac POST 0.041 lb a.i./Acre
[3]metolachlor PRE 2.0 lb a.i./Acre bentazon POST 1.0 lb a.i./Acre
[4]bentazon 1.0 lb a.i./Acre POST
[5]bentazon 1.0 lb a.i./Acre PLUS flumiclorac 0.041 lb a.i./Acre POST
[6]bentazon 1.0 lb a.i./Acre E. POST/POST
[7]bentazon 1.0 lb a.i./Acre E. POST/bentazon plus flumiclorac 0.041 lb a.i./Acre POST
[8]handweeded control
[9]untreated control

Table 4. Weed density in sugarbeet each year averaged over previous crop and herbicide treatment.

Year	Redroot Pigweed - number/acre-	Common Lambsquarter - number/acre-	Total - number/acre-
1996	1398	1037	2435
1997	711	1127	1837
Significance	**	ns	**

** Significance at the 0.01 probability level.

* Significance at the 0.05 probability level.

ns Not significant

Table 5. Weed density in sugarbeet in each weed management treatment in corn and soybean residue averaged over years.

Herbicide Treatment	Redroot Pigweed density/acre		Common Lambsquarter density/acre		Total Weeds density/acre	
	Corn Res.	Soybean Res.	Corn Res.	Soybean Res.	Corn Res.	Soybean Res.
desmedipham+phenmedipham+ethofumesate[1]	417	925	400	700	817	1625
desmedipham+phenmedipham+ethofumesate[2]	400	833	400	833	800	1666
desmedipham + phenmedipham[3]	308	558	433	708	742	1267
Handweeded control[4]	0	0	0	0	0	0
Pyrazon[5]	2470	4363	3121	4220	5862	8583
LSD (0.5)	234	267	100	217	310	451

[1] Applied desmedipham at 0.0367 lb a.i./Acre plus phenmedipham at 0.0367 lb a.i./Acre plus ethofumesate 0.0367 at 0.0367 lb a.i./Acre seven days after first cultivation

[2] Applied desmedipham at 0.02 lb a.i./Acre plus phenmedipham at 0.02 lb a.i./Acre plus ethofumesate at 0.02 lb a.i./Acre three days prior to cultivation and seven days after cultivation

[3] Applied desmedipham at 0.085 lb a.i./Acre plus phenmedipham at 0.085 lb a.i./acre three days prior to cultivation and seven days after cultivation

[4] Hand labor and mechanical weed control only

[5] Pyrazon PRE 3.0 lb a.I./Acre

Footnote: All treatments received Pyrazon PRE in a ten inch band

Table 6. Sugarbeet stand, percent sugar, and recoverable white sugar per acre in 1996 and 1997, averaged over previous crop and herbicide treatments.

Year	Stand	Root Yield	% Sugar	RWSA
	- 100 ft of row -	- T/Acre -		- lb/Acre -
1996	99	14.7	14.8	3095
1997	126	27.2	16.9	6349
Significance	**	**	**	**

** Significance at the 0.01 probability level.

* Significance at the 0.05 probability level.

Table 7. Influence of previous crop on sugarbeet stand, root yield, and recoverable white sugar per acre, averaged over year and herbicide treatment.

	Stand	Root Yield	% Sugar	RWSA
	- 100 ft of row -	- T/Acre -		- lb/Acre -
Corn Residue	127	21.8	16.2	5042
Soybean Residue	98	20.1	15.4	4402
Significance	**	ns	**	**

** Significance at the 0.01 probability level.
* Significance at the 0.05 probability level.
ns Not significant

Table 8. Influence of herbicide treatment each year on beet stand, root yield, percent sugar, and recoverable white sugar per acre.

Herbicide Treatment	Stand - 100 ft of row-		Root Yield - T/Acre -		% Sugar		RWSA - lb/Acre -	
	96	97	96	97	96	97	96	97
desmedipham+phenmedipham+ethofumesate[1]	83	127	14.3	27.0	13.9	16.0	2767	6063
desmedipham+phenmedipham+ethofumesate[2]	123	131	18.4	28.1	14.6	17.0	3807	6727
desmedipham + phenmedipham[3]	77	129	12.0	27.9	14.3	17.2	2383	6626
Handweeded control[4]	111	133	18.2	28.4	15.6	16.8	4153	6567
Pyrazon[5]	99	110	10.7	24.4	15.4	17.5	2365	5758
LSD (0.05)	14	5	1.9	1.6	0.2	0.3	495	402

[1] Applied desmedipham at 0.0367 lb a.i./Acre plus phenmedipham at 0.0367 lb a.i./Acre plus ethofumesate 0.0367 at 0.0367 lb a.i./Acre seven days after first cultivation

[2] Applied desmedipham at 0.02 lb a.i./Acre plus phenmedipham at 0.02 lb a.i./Acre plus ethofumesate at 0.02 lb a.i./Acre three days prior to cultivation and seven days after cultivation

[3] Applied desmedipham at 0.085 lb a.i./Acre plus phenmedipham at 0.085 lb a.i./acre three days prior to cultivation and seven days after cultivation

[4] Hand labor and mechanical weed control only

[5] Pyrazon PRE 3.0 lb a.I./acre

Footnote: All treatments received Pyrazon PRE in a ten inch band

Figure 1. Relationship of RWSA to sugar beet population, combined over previous crop and years.