Four Tillage Methods of Soybeans
Annual Report
North Central Sustainable Agriculture Research & Education Program

1. **Date:** December 15, 2000

2. **Title:** Integrating Organic Soybean Production following Conservation Reserve Program (CRP) Land into Sustainable Farming Systems

3. **Project No.:** LCN 99-160

4. Summary:

An experiment was conducted to evaluate the effect of four tillage methods for organic soybean production following CRP land in 1999 and 2000 at the ISU McNay Research and Demonstration Farm in Chariton, Iowa. Plots were laid out in a randomized complete block arrangement with four treatments and four (2000) or eight (1999) replications on CRP land. Treatments consisted of four primary tillage methods: Fall moldboard plowing; Fall Kverneland® plowing; Fall and spring tillage with a Howard Rotavator®; and Spring moldboard plowing. All organic soybean systems yielded well, averaging 49.3 bushels/acre in 1999 and 56.4 bushels/acre in 2000. These yields were above the county average in both years.

5. **Type of Report:** Annual/First-year Report

6. **Project Coordinator:**

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Matt Liebman, Associate Professor, Iowa State University, Dept. of Agronomy, Ames, IA
Lori Altheide, Soil Conservationist, Natural Resources Conservation Services, Ottumwa, Iowa

8. **Duration of Project:** Two years (FY 00-01)
9. **Project Status:** First-time Recipient

ABSTRACT
"Integrating Organic Soybean Production following Conservation Reserve Program (CRP) Land into Sustainable Farming Systems"
Project Contact: Kathleen Delate, Iowa State University

Organic farming has increased to a $6 billion industry in the U.S. and continues to expand approximately 20% annually. In Iowa alone, organic acreage has increased from 13,000 in 1995 to 150,000 in 1999. Across the North Central region, there has been a great interest in planting organic soybeans on Conservation Reserve Program (CRP) land, where up to a 400% premium can be obtained compared to conventionally raised soybeans. Top research needs for organic farmers in Iowa include "CRP conversion to organic production" and the issue of "long- vs. short-term rotations." Compliance with soil conservation plans is mandatory in the development of ideal cropping systems. Regulation of soil organic matter through additions of plant residues and proper crop rotations will determine the long-term sustainability of the system. The Objectives of this research and education program include the following: (1) Establish plots dedicated to organic farming research on CRP land; (2) Implement production and management regimes for opening CRP land and for weed control in organic systems on CRP land; (3) Evaluate the biological and economic outcomes of the different systems; and (4) Promulgate technology transfer through demonstrations/Field Days and publications for area farmers and agricultural professionals. The Methods adopted for this project included the establishment of a long-term agroecological research (LTAR) site in southeast Iowa. Plots were established at the Iowa State University McNay Research and Demonstration Farm in Chariton, Iowa, in a randomized complete block arrangement with four treatments and four (2000) or eight (1999) replications on CRP land. Treatments consisted of four primary tillage methods: Fall moldboard plowing; Fall Kverneland® plowing; Fall and spring tillage with a Howard Rotavator®; and Spring moldboard plowing. Soil samples were taken pre- and post-harvest to determine physical and chemical changes in the system. Sampling for plant performance, weeds, insects and nematodes followed methods developed for the all LTAR sites. Results from the McNay Farm were very encouraging. All organic soybean systems yielded well, averaging 49.3 bushels/acre in 1999 and 56.4 bushels/acre in 2000. These yields were above the county average in both years. Plant populations were reduced significantly by tillage operations, but there were no significant differences among tillage treatments in final stand counts. Early weed counts in 1999 demonstrated a significant increase in grass weeds in the rotavated plots but no significant differences were detected with broadleaf weeds. Despite differences early in the season, there were no significant differences in weed populations at the end of the 1999 season. Yields were greatest in the spring-plowed plots (51.7 ± 3.02 bushels/acre) in 1999 and in 2000 (59.8 ± 1.69). Soybean grain quality was also high in all systems. Protein content averaged 42.2% in 1999 with soybeans from spring-plowed plots averaging 42.4 ± 0.46%.

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INTRODUCTION

Organic farming has increased to a $6 billion industry in the U.S. and continues to expand approximately 20% annually. In Iowa alone, organic acreage has increased from 13,000 in 1995 to 150,000 in 1999 (IDALS, 1999). Across the North Central region, there has been a great interest in planting organic soybeans on Conservation Reserve Program (CRP) land, where up to a 400% premium can be obtained compared to conventionally raised soybeans. Top research needs for organic farmers in Iowa include "CRP conversion to organic production" and the issue of "long- vs. short-term rotations." Compliance with soil conservation plans is mandatory in the development of ideal cropping systems. Regulation of soil organic matter through additions of plant residues and proper crop rotations will determine the long-term sustainability of the system.

OBJECTIVES

The objectives of this research and education program include the following: (1) Establish plots dedicated to organic farming research on CRP land; (2) Implement production and management regimes for opening CRP land and for weed control in organic systems on CRP land; (3) Evaluate the biological and economic outcomes of the different systems; and (4) Promulgate technology transfer through demonstrations/Field Days and publications for area farmers and agricultural professionals.

METHODS

McNay Memorial Research Farm

In 1999, an experiment was initiated at the ISU McNay Research and Demonstration Farm in Chariton, Iowa, to evaluate the effect of four tillage methods for organic soybean production following CRP land. The Research Farm dedicated approximately two acres of a five-year old field (bromegrass and alfalfa) for this study. Bromegrass predominated in the field, as is typical of CRP land in this area of the state.

Experimental Design

As part of a Leopold Center for Sustainable Agriculture project, plots were laid out in a randomized complete block arrangement with four treatments and eight replications on September 30 and October 7, 1998. Thirty-two plots were established, measuring 30 x 60 ft. each. Treatments consisted of four tillage treatments: Treatment 1 = fall moldboard plow followed by standard spring disking and harrowing to finish the seedbed; Treatment 2 = fall plowing with a Kverneland® plow plus standard spring preparation; Treatment 3 = fall and spring tillage with a Howard Rotavator®; Treatment 4 = spring plowing with a moldboard plow plus standard spring preparation. For the 2000 field season, forty-eight plots (four tillage treatments, four replications and three crops) were established, in order to examine the issue of which crop in the required three-year rotation (soybeans, corn or oats) would prove the most advantageous in terms of yields, soil quality and economic benefits when transitioning CRP land into organic production. Sufficient land was not available at the 2000 field site to establish the required 30 feet minimum border between certified organic and conventional plots. Thus, the conventional v. organic yield comparisons would consist of comparisons at the certified organic Neely-Kinyon LTAR site in Greenfield, Iowa (Delate et al., 2000).

Field Operations

All fall tillage was accomplished on October 14, 1998, for the 1999 season, and on October 10, 1999, for the 2000 season. Winter rye was broadcast with a three-point mounted spreader on all plots that would be planted to soybeans. Rye planting occurred on October 15, at a rate of one bushel per acre to serve as a ground cover to prevent erosion and mitigate weed populations in the spring. Manure was applied to plots going to corn and soybeans on May 4, 1999, and on April 4, 2000, at a rate of 4,500 lb./acre. Plots were disked on May 4 and 28 in1999, and on March 3 and April 14 in 2000. Harrowing occurred on March 25, 2000. Spring plowing was completed on May 4 in 1999, and on March 16 in 2000. Oats ('Jerry') were planted at a rate of 2 bushels/acre with an underseeding of 'Cherokee' red clover (12 lb./acre) on March 25, 2000. Soybeans ('IA 2034'in 1999 and 'Pioneer 9305' in 2000) were planted at a population of 175,000 plants/acre on May 28, 1999 and on May 16 in 2000. Plots were rotary-hoed for weed control on June 6 and June 18, 1999, and on June 6 and 13, 2000. Row cultivation occurred on June 24, July 7 and 15 in1999, and on June 20 and July 10 in 2000. Soybean plots were "walked" (large weeds removed by hand) on August 15, 1999, and on July 21 and 28, 2000, as per local organic practices to remove any potentially staining weeds prior to harvest. Because of unsuitable weather conditions (long periods of high moisture soil), we could not utilize the propane flame burner in the LTAR plots. A separate organic corn flaming trial was established to evaluate this effect. Corn was flamed on July 3, 2000, when plants were 22 inches in height. Oats were harvested on July 14, 2000. Corn and soybeans were harvested with a combine with an enclosed scale on October 7, 1999, and on October 8 in 2000.

Sampling

Soil samples (five random samples per plot) were taken on October 7, 1998, and on November 17, 1999, using methods described by Cambardella (1994) for the Neely-Kinyon LTAR site. Sampling for soil, plant performance, weeds, insects and nematodes followed methods developed for the Neely-Kinyon LTAR site (Delate 1999). Crop stand counts were taken on June 21, 1999, and on June 9, 2000 (24 days after planting). Weed counts (3 square meter quadrats per plot) were taken on June 21 and August 26, 1999; and on June 9, 2000. Weed counts were also taken prior to flaming (July 3) and 37 days following flaming (August 7) in the organic corn flaming trial. Bean leaf beetles, which are associated with the soybean staining disease complex, were sampled in soybean plots on July 7, 2000, by sweeping 15 times per plot with a15 inch diameter net). Corn borer populations were sampled by removing 3 randomly selected corn whorls per plot, and recording number of corn borer feeding holes, and actual larvae.

RESULTS

Results at the McNay Farm were very encouraging. Soils were sampled in November 1998 in order to characterize the pre-plowing soil conditions. Organic matter averaged 5.4%, pH averaged 7.1, P levels averaged 7.7 ppm and K averaged 116 ppm. Soils were rated in the low-to-medium range for phosphorus in 1998. Following tillage and harvest, soil quality was not significantly different among treatments (Table 1). Rotavated plots averaged greater P levels (32 ± 9 ppm) compared with other treatments, but differences were not significant. All organic soybean systems yielded well, averaging 49.3 bushels/acre in 1999 and 56.4 bushels/acre in 2000. These yields were above the county average in both years. Plant populations were reduced by secondary tillage operations in both years. There were no significant differences among tillage treatments in stand counts at 21 days after planting in 1999 (Figure 1). In 2000, soybean stand counts were significantly lower in the plots that were rotavated (Table 2).

Table 2. Effect of primary tillage following CRP on weed populations and crop stand in organic soybean, 2000.

Treatment	Grass Weed Populations/ Square Meter (Mean ± SE)	Statistical Significance	Broadleaf Weed Populations/ Square Meter	Statistical Significance	Plant Population/ acre
Soybeans-Fall Plowed	1.4 ± 0.4	NSD*	2.8 ± 0.5	NSD	156,525 ± 11,235
Soybeans-Spring Plowed	2.2 ± 1.0	NSD	2.5 ± 0.4	NSD	162,333 ± 5,288
Soybeans-Kverneland®	1.7 ± 0.6	NSD	2.8 ± 0.9	NSD	155,583 ± 9,596
Soybeans-Rotavator®	3.4 ± 0.8	NSD	1.0 ± 0.2	Sig. lower than other tmnts.	130,417 ± 5,8611[1]

*NSD = No significant differences among treatments, unless designated (P • 0.05)
[1] Significantly lower than Spring Plowed, Rotavator® and Fall Plowed treatments

Early weed counts in soybeans in 1999 reflected a significant increase in grass weeds in the rotavated plots (Figure 3) but no significant differences were detected in broadleaf weed populations (Figure 3). Despite differences early in the season, there were no significant differences in weed populations at the end of the season (Figures 4 and 5).

In 2000, there were no significant differences in grass weed populations, but rotavated soybean plots had significantly lower broadleaf weeds (Table 2). Yields were greatest in the spring-plowed plots (51.7 ± 3.02 bushels/acre) in 1999, although differences among treatments were not significant (Figure 6). Soybean grain quality was also high in all systems (Figure 7). Protein content averaged 42.2%, with soybeans from spring-plowed plots averaging 42.4 ± 0.46%. Oil and fiber content averaged 15.7 ± 0.16% and 4.5 ± 0.03%, respectively. In 2000, spring plowed plots had significantly greater yields, but there were no significant differences in grain quality (Table 3). At peak population levels (July 7), bean leaf beetle populations were not significantly different among treatments (Table 3).

Table 3. Soybean pest populations, grain quality, and yields, 2000.

Treatment	Bean Leaf Beetle (Per15 sweeps)	Protein (%)	Oil (%)	Fiber (%)	Yields (Bu/acre)
Soybeans-Fall Plowed	0.17 ± 0.11*	38.59 ± 0.17*	18.24 ± 0.14*	4.66 ± 0.04*	56.3 ± 0.9

Soybeans-Spring Plowed	0.08 ± 0.08	38.65 ± 0.21	18.18 ± 0.14	4.68 ± 0.03	59.8 ± 1.6[1]
Soybeans-Kverneland®	0.17 ± 0.11	38.29 ± 0.16	18.28 ± 0.14	4.65 ± 0.04	55.8 ± 0.9
Soybeans-Rotavator®	0.17 ± 0.11	38.51 ± 0.27	18.18 ± 0.22	4.68 ± 0.04	53.6 ± 0.5

*NSD between treatments

[1] Significantly greater than Kverneland®, Rotavator® and Fall MB Plowed treatments

Corn yields were significantly greater in 2000 in spring plowed plots (Table 4). Despite greater yields in the spring-plowed plots, grass and broadleaf weed populations were not lower in these plots. Overall, excellent weed control was achieved with secondary tillage in 2000.

Table 4. Effect of primary tillage following CRP on weed populations and yield in organic corn, 2000

Treatment	Grass Weed Populations/ Square Meter	Statistical Significance	Broadleaf Weed Populations/ Square Meter	Statistical Significance	Yields (Bu/acre)	Statistical Significance
Corn-Fall Plowed	1.5 ± 0.6	NSD*	2.6 ± 0.5	NSD	220.1 ± 5.3	NSD
Corn-Spring Plowed	1.5 ± 0.5	NSD	3.9 ± 0.8	NSD	227.2 ± 11.4	Sig. greater than other tmnts.
Corn-Kverneland®	2.1 ± 0.8	NSD	2.3 ± 0.6	NSD	207.1 ± 5.0	NSD
Corn-Rotavator®	5.1 ± 1.3	NSD	2.0 ± 0.3	NSD	193.6 ± 4.8	NSD

*NSD = No significant differences among treatments, unless designated (P • 0.05)

There were no significant differences among treatments in corn stand in 2000 (Table 5). Corn borer was not detected in any plots during peak population periods. Grain quality varied among treatments: Protein content in the Fall Plowed plots was significantly greater, and oil content was significantly lower than corn from the Rotavator® treatment; and starch content in the Kverneland® plots was significantly lower than Rotavator® and Fall Moldboard treatment

Table 5. Corn plant performance, pest populations and grain quality, 2000.

Treatment	Corn Borer (Per 12 plants)	Plant Population/acre	Protein (%)	Oil (%)	Starch (%)
Corn-Fall Plowed	0	23,583 ± 743	8.33 ± 0.05[1]	3.63 ± 0.03[2]	60.88 ± 0.05

Corn-Spring Plowed	0	22,917 ± 557	8.20 ± 0.04	3.68 ± 0.03	60.85 ± 0.07
Corn-Kverneland®	0	22,167 ± 787	8.40 ± 0.081	3.73 ± 0.05	60.63 ± 0.093
Corn-Rotavator®	0	22,417 ± 874	8.03 ± 0.10	3.75 ± 0.03	60.95 ± 0.10

[1] Significantly greater than Rotavator® treatment
[2] Significantly lower than Rotavator® treatment
[3] Significantly lower than Rotavator® and Fall Moldboard treatment

Flame weeding in the separate organic corn flaming trial, established to evaluate flaming as an additional tool for weed management, demonstrated a significant effect on grass weed populations post-flaming (Table 6). Yields, however, were not significantly increased when corn was flamed at the 22-inch height stage (Table 7). Oat yields averaged 77 bushels/acre.

Table 6. Effect of propane flame burning on weed populations in Organic Corn Flaming Trial, 2000

Treatment	Pre-Flaming Grass Weed Populations/ Square Meter (± SE)	Statistical Significance	Post-Flaming Grass Weed Populations/ Square Meter	Statistical Significance	Post-Flaming Broadleaf Weed Populations/ Square Meter	Statistical Significance
Flamed Corn	9.8 ± 5.1	NSD*	4.9 ± 1.2	NSD	11.4 ± 2.6	NSD
Non-Flamed Corn	8.0 ± 3.3	NSD	21.8 ± 6.3	Sig. lower	11.4 ± 5.7	NSD

*NSD = No significant differences between treatments, unless designated (P • 0.05)

Table 7. Effect of flaming on organic corn yield, 2000.

Treatment	Yields (Bu/acre)	Statistical Significance
Flamed Corn	132.9 ± 5.5	NSD*
Non-Flamed Corn	137.9 ± 3.0	NSD

*NSD = No significant differences between treatments (P • 0.05)

DISCUSSION

Results from this CRP experiment demonstrated excellent production of high quality organic soybeans on land following CRP. Corn yields were also above average. Oats suffered from a wet spring, which led to high populations of oat rust that lowered photosynthetic capacity in the crop. In a drier year (1999), at the Neely-Kinyon organic farm, oats yielded 85 bushels/acre. We were pleased to obtain excellent yields and grain quality in soybean plots that were spring plowed as

opposed to fall plowed. Spring plowing will allow for a vegetative cover during the winter and avoidance of soil erosion associated with fall plowing. Organic farmers in the Midwest, however, prefer fall plowing because of several reported reasons:

- Farmers normally have more time for plowing in the fall than the spring when other tillage, planting and compost-spreading activities occur
- Fall plowing allows for a more complete break-up of soil through the freezing and thawing in winter, and
- Wet springs may preclude spring plowing.

For these reasons, we will continue this experiment in order to determine yield and weed differences in the case of poor weather in the spring. Flame burning significantly lowered grass weed populations, but there was no effect on yield. We will continue to experiment with this technique in 2001.

Current economics dictate the superior economic value of certified organic soybeans ($15/bu) compared to organic corn ($3.75/bu) or organic oats ($2.25/bu). In addition, compared with corn crop demands, soybeans can produce adequately on poorer soil, typical of CRP land. Corn yields were excellent in 2000, however, with returns for certified organic corn totaling $830/acre (before costs). Complete economic analysis for all crops is underway with ISU professor of economics, Mike Duffy (Chase & Duffy, 1991).

CRP conversion may alter existing ecosystem processes, such as nutrient cycling and biological control. Both the CRP program and organic farming practices strive to preserve soil structure and quality on erodable lands, and protect waterways from silting and runoff. Compliance with soil conservation plans is mandatory in the development of ideal cropping systems. Regulation of soil organic matter through additions of plant residues and proper crop rotations will determine the long-term sustainability of the system. With the mineralization of soil organic matter in CRP land during tillage operations, nutrient deficiencies in subsequent crops may occur. Excellent yields in 1999 and 2000, however, demonstrated favorable mineralization for corn and soybean crops.

IMPACTS AND POTENTIAL CONTRIBUTIONS

Transfer of information gathered in this research is imperative if the University hopes to have an impact in rural communities. At the first Organic Farming Research Field Day at the McNay Research Farm on September 7, 1999, and 2000, a total of 198 attendees visited research plots and discussed the benefits of organic production. Since the Field Day, county extension personnel and other agricultural professionals have requested more information on organic farming research in the form of extension publications. The Leopold Center for Sustainable Agriculture also supports this project and results are published through their website and in Annual Reports that are distributed to thousands of Iowans. K. Delate presented 68 slide shows to an audience of 4,500 people in 2000 on the ISU Organic Agriculture Program that included discussions on this CRP Project.

ECONOMIC ANALYSIS

We are currently analyzing all costs of inputs and operations and returns with ISU professor of economics. Expected time of completion is January 2001.

FARMER ADOPTION, IMPACT, AND INVOLVEMENT

Farmers have been involved in this project from its inception. The Leopold Center for Sustainable Agriculture supported Organic Farming Focus Groups in 1998 where the idea for evaluating CRP land into organic production originated. We anticipate offering recommendations for farmers in 2001.

Involvement of Other Audiences

Working with cooperators, including Dr. Cynthia Cambardella of the USDA National Soil Tilth Lab.; Lori Altheide of the local NRCS offices; Mike Duffy (ISU Economics); Dick Thompson (Practical Farmers of Iowa); the ISU Research & Demonstration farm staff (Jim Secor, Mark Honeyman, Dennis Shannon), ISU weed scientists Bob Hartzler and Matt Liebman, Nematologist Greg Tylka, the diagnostic labs. in Agronomy, Horticulture, and the Grain Quality Initiative, and local Extension crops specialist, Mark Carlton, has enhanced the impact of this project. The Organic Crop Improvement Association (OCIA) and Heartland Organic Marketing Cooperative have also been involved as consultants and participants in dissemination of information gathered from this research. We gratefully acknowledge the help of the Howard Rotavator ® Company in providing equipment for this research.

Areas Needing Further Study

A third year of data collected from this research, including the economic analysis, is critical. In addition, reports from area farmers on their experiences with CRP conversion to organic production will be incorporated into the final report.

Information Products and Outreach

An Extension brochure on “Growing Organic Soybeans on CRP Land” has been sent to the publisher. Expected date of printing is February 2001. A slide show is also under development.

Figure 1. Soybean stand counts at McNay CRP trial, 1999.

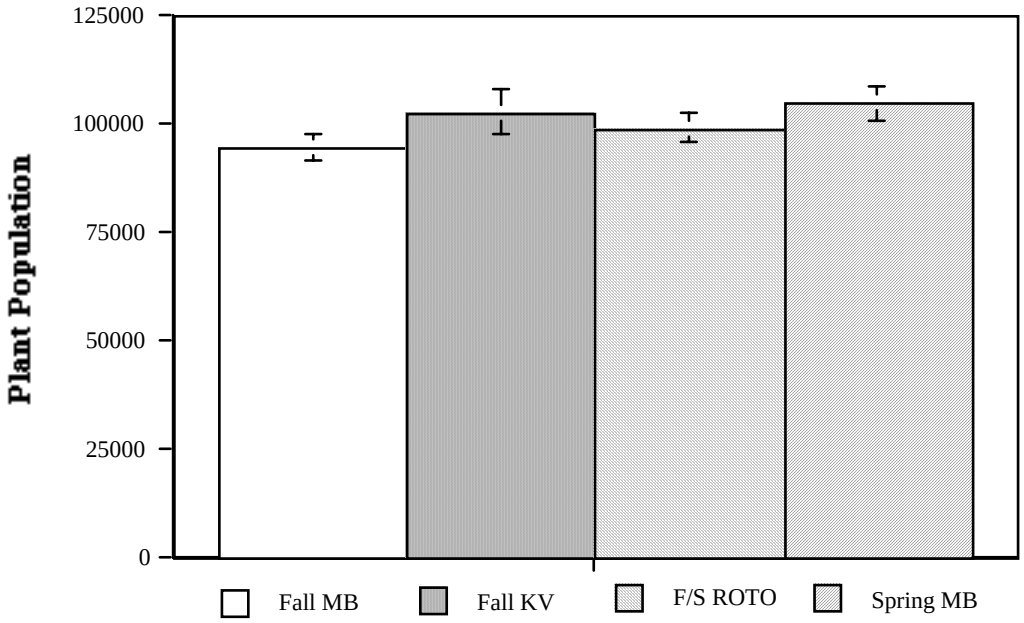

Figure 2. Early grass weed populations in soybean plots, McNay Farm, 1999.

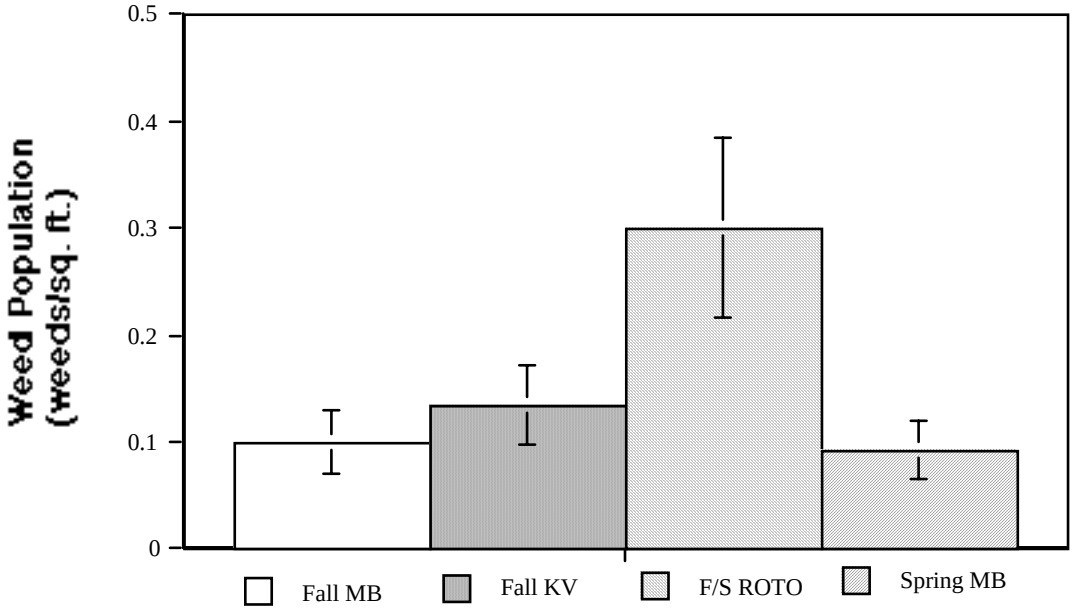

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Figure 3. Early broadleaf weed poulations, McNay Farm, 1999.

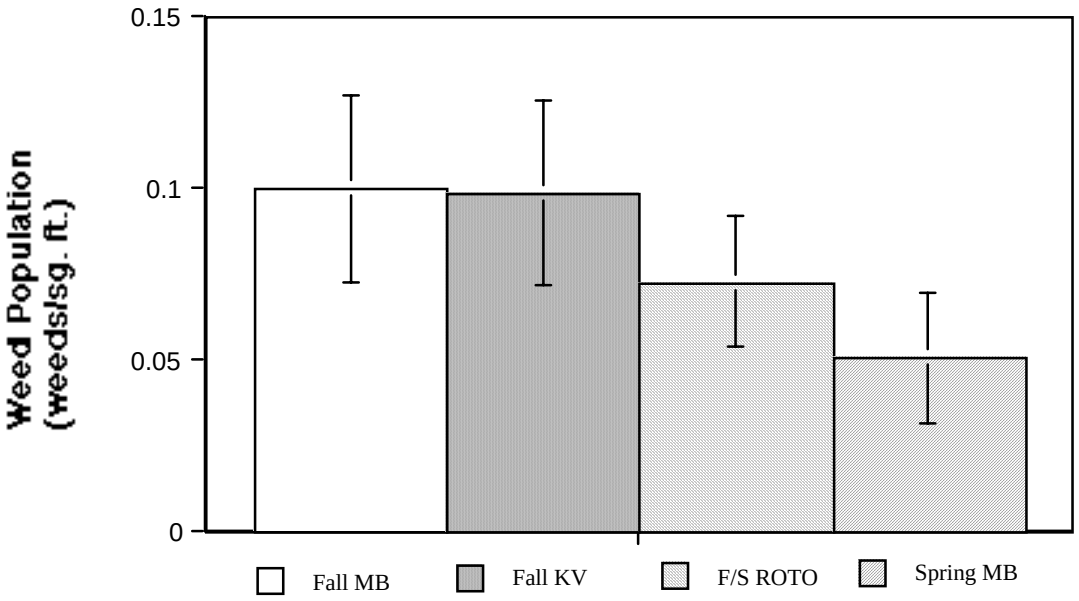

Figure 4. Late grass weed populations in soybean plots, McNay Farm, 1999.

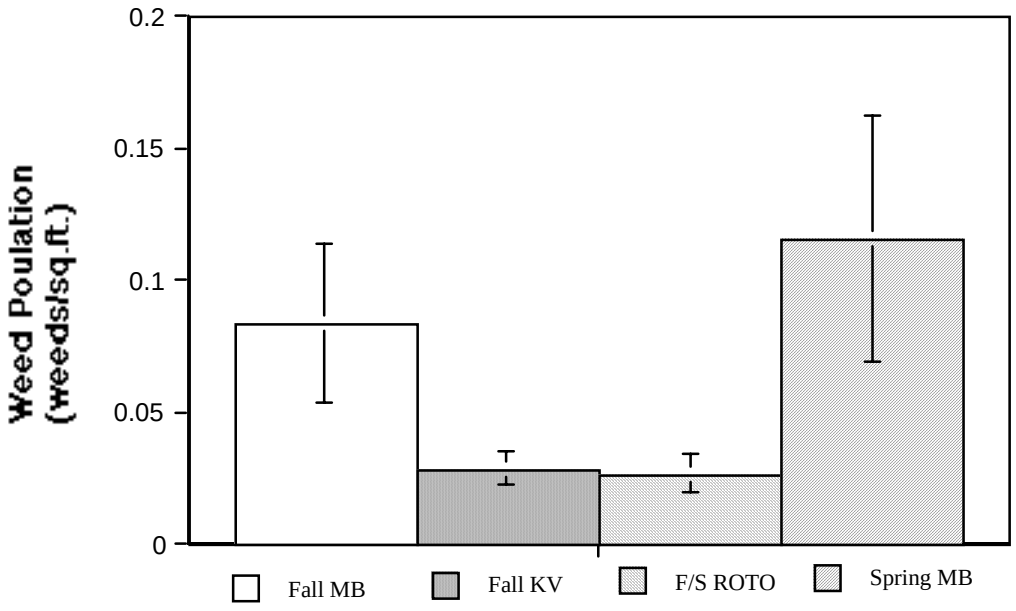

Figure 5. Late broadleaf weed populations in soybean plots, McNay Farm, 1999.

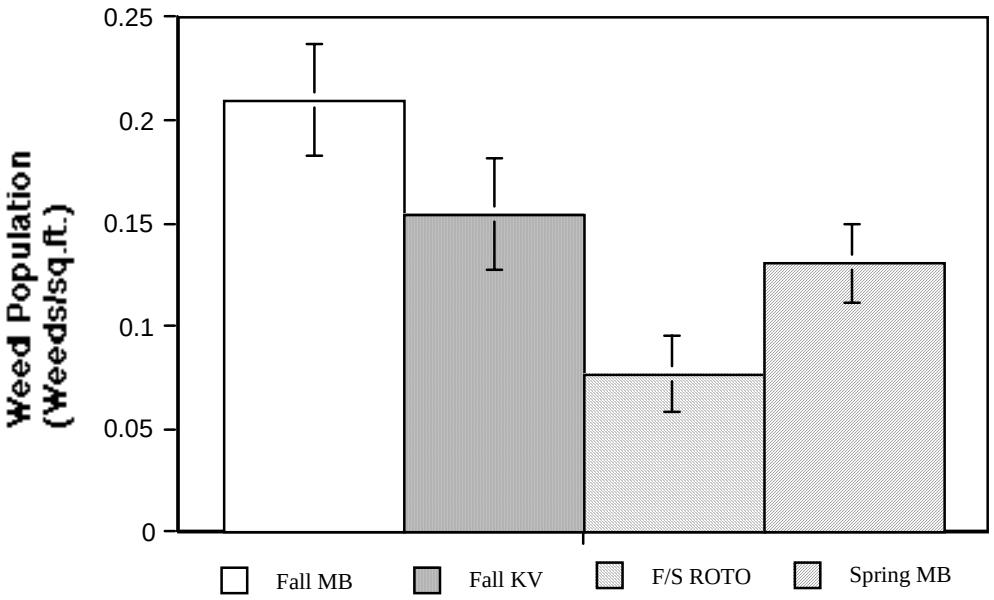

Figure 6. Soybean yields from McNay CRP trial, 1999.

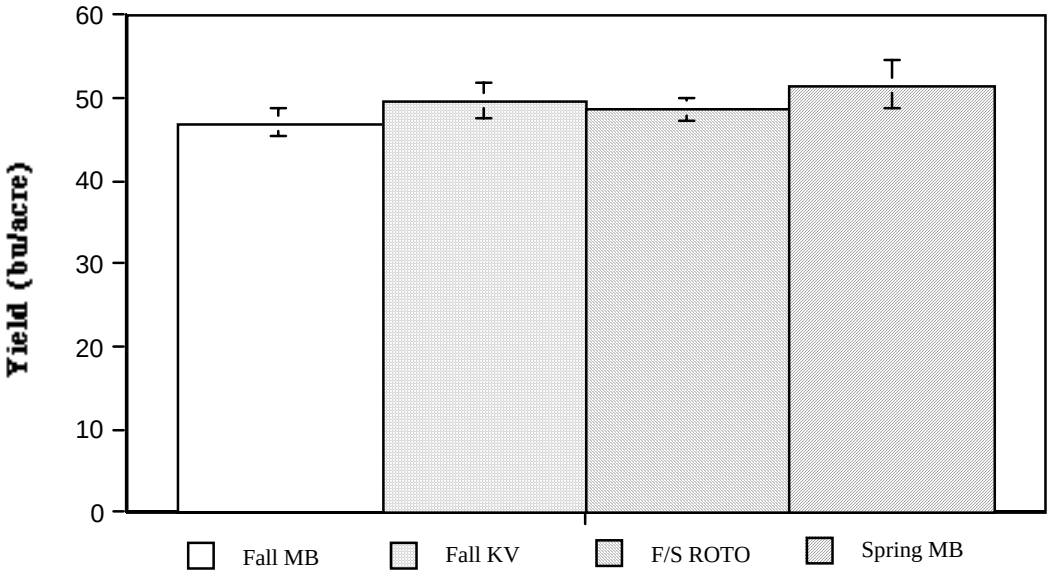

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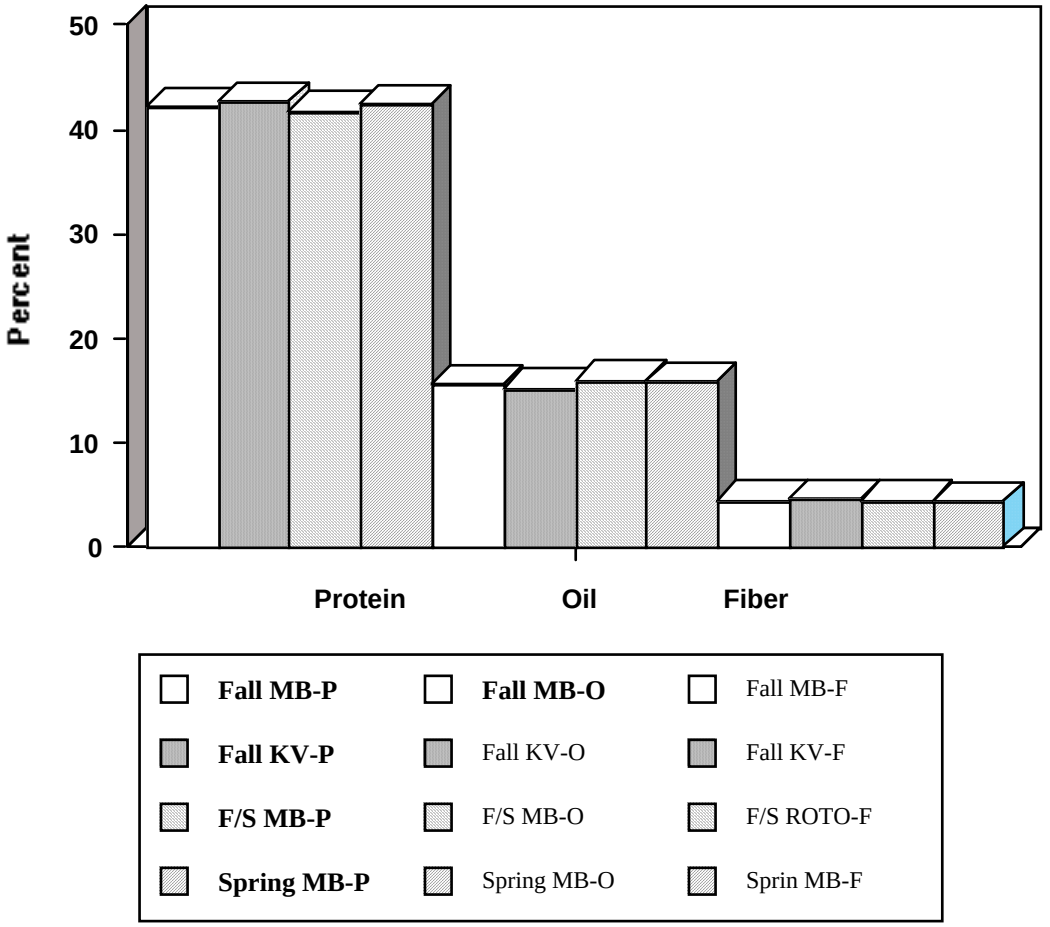
Figure 7. Soybean grain analysis, McNay Farm, 1999.



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