Technical **Bulletin** TB02-2

Agricultural Experiment Station | Soil and Crop Sciences Department | Southwestern Colorado Research Center | Cooperative Extension

May 2002

Developing Sustainable Dryland Cropping Systems in SW Colorado and SE Utah Using Conservation Tillage and Crop Diversification

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Knowledge to Go Places

Developing Sustainable Dryland Cropping Systems in SW Colorado and SE Utah Using Conservation Tillage and Crop Diversification

2000 & 2001 Results

by

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Technical Bulletin from the Agricultural Experiment Station, Colorado State University
2002

Funding for this project was provided by the USDA/CSREES (Western SARE Project no. SW99-56) and by the Colorado Agricultural Experiment Station.

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Acknowledgments

Our sincere gratitude goes to Steve Chappell, Kirk Crowley, Bill Richardson, and Bob Barry for providing land and/or actively participating to the management of the on-farm trials. We thank Mark Stack, Manager, and Jerry Mahaffey, Research Technician who provided valuable help for the installation and management of the field trial at the Southwestern Colorado Research Center. Our thanks extend to Daniel Fernandez, Dolores County Extension Director, Douglas Ramsey of NRCS-Cortez, Don Michael Andrews of NRCS-Monticello, and James Keys, Southeastern Utah Regional Department Head for their assistance with the outreach and other activities. We also would like to thank Professors Kenneth Barbarick and Dwayne Westfall for reviewing this report and providing valuable comments.

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Abstract

Low and erratic precipitation, low crop yields, and moderate to high soil erosion potential characterize the farming area of the San Juan Basin within the Colorado Plateau. Soil erosion is of particular concern in the project area due to the erosive nature of the soils, the rolling topography, and tillage intensity. The two major dryland crops in the San Juan Basin, winter wheat (*Triticum aestivum*) and dry bean (*Phaseolus vulgaris*) averaged 18 bu./acre and 390 lb./acre, respectively from 1989 to 1997.

No-till and minimum tillage practices combined with proper nutrient management have been used in semi-arid regions to reduce soil erosion, improve water storage and use efficiency, and increase grain and stover yield. Our experience at the Southwestern Colorado Research Center indicates that winter wheat can be grown successfully with no-till and minimum till management systems in either the wheat-bean or the wheat-fallow sequence. In contrast, no-till dryland dry bean production has not been feasible in southwestern Colorado. Surface soil compaction appears to be the primary constraint in no-till beans. Minimum till wheat-bean management systems compete better with conventional tillage, but the use of herbicides must be minimized to make the system profitable.

A three-year SARE project was funded in 2000 to evaluate dryland cropping systems that would maximize water use efficiency and economic return and minimize the detrimental effects to the environment such as soil erosion. One field trial was established in 1999 at the Southwestern Colorado Research Center in Yellow Jacket and two on farmers' fields in 2000 at Goodman Point in Colorado and Eastland in Utah. The primary research objective was to determine the effectiveness of alternative soil and crop management systems on crop yield, soil and water conservation, soil fertility, and pest management. Information dissemination was a focus of the SARE project. Treatments consisted of two- and three-year crop rotations managed

using conventional (CT) or minimum tillage (MT) systems.

A severe drought during most of the 1999-00 season (October-September) resulted in partial or total failure of the spring crops at all three sites. Only winter wheat after summer fallow produced normal grain yield. The lowest wheat yield at Yellow Jacket was obtained after chickpea (*Cicer arietinum* L.), probably due to extensive soil moisture extraction by chickpea as compared to pinto bean, which has a shallower root system.

The 2000-01 season was not as dry as the previous season but it was 4.5 inches below normal (11.38 versus 15.88 inches). A frost on June 14 caused damage to pinto bean, corn (*Zea mays*), and winter triticale (x *Triticosecale* spp.). Bean yields were higher in 2001 than in 2000 at all three sites. Bean after winter wheat in CT wheat-bean and bean after corn in MT wheat-corn-bean produced significantly more than bean after safflower (*Carthamus tinctorius* L.) at Yellow Jacket due to more available soil moisture at planting. Winter wheat yield was extremely low at Goodman Point, due to late planting, dry conditions in the spring of 2001, and high residual soil nitrogen. Soil nitrogen promoted excessive early wheat growth, which depleted soil moisture quickly. A poor wheat stand at Eastland resulted in low yield compared to 2000. Winter wheat yield at Yellow Jacket was significantly higher in MT wheat-fallow than in CT wheat-fallow due to the addition of N and P fertilizer and more available soil moisture at planting in MT wheat-fallow. Winter wheat after chickpea or after pinto bean in wheat-corn-bean was similar to MT wheat-fallow. More testing is needed before recommendations can be made concerning the sustainability of dryland cropping systems in SW Colorado and SE Utah.

Introduction

The project area includes Dolores, Montezuma, and San Miguel counties in southwestern Colorado and San Juan County in southeastern Utah. It is part of the San Juan Basin within the Colorado Plateau. Seventy six percent of the total cropland (350,000 acres) in this area is dryland and will not have irrigation water available at any time in the future (Utah Agricultural Statistics Service, 1989-1997). Crop yields are limited by the low and erratic precipitation (range of 7 to 24 inches, long-term annual average of 13 to 16 inches), the short growing season (100 to 150 frost-free days), and poor soil fertility. The two major crops, winter wheat and dry bean

(primarily pintos) averaged approximately 18 bu./acre and 390 lb./acre, respectively from 1989 to 1997 (Colorado Agricultural Statistics Service, 1989-1997; Utah Agricultural Statistics Service, 1989-1997).

Excessive tillage and a low level of inputs are believed to contribute to the low soil productivity in the project area. Tillage practices commonly used in the area include disking and moldboard plowing in the fall after wheat harvest, two to four operations in the spring with a field cultivator, one operation with a tine-tooth harrow shortly before bean emergence, and one or two between-row cultivations. Most cultivated soils in the project area have low organic matter content and thus have low nitrogen supply capacity, along with low phosphorus availability. The majority of dryland farmers do not fertilize their wheat or bean crops and few use herbicides other than 2,4-D to control weeds.

The combination of fine, weakly structured, silty soils and relatively steep sloping terrain (predominant slopes are 3 to 6%) subjects this primarily "clean" tilled area to potentially severe water erosion. The principal erosion hazard is due to spring runoff from melting snow (Brengle et al., 1970). Wind erosion is rarely a serious problem. Erosion rates measured in the Colorado Plateau, on eolian soils for 50 years ranged from 13 tons/acre/year on cultivated fields with 2 to 3% slope to 39 tons/acre/year on fields with 6 to 7% slope (U.S. Department of Agriculture, Soil Conservation Service, 1992). Recent estimates of soil erosion utilizing RUSLE (Revised Universal Soil Loss Equation) range from 4 to over 7 tons/acre/year in Montezuma County (NRCS-Cortez). These rates result in large amounts of sediments and salts that reach the Colorado River system each year and cause water quality impairment. Efforts to reduce soil erosion, protect water quality, and improve wildlife habitat have resulted in a large acreage of CRP and other conservation compliance programs but the adoption of conservation tillage practices is not widespread (Conservation Technology Information Center, 1997).

Conservation tillage is the exception rather than the norm in the project area (Conservation Technology Information Center, 1997). Farmers' concerns about conservation tillage include problems associated with operating edible dry bean equipment in wheat residue and maintaining adequate weed and insect control. Research results at the Southwestern Colorado Research Center indicate that winter wheat can be grown successfully with no-till (NT) and MT management systems in either the wheat-bean or the wheat-fallow sequence (Berrada et al.,

1995). In contrast, NT dryland dry bean production was not successful. Bean yield in NT systems was significantly lower than in conventional systems, even though soil water storage had been improved by the NT practice. Surface soil compaction appeared to be the primary constraint in NT beans. Physical properties of the high silt content soils created a poor root environment for the bean plant. Also, a dry-hard surface at harvest makes undercutting the beans very difficult. Croissant et al. (1991) reported a 26% decline in pinto bean yield due to soil compaction over a three-year period. Dry bean is also sensitive to low soil temperature (Hardwick, 1998). Crop residues in NT systems create a colder environment near the soil surface compared to conventional tillage. In general, lower dry bean yields have been reported with NT than with moldboard plowing (Smith and Yonts, 1988; Xu and Pierce, 1998).

Herbicide cost, low precipitation, and low crop yield and return make NT dryland dry bean production in southwestern Colorado a challenge. Minimum till wheat-bean management competes better with conventional tillage, but the use of herbicides must be minimized to make the system profitable (Berrada et al., 1995).

Timing of tillage and herbicide application is essential to achieving good weed control. Fall tillage may be replaced with an application of glyphosate (Roundup) or glyphosate + 2,4-D to control volunteer wheat and winter annuals. Leaving as much crop residue on the soil surface as possible during winter and early spring should also help conserve valuable moisture. One or two timely subtillage operations in the spring will control troublesome weeds such as Russian thistle (*Salsola tragus* L.), prickly lettuce (*Lactuca serriola* L.), and any volunteer wheat that may have emerged in the spring. Trifluralin (Treflan 4EC) applied at 1 pt./acre and incorporated as close to bean planting as possible could be used to control redroot pigweed (*Amaranthus retroflexus* L.) and prostrate pigweed (*A. blitoides* S. Wats.). However, dry bean planting date (early June) coincides with the driest time of the year in the project area, which limits the effectiveness of pre-plant herbicides. Fall application of Trifluralin may work better for this reason. There are a number of pre- and post- emergence herbicides that are labeled for dry bean production but the cost of using them may be prohibitive under dryland conditions. One or two timely row cultivations as part of an integrated weed management system can maximize weed control and minimize herbicide use (Buhler et al., 1992; VanGessel et al., 1995).

The benefits of NT and MT systems have been well documented in other dryland farming

areas, but the soil-climate-cropping system combination in our project area is unique so that direct transfer of that technology has not been possible. Most dryland farming in the area is practiced at elevations exceeding 6500 ft., which limits the number of crops that can be successfully grown. The average length of the frost-free season is only 110 days. Annual precipitation ranges from 7 to 24 inches with a long-term average of 13 to 16 inches, and is nearly equally distributed by month throughout the year, except for a low in June (Colorado Climate Center, 1994). Winter wheat-pinto bean is the main crop rotation in the central part of the project area and winter wheat-fallow is predominant farther north where dry bean production is too risky due to the short growing season. Both wheat and dry bean yields have been extremely low compared to other dryland farming areas with similar amounts of precipitation.

Wheat-bean rotation is preferable to wheat-fallow since it produces a crop each year. Dry beans obtain most of their water from the upper two feet of soil, thereby leaving any subsoil moisture to the following wheat crop (Brengle et al., 1970; Yonts, 1996). Wheat should be planted by mid-September after fallow, or as soon as bean harvest is completed, for optimum yields (Brengle et al., 1976). Late planting not only reduces wheat yield; it also increases the risk of soil erosion since wheat plant establishment may not occur until early spring.

Response of dryland dry bean to N and P fertilizer in southwestern Colorado has been marginal. In contrast, winter wheat grain yield and protein content were significantly increased due to N fertilization in a four-year study at Yellow Jacket, CO (Stack and Fisher, 1992). The marginal return analysis indicated that it would be profitable to apply N fertilizer at 20 lb. N/acre in most years. In years with above average precipitation, up to 60 lb. N/acre may be profitable. There was no significant response to 40 lb. P_2O_5/acre. However, the application of P can increase retention of wheat tillers and hasten maturity if soil available P is low (Rasmussen, 1996).

Traditional dryland farmers in this area have been able to stay in business primarily by farming more land and generating additional revenues through outside employment and business opportunities. Government programs have contributed to the stability of the local farm economy but until recently (http://www.fsa.usda.gov/pas/farmbill.htm), they were a deterrent to crop diversification. Several alternative crops have been evaluated in the project area but few have been commercially grown. Safflower offers the most promise. Safflower is grown under

contract and is processed for cooking oil or birdseed. Four thousand to 5000 acres of safflower were grown in the project area in 1997 (Utah Agricultural Statistics Service, 1989-1997). Safflower yield in San Juan County, UT ranged from zero in 1996 (an exceptionally dry year) to 1050 lb./acre in 1997 (a wet year). Markets for safflower are well established and there appears to be room for expansion. Safflower is a deep-rooted crop that is more drought tolerant than small grains (Berglund et al., 1998). It is planted in late April to mid-May in the project area and is harvested by late September. A good weed management program is important for optimum production as safflower competes poorly with weeds early in the season. Safflower leaves very little crop residue after harvest and should be grown using conservation tillage practices to reduce the potential for soil erosion (Berglund et al., 1998).

Chickpea, better known as garbanzo bean in the U.S., is another crop that shows promise as an alternative to dry bean. Chickpea is more frost tolerant than dry bean and can be planted and harvested two to four weeks earlier, allowing for a more optimum planting date for winter wheat. Hammon et al. (1999) reported a strong correlation between winter wheat planting date and grain yield over a seven-year period at Yellow Jacket, CO. Wheat yield decreased in a linear fashion as planting was delayed past Sept. 1. Chickpea produced substantially higher seed yields than pinto bean in three out of the last four years at Yellow Jacket, CO (Brick et al., 1998). An additional advantage of chickpea is the possibility of direct combining. Other management practices are similar to those used for dry bean production. Large seeds with cream color bring a premium price. Good seed quality has been produced in southwestern Colorado but late planting and/or late summer rains can delay maturity and increase the incidence of green and stained seeds (Berrada et al., 1999).

Objectives:

Research objectives:

1. Determine the effectiveness of alternative soil and crop management systems on crop yield, soil and water conservation, soil fertility, and pest management.
2. Evaluate the costs and returns of these systems in the context of the whole farm enterprise.

Educational objectives:

1. Increase grower awareness and adaptation of conservation tillage practices.
2. Provide information on alternative cropping systems and how they can be used to enhance the sustainability of dryland cropping systems in the project area.

Materials and Methods

Sites, treatments, and experimental design:

One field trial was established in 1999 at the Southwestern Colorado Research Center (SWCRC) in Yellow Jacket, CO and two on farmers' fields in 2000. The on-farm trials were located at Eastland, UT and Goodman Point, CO. The cropping systems at each site were:

Site: Yellow Jacket, CO

1. Conventional Tillage Winter Wheat-Fallow (CT Wheat-Fallow)
2. Minimum Tillage Winter Wheat-Fallow (MT Wheat-Fallow)
3. Conventional Tillage Winter Wheat-Dry Bean (CT Wheat-Bean)
4. Minimum Tillage Winter Wheat-Dry Bean (MT Wheat-Bean)
5. Minimum Tillage Winter Wheat-Safflower-Spring Oat (*Avena sativa* L.) (MT Wheat-Safflower-Oat)
6. Minimum Tillage Winter Wheat-Safflower-Dry Bean (MT Wheat-Safflower-Bean)
7. Minimum Tillage Winter Wheat-Chickpea (MT Wheat-Chickpea)
8. Minimum Tillage Winter Wheat-Corn-Dry Bean (MT Wheat-Corn-Bean)
9. Three-year Alfalfa (*Medicago sativa* L.) (Alfalfa)

Site: Eastland, UT

1. Conventional Tillage Winter Wheat-Fallow (CT Wheat-Fallow)
2. Minimum Tillage Winter Wheat-Fallow (MT Wheat-Fallow)
3. Conventional Tillage Winter Wheat-Dry Bean (CT Wheat-Bean)
4. Minimum Tillage Winter Wheat-Dry Bean (MT Wheat-Bean)
5. Minimum Tillage Winter Wheat-Safflower-Fallow (MT Wheat-Safflower-Fallow)
6. Minimum Tillage Winter Triticale-Corn-Safflower (MT Triticale-Corn-Safflower)
7. Minimum Tillage Winter Triticale-Dry Bean (MT Triticale-Bean)

Site: Goodman Point, CO

1. Three-year Chickpea Monoculture (Chickpea)
2. Three-year Dry Bean Monoculture (Pinto Bean)
3. Winter Wheat-Chickpea Rotation (Wheat-Chickpea)
4. Winter Wheat-Dry Bean Rotation (Wheat-Bean)

The elevation at the three sites ranges between 6800 and 6900 ft. above sea level. The frost-free season is 100 to 120 days for summer crops such as dry bean. Normal precipitation at Yellow Jacket is 15.9 inches per year (Table 1), of which approximately 40% comes from snow (Colorado Climate Center, 1994). Monthly average precipitation ranges from 0.6 to 1.9 inches, with June being the driest month. Precipitation amount and distribution is similar at Eastland and Goodman Point. The soil is also similar. It consists of wind-deposited material overlying sandstone (Price et al., 1988). The predominant soil type at Yellow Jacket and surrounding areas is Wetherill loam (fine, silty, mixed, mesic Aridic Haplustalfs). It is well drained, deep to moderately deep and suitable for cultivation of annual and perennial crops, except on steep slopes where soil erosion hazard is high. Slopes of 1 to 6% are common in the cropland.

Each phase of each crop rotation was present each year. Therefore, there were 20 treatments at Yellow Jacket, 16 at Eastland, and six at Goodman Point. The treatments were assigned at random to the plots within each block (randomized complete block design). The

experiment at Yellow Jacket had three replications and the on-farm trials had two replications each. Plots were laid out as best as possible to minimize extraneous variability, e.g., due to soil and topography within each block. Plot size was based on land availability and equipment size such as planter and combine width. Plots were 42.5 ft. x 140 ft. at Yellow Jacket, 120 ft. x 400 ft. at Eastland, and 38 ft. x 2640 ft. at Goodman Point.

Management:

The field trial at Yellow Jacket was entirely managed by the SWCRC staff. The trial at Goodman Point was entirely managed by the farmer-cooperator. Several farmers as well as the research staff were involved in the management of the SARE trial at Eastland. The farm owner and his helper planted and harvested wheat and safflower and did most of the tillage operations. Another farmer planted and harvested pinto beans while a third farmer planted and harvested corn. The bean and corn farmers paid crop shares to the farm owner. The research staff at the SWCRC assisted with field operations at Eastland, such as fertilizer and herbicide application, tillage, and planting of winter triticale. Decisions on when to plant and harvest the crop and when to work the ground were made by the farmer-cooperator, in consultation with the SARE project field coordinator.

All the plots at Goodman Point were managed conventionally with heavy reliance on tillage to control weeds. The only herbicide used was 2,4-D in winter wheat, in the spring of 2001. No fertilizers were used in 2000 or 2001. Most of the chickpea acreage and some of the bean acreage on this farm is grown organically. The common rotation is alfalfa for seven to eight years followed by chickpea or dry bean in monoculture for three to five years. Adjustments in the crop rotation are made occasionally to meet the requirements for organic certification. Very little wheat is grown on this farm. The plot area was in alfalfa for seven years, until it was undercut with noble sweep blades in the summer of 1999 and moldboard plowed in the fall of the same year. 'Fisher' pinto bean and 'Sanford' chickpea were planted on May 18, 2000 in 36-in. rows, running north and south. 'Fairview' winter wheat was planted on October 18, 2000 in one third of the plots that were either in chickpea or pinto bean.

The whole plot area at Eastland was planted to Fairview wheat in the fall of 1999 after

approximately 14 months of summer fallow. The primary crop rotation on this farm is winter wheat-fallow and to a lesser extent winter wheat-safflower-fallow. In 2001, 400 acres were planted to chickpea for the first time. Most of the safflower acreage is contracted for organic production. The reason the whole plot area was planted to winter wheat in the fall of 1999 was because details of the experiment were not yet finalized. On April 24, 2000, the plots assigned to treatments other than winter wheat were disked[1]. These plots were either left fallow or planted to alfalfa, safflower, corn, or pinto bean. Originally, Cropping System 6 was MT winter triticale-corn-safflower-bean and Cropping System 7 was three-year alfalfa. Alfalfa was planted on May 2, 2000 in dry soil. Safflower was planted on May 11 after it rained 0.34 inch on May 8. Few, if any alfalfa or safflower seeds germinated or emerged due to the dry and windy conditions that prevailed in May and June. Cropping System 6 was later changed to a three-year rotation, winter triticale-corn-safflower and Cropping System 7 to a two-year rotation, winter triticale-bean, given the 2000 drought and the duration (2000-2002) of the SARE project.

The plot area at Yellow Jacket was disked and moldboard plowed in the fall of 1996 and planted to Fisher and 'Cahone' pinto beans in early June 1997. Bean yields averaged 800 to 900 lb./acre. Fairview wheat was planted on October 28, 1998 at 50 lb./acre in the designated plots. 'S-317' safflower and 'Monida' oat were planted on April 20, 1999 at 20 and 50 lb./acre, respectively. 'Blazer XL' alfalfa was planted on May 12 at 12 lb./acre. Sanford chickpea and Grand Valley 'SX-115' hybrid corn were planted on May 20 at approximately 35,000 and 18,000 seeds/acre, respectively. Cahone pinto bean was planted on May 28 at 25,200 seeds/acre. Pinto bean, corn, and chickpea were planted with a Buffalo planter in 30-inch rows. Alfalfa, oat, safflower, and wheat were planted with a Great Plains drill in 8-inch rows. Safflower seeding rate was increased to 28 lb./acre in 2001 to compensate for bird and rodent damage.

No fertilizer or pesticide was applied to any of the treatments in the fall of 1998. Dry fertilizer was broadcast on May 17, 1999 to plots to be planted to pinto bean and chickpea with 15.5 lb. of N, 12.3 lb. of P_2O_5, and 3.6 lb. of Zn/acre and to the corn plots at 32 lb. of N plus 25 lb. of P_2O_5/acre. Soil moisture at planting and throughout most of the 1998-99 growing season was excellent, resulting in record crop yields. Weeds were a problem in the spring crops.

[1] The plan was to spray these plots with Roundup as early as possible in the spring, but persistent and gusty winds made it risky.

They were controlled by cultivation and/or hoeing.

Differentiation between CT and MT soil management systems was not started until the fall of 1999 and spring of 2000. Cultural practices in CT wheat-fallow and CT wheat-bean were typical of those used by dryland farmers in the project area. Minimum till management was based upon the best practices developed at the SWCRC, the type and availability of tillage, planting and spraying equipment; and other factors such as soil condition and weed infestation. The basic premise was to leave as much crop residue on the soil surface as practical while minimizing the use of herbicides to keep the costs down. The main difference between CT and MT at Yellow Jacket and Eastland was moldboard plowing in the fall after wheat harvest in CT but not in MT. Another difference was that CT treatments were not fertilized, while MT treatments were, based on soil test results. The field operations in 2000-01 are shown in Tables 1A to 3A in Appendix A.

Measurements:

Climate:

A rain gauge was installed at each site in early spring and removed before a hard freeze occurs in the fall. Snowfall and other climatic data were obtained from the nearest weather station.

Soil testing:

Composite samples were taken from each site before the establishment of the field trials in the top two ft. of soil and analyzed for pH, soil organic matter, NO_3-N, available P, K, and Zn. In addition, soil samples were taken annually from selected treatments to determine the fertilizer requirements for each crop grown with MT.

Soil water:

Soil cores were taken with a Giddings hydraulic probe mounted on a truck, before planting and after harvest of each crop. They were then weighed, dried for 48 hours at 105°C, and re-weighed to determine soil water content. Bulk density values used to calculate soil water content (dry mass water x bulk density x soil depth) were obtained from previous experiments at Yellow Jacket. The wilting point (WP) of representative soil samples was determined with the pressure chamber method (Klute, 1986). Available water is the difference between total soil water at field capacity minus water content at WP. Sampling depths were 0-1 ft., 1-2 ft., 2-3 ft., and 3-4 ft., but were limited by how deep the hydraulic probe could penetrate the soil. Soil cores were taken from three randomly selected sites in each plot at Yellow Jacket and Eastland and 10 to 14 sites per plot at Goodman Point.

Soil penetration resistance:

Soil penetration resistance, utilizing a manual push cone penetrometer, was measured from 0 to 11.8 inches (0 to 17.7 inches in 2001), at 1.97 inch depth increments. A Spectrum Technologies recording cone penetrometer was used. ASAE EP542 and ASAE S313.3 (ASAE Standards, 1999a,b) Standards were followed using a 0.5 inch base diameter cone. A maximum of 870 lb. $in.^{-2}$ was recorded when the soil penetration resistance exceeded the level allowable by the recording equipment. Measurements were made in June of 2000 and 2001 at the Yellow Jacket site only. Three cone penetration resistance profiles were measured in each plot of each replication (60 plots total). The 20 treatments were combined into six categories. These categories consisted of:

1. Conventional till winter wheat (CT WW)
   Wheat in CT wheat-fallow (2)[2]
   Wheat in CT wheat-bean (6)

[2] Treatment number.

2. Minimum till winter wheat (MT WW)
    - Wheat in MT wheat-fallow (4)
    - Wheat in MT wheat-bean (8)
    - Wheat in MT wheat-chickpea (10)
    - Wheat in MT wheat-safflower-oat (13)[3]
    - Wheat in MT wheat-safflower-bean (16)
    - Wheat in MT wheat-corn-bean (20)
3. Conventional till fallow (CT Fallow)
    - Fallow in CT wheat-fallow (1)
4. Minimum till fallow (MT Fallow)
    - Fallow in MT wheat-fallow (3)
5. Spring crops
    - Pinto beans in:
        - CT wheat-bean (5)
        - MT wheat-bean (7)
        - MT wheat-safflower-bean (15)
        - MT wheat-corn-bean (19)
    - Chickpeas in MT wheat-chickpea (9)
    - Safflower in:
        - MT wheat-safflower-oat (11)
        - MT wheat-safflower-bean (14)
    - Corn in MT wheat-corn-bean (18)
    - Oat in MT wheat-safflower-oat (12)
6. Alfalfa (17)

[3] Spring barley was planted in 2001 in lieu of winter wheat (13).

Yield parameters:

Crop yield at Eastland and Goodman Point was estimated from the whole plot weight. The crop was unloaded in a grain trailer or truck after each crop was harvested and weighed with a commercial scale at the nearest grain elevator. The empty truck and/or trailer weight (tare) was weighed before each harvest operation at the same scale. Scale accuracy was ± 20 lb.

Plot weight = last weight – previous weight.

The weight of the first plot to be harvested = total weight – tare.

A grain sample was taken from each load (plot) to determine test weight and moisture content (wheat, triticale, safflower), protein content (wheat and triticale), or a sample was kept for future reference (chickpea). The dock (% of impurities and unmarketable grain) was determined at the grain elevator. Corn at Eastland was chopped for silage and weighed in the same manner as the grain crops were. Three samples were taken from each load of the chopped corn, weighed, dried in an oven at 80°C for 48 hours and re-weighed to determine the moisture content.

At Yellow Jacket, one or two 4 ft. x 140 ft. strips were harvested from each wheat, oat, barley (*Hordeum vulgare* L. subsp. *vulgare*), and safflower plot with a 125B Hege to estimate grain yield. The grain was collected in a grocery bag or burlap sack, cleaned and weighed with an Ohaus electronic scale (model I10). Test weight and moisture content, in percent, were measured with a Seedburo GMA-128 Analyzer. Corn was harvested with a Kincaid prototype plot combine and handled in the same manner as the other grain crops. A sample of wheat grain from each plot was sent to a private laboratory for protein analysis (% protein). Chickpea and pinto bean were undercut with knives mounted in front of a tractor, raked with a bean rake, and left to dry for one to two weeks (or longer for chickpeas). Each plot had two windrows of approximately six and 12 rows each. Forty (chickpea) to 60 ft. (pinto bean) of the larger of the two windrows were then threshed with a 125 Hege. The seeds were cleaned and weighed. What was left of the crops in the plots was later harvested with a JD 4440 combine, except for the safflower (Hege) and the corn (Kincaid). Alfalfa was cut with a NH 116 swather in early to mid June and baled with a NH 325 baler when the hay moisture was 20% or less. The bales were

then counted and weighed and a sample was taken from each bale to determine its moisture content. A composite sample per plot was sent to a private laboratory to determine its relative feed value (RFV).

Crop residue:

The amount of crop residue after harvest and prior to planting was measured by clipping, picking, and weighing all plant residues on the soil surface in three 1.5 x 3 ft. areas within each plot at Yellow Jacket. The line and point method of evaluating percent residue cover was used at Goodman Point and Eastland since the plots were much larger than at Yellow Jacket. Crop residue data is shown in Tables 4A, 5A, and 6A for information purposes. The residue data have not been analyzed.

Pest evaluation:

Weeds:

Predominant weed species and weed infestation (ratings of 0 [none] to 5 [highest infestation]) were recorded for selected treatments at physiological maturity and prior to herbicide application or tillage.

Cutworm damage:

Cutworm damage in wheat and triticale was evaluated at Eastland on May 15, 2001 by counting the total number of plants in four 10-ft row sections per plot, and the number of plants that were damaged, e.g., cut at the stem or leaves. Cutworm damage assessment in corn at Yellow Jacket and Eastland and chickpea at Yellow Jacket and Goodman Point was done on June 11, 2001 using the same method as described above, except that more rows (six to 12 per plot) were monitored.

Pale western cutworm (Agrotis orthogonia Morrison*) and army cutworm [Euxoa auxiliaris* (Grote)*] moth count:*

This was part of a Western Region IPM project that included Montana, South Dakota, Wyoming, Idaho, western Colorado, and western Nebraska. Four pheromone traps were installed at Yellow Jacket and four at Eastland in late July 2001. Trapped moths were counted and disposed of weekly, for eight weeks. Trap setup instructions and moth counts can be found at www.cutworm.org. Larval counts will be made in the spring of 2002 to validate the forecast model used in the study. The results will be reported in a later publication.

Other insects:

Russian wheat aphids, RWA [*Diuraphis noxiu* (Mordvilko)], were monitored closely due to their incidence in the project area but were not a problem in 2000 or 2001.

Outreach activities:

The SARE project results and information on alternative crops and cropping systems were presented at several meetings, workshops and field demonstrations. The list of completed and planned outreach activities is shown in Appendix B. The impact of the SARE project on dryland farming is southwestern Colorado and southeastern Utah will be assessed after the completion of the project in 2002. This will include an analysis of the economic viability of the cropping systems tested.

Results and Discussion

2000 Results:

Climatic conditions:

The 1999-00 season was one of the driest years on record in southwestern Colorado (http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?coyell). Total precipitation from October 1999 through September 2000 at Yellow Jacket, Colorado averaged 8.4 inches compared to a 30-year average of 15.9 inches (Table 1). October through December 1999 was extremely dry, as was February, April, May, June, and July 2000. Only March and August had above normal precipitation.

Winter wheat:

Fairview winter wheat was planted on October 8, 1999 at 50 lb./acre in all the treatments at Yellow Jacket. Emergence was erratic in the fall and occurred only in the plots that were in summer fallow. There was not enough moisture in the seedbed to germinate wheat seed in the plots that had a spring crop in 1999. Most of the wheat emerged in February and March of 2000. It averaged 15.5 bu./acre with significant differences among the treatments (Table 2). Wheat after fallow had the highest yield in both CT and MT wheat-fallow. The lowest wheat yield was obtained after chickpea, possibly due to greater soil moisture depletion by chickpea, which out yielded pinto bean by a factor of 1.74 in 1999 (1595 vs. 914 lb./acre). Chickpea appears to have a more extensive root system than dry bean. The 1999 crop yields at Yellow Jacket are shown for information purposes only. They are indicative of the yield potential in a good year. Total precipitation during the 1998-99 season (Oct. to Sept.) was slightly above normal (16.4 in.). The field trial at Yellow Jacket was started in the fall of 1998 but differentiation between treatments in terms of soil management did not occur until the fall of 1999. Winter wheat after pinto beans averaged 14.3 bu./acre in 2000, with no significant differences among treatments, as would be expected.

Winter wheat at Eastland averaged 23 to 31 bu./acre in 2000, with no significant differences among the treatments (Table 3). Wheat in MT wheat-fallow produced 35.3 bu./acre in Rep I (Plot 101) and 26.3 bu./acre in Rep II. There was less difference in wheat yield between Replications I and II in the other treatments. Plot 101 is located at the bottom of a 4% slope and could have benefited from runoff moisture. The plot area and adjacent field were summer-fallowed in 1998-99. Soil moisture on Sep. 28, 1999 averaged 15 to 17% by weight in the top four ft., or approximately 2.5 to 3.2 inches of available moisture (data not shown). The wheat plots, with the exception of CT wheat-fallow and CT wheat-bean, were top-dressed with 40 lb. of N/acre (as ammonium nitrate) on April 27, 2000. The fertilized plots produced 4 to 8 bu./acre more grain on average than the non-fertilized plots but the difference was not statistically significant ($Pr>F = 0.308$, CV = 13.3%). Wheat protein content was higher at Yellow Jacket (15.2%) than at Eastland (8.2%) with no significant differences among the treatments at either site. The reason for the large difference in protein concentration between the two sites is not known.

Spring crops:

Extremely dry conditions throughout most of the season resulted in complete failure and/or poor yield of spring crops and alfalfa at all three sites. None of the spring crops were harvested at Eastland. The whole plot area was planted to winter wheat in the fall of 1999. The plots that were assigned to treatments other than winter wheat were disked on April 24, 2000. This did not help the establishment of spring crops since most of the moisture in the topsoil was depleted by winter wheat. Safflower failed completely (no stand) while corn and pinto beans had a poor stand and did not produce enough dry matter or seeds to warrant harvesting.

Fisher pinto bean and Sanford chickpea were planted at Goodman Point on May 18, 2000. Usually, pinto beans are not planted until early to mid-June to avoid the possibility of a killing frost. Chickpeas are more frost tolerant and can be planted earlier (Berrada et al., 1999). Pinto beans were not harvested and chickpeas only averaged 141 lb./acre. No winter wheat was planted at this site in 1999-00. The plot area at Goodman Point was in alfalfa for seven years until late summer 1999 when alfalfa was killed using a noble blade implement. It was later

plowed and cultivated before it was planted to chickpea and pinto bean in the spring of 2000. The combination of tillage, drought, and deep soil moisture extraction by alfalfa left very little moisture at planting for the bean and chickpea crops. Additional stress may have resulted from too much residual N (Table 7), which could have favored vegetative growth at the expense of seed production, given the dry conditions in 2000.

Corn and oat averaged 11 bu./acre at Yellow Jacket. Pinto beans and chickpeas averaged 171 lb./acre, with no significant differences among the treatments (high CV). Safflower produced significantly more seed in wheat-safflower-bean (715 lb./acre) than in wheat-safflower-oat (480 lb./acre). Better weed control was achieved in wheat-safflower-bean due to the application of Treflan at 1 pt./acre on May 3. Safflower was planted on May 5 in both crop rotations. There was also more available moisture in the top four ft. of soil at planting in wheat-safflower-bean (2.2 in.) than in wheat-safflower-oat (1.4 in.), for unknown reasons[4].

Cone penetration resistance:

The cone penetration resistance (CPR) measurements in June 2000 at Yellow Jacket were indicative of the dry soil conditions in the wheat, oat, and alfalfa plots (Fig. 1). Typically, cone penetration resistance exceeding the 290 to 435 lb. $in.^{-2}$ range will inhibit root development (depending on the crop) to the point of yield reduction. Winter wheat and oat were at the flowering (winter wheat) or boot (oat) growth stage when CPR measurements were made. Most of the available soil moisture was depleted by then and no recharge occurred due to the extremely low precipitation in April, May, and June. The same was true for alfalfa, which had reached its maximum growth before being cut for hay on June 6. Root growth had probably ceased (wheat and oat) or slowed down considerably (alfalfa), so it is unlikely that the high CPR values impeded root development for these crops. The fallow treatments exhibited low CPR values indicating sufficient moisture and possibly low soil density. The CT fallow and CT bean (5) exhibited much lower CPR values than MT fallow or MT bean (7), indicating a soil

[4] Safflower in both crop rotations was managed in the same way, except for the application of Treflan to wheat-safflower-bean. Winter wheat yield in 1999 was similar.

condition in which root growth would not be inhibited by mechanical impedance. As experienced in the past, the cone penetration resistance in the minimum till plots tends to be higher than the conventional till plots (Croissant et al., 1991). Cone penetration resistance was below 290 lb. $in.^{-2}$ in all the bean treatments (5, 7, 15, and 19), which could reflect higher soil moisture content compared to the earlier planted spring crops. Chickpea, safflower, and corn exhibited CPR values near the 290 lb. $in.^{-2}$ value. Cone penetration resistance of Treatment 12 (oat) was near 580 lb. $in.^{-2}$. Oat was planted on May 4, followed by safflower (May 5), chickpea (May 10), corn (May 11), and pinto beans (June 8). For the pinto bean crop, which is characterized by a weak growing root, some reduction in root growth could occur. However, significant yield reduction due to "soil compaction" would not be expected.

2001 Results:

Climatic conditions:

The 2000-01 season (Oct. 2000 to Sept. 2001) was not as dry as the previous season but it was 4.74 inches below normal (11.38 in. vs. 15.88 in.). October precipitation was slightly above normal while that of Nov. 2000 through March 2001 was substantially below normal. April and August had above normal precipitation but May, June, July, and September were very dry at all three sites (Table 1). A late freeze on June 14, 2001 caused considerable damage to pinto beans at Goodman Point but only slight damage to the beans at Yellow Jacket and Eastland. The freeze killed 90 to 100% of the corn leaves at Yellow Jacket. Fortunately the growing point was below the frost line so most of the corn plants grew back. Winter triticale at Eastland was at full bloom when the frost occurred, causing 10 to 15% seed abortion. There was also noticeable cutworm activity in 2001, causing a 1 to 9% stand reduction, mostly in the wheat, triticale, and corn plots at Eastland and Yellow Jacket (data not shown).

Winter wheat:

Winter wheat yield at Yellow Jacket was much higher in 2001 than in 2000 due to more snow and rain in 2000-01 and earlier seeding in three out of seven treatments (Table 2). Total precipitation during the growing season in 2000-01 was 7.2 to 8.2 inches compared to approximately 5.0 inches in 1999-00. Winter wheat in MT wheat-fallow produced significantly more grain than CT wheat-fallow or wheat after bean in the CT wheat-bean and MT wheat-safflower-bean cropping systems. Wheat after chickpea and wheat after bean after corn in wheat-corn-bean was similar to MT wheat-fallow. The application of 50 lb. of N and 25 lb. of P_2O_5 per acre to MT wheat-fallow in the fall of 2000 greatly enhanced wheat yield compared to CT wheat-fallow, which was not fertilized. Both treatments had similar soil N and P soil test levels at planting (Table 8). There was slightly more available soil moisture at planting in MT than in CT wheat-fallow and in MT wheat-corn-bean compared to MT wheat-safflower-bean (Table 10). Cone penetration resistance was lower in June 2001 in MT wheat-fallow than in all the other wheat treatments, but high, nonetheless (Fig. 2). These high values were probably a result of the low soil moisture conditions in June and may not have impeded winter wheat root development.

The early-planted wheat, i.e., wheat after fallow (Sep. 14) and wheat after chickpea (Sep. 27), was well established in the fall of 2000, providing little opportunity for weeds to thrive, and eliminating the need for a herbicide application in the spring of 2001. Wheat after bean was seeded on Oct. 17 and did not emerge until February of 2001. It was sprayed in May with Harmony Extra and 2,4-D (2,4-D only at Eastland) to control winter annuals (Table 1A). Wheat after bean had a significantly higher grain protein concentration than wheat after fallow (Table 2). The soil tested higher in nitrate N at planting in wheat following bean, except in CT wheat-bean, than in wheat following fallow (Table 8).

Winter wheat at Eastland averaged 16.2 bu./acre in 2001 compared to 26.7 bu./acre in 2000 (Table 3). Wheat and triticale were planted on Sep. 27, in all the treatments. They were planted deep to get to the moisture since the soil surface was dry. Subsequent rain events caused crust formation, particularly in the furrows created by the drill's press wheels. Low soil moisture, deep seed placement, and crust caused low emergence. The final stand was estimated at 50 to

60% of normal. Liquid N and P fertilizer was injected in the fall and in the spring to the MT wheat and triticale plots (Table 2A). The intention was to apply all the fertilizer in the fall, but an error in calibration caused only 35% of N and 42% of P to be applied in the fall[5]. The spring application was late (April 26) and may not have been effective, especially since precipitation in May through harvest was very low.

There were no significant differences in grain yield among the wheat and triticale treatments in 2001, although average yield ranged from 11 to 21.5 bu./acre. This could be due to the large variation in wheat yield (and to a lesser extent triticale after bean) among Replications I and II in the CT wheat-bean and MT wheat-safflower-fallow treatments due to topography. Plots situated in the lower areas of the landscape tended to produce more wheat than those situated on the summit. Lower areas collect runoff and may have more available N and P than the generally more eroded hilltops. Wheat and triticale grain protein content at Eastland ranged from 12.1 to 13.5%, with no significant differences among treatments (Table 3).

Winter wheat at Goodman Point was planted on October 19, 2000 in extremely dry soil (Table 11). Subsequent precipitation allowed good wheat emergence and early spring growth but the dry conditions in April through June resulted in extremely low yield (Table 4). High residual soil nitrate N contributed to the low yield by promoting vegetative growth. Excessive early growth led to early soil moisture depletion, thus hampering seed production. The wheat plots were in chickpea or pinto bean in 2000 and in alfalfa in 1993-1999. Soil nitrate N averaged 16 to 17 ppm in the top two ft. of soil prior to wheat planting (Table 7). No fertilizer was applied in 2000 or 2001 (Table 3A). A grasshopper invasion in June caused some damage to the wheat crop and destroyed the bean plants in the rows adjacent to the wheat plots. Wheat was sprayed once in the spring to control weeds. Total season precipitation was 7.52 inches, including rain events of 0.02 inch or less. Wheat grain protein content was high (19%), reflecting the low yield and the elevated soil nitrate N.

[5] The liquid fertilizer was applied by a commercial outfit.

Spring crops:

Pinto bean yield was substantially higher in 2001 than in 2000 at all three sites. There was sufficient soil moisture for germination and stand establishment in June. June and July rainfall was low but August rains were timely (pod fill) and above normal. A frost on June 14 caused minor damage to the bean crop at Yellow Jacket and Eastland and severe damage (60% kill) at Goodman Point. The bean plots were re-planted at Goodman Point on June 20 with 'Bill Z.' They averaged 385 lb./acre in 2001 compared to 0 lb./acre in 2000 (Table 4). Bean yield at Eastland was approximately 336 lb./acre in MT wheat-bean, 305 lb./acre in CT wheat-bean, and 556 lb./acre in MT triticale-bean, with no significant differences among treatments (Table 5). Alfalfa was seeded in the spring of 2000, in lieu of triticale but did not get established due to drought. So, in effect, the beans in triticale-bean were planted after a 13-month fallow. Consequently, there was more available soil moisture at bean planting in MT triticale-bean than in MT wheat-bean or CT wheat-bean (Table 12). Treflan was applied at 1 pt./acre to MT wheat-bean on June 1 and incorporated with a field cultivator (Table 2A). Cahone bean was planted on June 5 in 36-inch rows in all the treatments. All the bean plots were worked with a spring tooth harrow on June 11, prior to bean emergence to control weed seedlings. This is a common practice in dryland bean production in the project area.

The CT wheat-bean and MT wheat-corn-bean treatments produced significantly more beans than did MT wheat-safflower-bean at Yellow Jacket in 2001 (Table 6). There was substantially less moisture in 0 to 4 ft. at bean planting after safflower than after winter wheat or corn (Table 10). The application of Treflan EC at 1.0 pt./acre PPI in MT wheat-bean did not appear to make a difference vis-à-vis weed control and bean yield (495 lb./acre) compared to CT wheat-bean, probably due to the dry conditions in May and June. Treflan application increased bean production costs, which far exceeded the gross income in MT wheat-bean. Weed infestation on August 28 was as follows: MT wheat-corn-bean (10%) < MT wheat-safflower bean (15%) < MT wheat-bean (20%) < CT wheat-bean (40%). Predominant weeds were red root pigweed, prostrate pigweed, and Russian thistle.

Chickpeas fared better at Goodman Point (411 lb./acre) than at Yellow Jacket (268 lb./acre) in 2001. The chickpea plots at Yellow Jacket were sprayed with Roundup on September 20,

2000 and on April 17, 2001, fertilized with 30 lb. of N and 20 lb. of P_2O_5 per acre, cultivated and planted on May 17, 2001. The field cultivator used before planting had sweep attachments, and because the soil surface was dry (there was good moisture below about 3 to 4 in.) and hard, the sweeps barely scratched the soil surface in places and probably compacted it. Cone penetration resistance exceeded 435 lb. $in.^{-2}$ in June, much more than in the bean plots, especially CT wheat-bean and MT wheat-bean (Fig. 2). There was also poor soil-seed contact and poor germination in the wheel tracks created during spraying and soil sampling. The shallow tillage operation before planting was ineffective in destroying seedlings and germinating seeds of the warm season weeds such as Russian thistle and pigweed; it also reduced the efficacy of row cultivation in June. The chickpea plots were very weedy throughout most of the growing season, despite occasional hand hoeing. August rain came about the time when chickpea seeds were starting to mature. This rain probably helped seed filling but it also triggered new growth, flowering, and pod formation and delayed harvest by approximately one month. Most of the pods that were formed after the August rains had aborted or minuscule seeds.

Safflower seed yield was significantly higher in the wheat-safflower-bean than in the wheat-safflower-oat rotation at Yellow Jacket (Table 6). There was adequate moisture for safflower seed germination and stand establishment in both rotations but more soil moisture was available in the top four ft. in wheat-safflower-bean than in wheat-safflower-oat (Table 10). All the available soil moisture was used up by harvest time in both rotations. Tillage was kept to a minimum. Wheat in wheat-safflower-oat was killed with sweeps on June 22, 2000 since it was inundated with volunteer oat and was too stressed to make a crop[6]. Both safflower treatments were sprayed with Roundup Ultra on September 20, 2000 and April 17, 2001, fertilized on May 2 with 30 lb. N and 20 lb. P_2O_5/acre and planted on May 9 (Table 1A). The safflower plots in wheat-safflower-bean were cultivated shortly before and after Treflan EC was applied at 1.5 pt./acre on May 7. No Treflan was applied in the wheat-safflower-oat rotation, which could explain the higher weed pressure rating (3.3 out of a maximum of 5) compared to that in wheat-safflower-bean (1.8 out of 5) on Aug. 28. The two tillage operations on May 7 may have benefited the safflower in wheat-safflower-bean by destroying weed seedlings and reducing soil

[6] Spring barley was planted in wheat-safflower-oat in 2001 in lieu of winter wheat. Barley grain yield was extremely low due to drought.

compaction. Safflower in wheat-safflower-oat was basically NT since no tillage was done except in June 2000 to kill the wheat crop. Cone penetration resistance was slightly lower in safflower after wheat after bean (14) than in safflower after wheat after oat (11) but high in both treatments (Figs 2a and 2b).

Safflower after corn at Eastland produced 245 lb./acre more seed than safflower after winter wheat but the difference was not significant. Both treatments received the same amount of fertilizer, 25 lb. N plus 20 lb. P_2O_5/acre, were planted on May 18 and harvested on October 1. Safflower after wheat, however, was sprayed with 1.5 pt./acre of Treflan PPI. Safflower after corn had slightly more available soil moisture at planting than did safflower after winter wheat (Table 12). Safflower at Yellow Jacket was seeded at a higher rate (29 lb./acre) than at Eastland (20 lb./acre) to compensate for bird and rodent damage, which was observed in 2000 at Yellow Jacket. The seeding rate at Eastland is more in line with the recommendation for semi-arid environments. Precipitation from planting to harvest was 3.4 in. at Eastland and 4.6 in. at Yellow Jacket.

Corn was harvested for silage at Eastland and for grain at Yellow Jacket. Corn yield was substantially higher in 2001 than in 2000 at both locations due to greater precipitation in the spring and summer of 2001. Alfalfa produced approximately 1.0 ton/acre of hay at Yellow Jacket in 2001, which compares favorably with the long-term average for Montezuma County (Colorado Agricultural Statistics Service, 2000).

Conclusions

Extremely dry conditions in April through July resulted in complete failure or poor yield of the 2000 spring crops at all three sites. The high residual soil N at Goodman Point, following seven years of alfalfa, was also a factor as was the late termination of winter wheat in the plots that were planted to spring crops at Eastland. Winter wheat after fallow produced normal yield at Yellow Jacket and Eastland. Winter wheat after pinto beans and especially chickpea was significantly less.

More wheat was produced at Yellow Jacket in 2001 than in 2000, probably because of greater season precipitation and earlier planting. The opposite was true at Eastland, although

precipitation was similar at the two sites. Wheat at Yellow Jacket produced significantly more grain in MT wheat-fallow than in CT wheat-fallow due to fertilizer application and slightly more available soil moisture at planting in the MT treatment. Early planting paid off through increased yield (MT wheat-fallow and MT wheat-chickpea) and/or reduced cost of production. Early-planted wheat was well established in the fall, leaving little room for weeds to thrive, thus eliminating the need for a herbicide application in the spring. Wheat grain protein content was significantly higher after bean than after fallow due to higher soil N test levels at planting. There were no significant differences in wheat and triticale grain yield or protein concentration at Eastland in 2001. There was a large variation in yield due to topography. A late spring application of N and P to wheat and triticale in the MT treatments was not effective due to the dry conditions in May through July. Efforts should be made to reduce and/or account for crop yield variability at all three sites, particularly Eastland.

Pinto bean after safflower produced significantly less seed than pinto bean after winter wheat or corn at Yellow Jacket in 2001. There was less soil moisture available at planting after safflower than after corn or wheat. The above normal precipitation in August benefited the seed yield of pinto beans much more than that of chickpeas, which were further along in their seed development. Nevertheless, poor soil management and weed control were a factor in the extremely low chickpea yield at Yellow Jacket. Greater chickpea yields are attainable; as evidenced by the results of the SARE trial in 1999 (Table 6) and the variety yield trials at Yellow Jacket (Berrada et al., 1999; also unpublished data).

Treflan applied at 1.5 pt./acre prior to safflower planting in MT wheat-safflower-bean reduced weed, i.e., pigweed, pressure, compared to MT wheat-safflower-oat at Yellow Jacket. There was no apparent advantage to applying Treflan in MT wheat-safflower-fallow (at 1.5 pt./acre) or wheat-bean (at 1.0 pt./acre) in 2001. The effectiveness of Treflan PPI was greatly reduced by the dry soil and/or extremely low precipitation in May and June. Consideration should be given to fall application and/or a lower application rate of Treflan to increase its effectiveness and reduce cost. This should also reduce carry over effects, although Treflan in 2001 was only applied to rotations with the least likelihood of damage to the succeeding crop.

More testing is needed before recommendations can be made regarding the sustainability of dryland cropping systems in SW Colorado and SE Utah, especially since 2000 and 2002 were

both dry years. The two-year results confirm that MT wheat-fallow produces at least as much grain as CT wheat-fallow and that early planting of winter wheat pays off in the project area. The results also indicate that:

- Winter wheat-safflower-oat rotation may not be feasible in dry years since there is very little time between oat harvest and winter wheat planting for soil moisture recharge and weed control. The wheat-safflower-fallow rotation would be a better alternative in the project area.
- Pinto beans do better after winter wheat or corn than after safflower, which could be attributed to more water extraction by safflower (less water for the beans).

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Tables and Figures

Table 1. Monthly precipitation at the SARE sites

	Eastland (in.)		Goodman Point (in.)		Yellow Jacket (in.)		
Month	2000	2001	2000	2001	1999-00	2000-01	1967-97
October					0.0	2.0	1.9
November					0.1	0.7	1.5
December					0.1	0.4	1.2
January					1.2	0.7	1.2
February					0.6	1.0	1.2
March		0.0		0.2	1.6	0.1	1.3
April		2.0		1.2	0.4	1.1	0.9
May	0.4	0.3		0.7	0.2	0.5	1.3
June	0.1	0.2	0.6	0.2	0.3	0.2	0.6
July	1.0	0.5	0.6	0.7	0.7	1.2	1.6
August	1.9	2.2	1.4	2.3	2.4	2.8	1.6
September	0.6	0.4	0.6	0.4	0.9	0.2	1.6
Total					8.4	10.8	15.9

Table 2. Winter wheat yield at Yellow Jacket, CO

	1999	2000	2001	2001
Crop rotation	bu/acre	bu/acre	bu/acre	Protein (%)
Wheat-Fallow (MT)	35.9	23.8	33.3	12.1
Wheat-Corn-Bean (MT)	37.9	13.1	30.4	16.4
Wheat-Chickpea (MT)	38.7	4.8	29.7	16.0
Wheat-Bean (MT)	40.0	14.3	25.6	17.1
Wheat-Fallow (CT)	36.1	22.8	24.6	12.8
Wheat-Safflower-Bean (MT)	37.8	15.7	24.0	16.9
Wheat-Bean (CT)	44.2	14.3	21.3	15.4
Average	**38.7**	**15.5**	**27.0**	**15.2**
$LSD_{0.05}$	5.0	5.4	8.3	2.0

Table 3. Winter wheat yield at Eastland, UT

Crop rotation	2000 bu/acre	2001 bu/acre	2001 Protein (%)
Wheat-Safflower-Fallow (MT)	27.9	21.5	12.9
Triticale-Corn-Safflower (MT)	-	18.6	13.5
Wheat-Fallow (MT)	30.8	16.6	12.4
Triticale-Bean (MT)	-	15.7	12.1
Wheat-Bean (MT)	28.0	15.5	12.9
Wheat-Fallow (CT)	22.8	14.4	12.4
Wheat-Bean (CT)	23.9	11.1	12.3
Average	**26.7**	**16.2**	**12.6**
$LSD_{0.05}$	NS	NS	NS

Table 4. Crop yield at Goodman Point, CO

Crop	Previous crop	2001 lb/acre	2001 bu/acre	2001 Protein (%)
Winter wheat	Pinto beans	-	7.3	18.9
Winter wheat	Chickpeas	-	7.3	19.1
Pinto beans	Pinto beans	385	-	-
Chickpeas	Chickpeas	412	-	-

2000 Chickpea (after alfalfa): 138 lb/acre
2000 Pinto bean (after alfalfa): Not harvested

Table 5. Spring crop yield at Eastland, UT

Crop rotation	2000 lb/acre	2001 lb/acre	2001 Moisture (%)
Wheat-**Bean** (CT)	Spring	305.4	-
Wheat-**Bean** (MT)	crops	335.8	-
Triticale-**Bean** (MT)	were	555.5	-
Wheat-**Safflower**-Fallow (MT)	not	617.1	11.0
Triticale-Corn-**Safflower** (MT)	harvested	862.1	6.9
Triticale-**Corn***-Safflower (MT)	in 2000	1842.4	70.7

*Dry matter yield

Table 6. Spring crop yield at Yellow Jacket, CO

Crop rotation	1999 lb/acre	2000 lb/acre	2001 lb/acre	2001 Moisture (%)
Wheat-**Bean** (CT)	827	117.0	645.6	4.4
Wheat-**Bean** (MT)	918	170.0	495.3	5.6
Wheat-Safflower-**Bean** (MT)	1019	130.0	394.4	4.9
Wheat-Corn-**Bean** (MT)	891	166.0	636.3	6.0
Wheat-**Chickpea** (MT)	1595	268.0	191.7	-
Wheat-**Safflower**-Bean (MT)	1006	465.0	800.7	5.2
Wheat-**Safflower**-Oat (MT)	959	726.0	219.8	5.4
Wheat-**Corn****-Bean (MT)	3727	601.5	2189.0	16.5
Wheat-Safflower-**Oat** (MT)	1814	400.1	265.2	7.7
Alfalfa (RFV = 186)	-	381.0	2127.3	8.1
Average	**1417.3**	**342.5**	**796.5**	**7.1**

**Grain yield

Table 7. Soil test results at Goodman Point

Date	Position	Harvested crop	Rep No.	Depth in.	pH	O.M. %	NO_3-N ppm	AB-DTPA P ppm	K ppm ppm
10/18/2000	North	Chickpea	1	0-12	7.3	0.8	18	3.4	209
10/18/2000	North	Chickpea	2	0-12	7.3	0.8	14	2.38	223
10/18/2000	Middle	Chickpea	1	0-12	7.3	0.8	12	2.38	217
10/18/2000	Middle	Chickpea	2	0-12	7.1	0.9	18	3.4	256
10/18/2000	South	Chickpea	1	0-12	7.2	1.1	15	6.8	236
10/18/2000	South	Chickpea	2	0-12	7.4	1.1	19	2.89	221
10/18/2000	North	Chickpea	1	12-24			15		
10/18/2000	North	Chickpea	2	12-24			13		
10/18/2000	Middle	Chickpea	1	12-24			13		
10/18/2000	Middle	Chickpea	2	12-24			12		
10/18/2000	South	Chickpea	1	12-24			38		
10/18/2000	South	Chickpea	2	12-24			16		
Average					**7.3**	**0.9**	**17**	**3.54**	**227**
10/18/2000	North	Pinto bean	1	0-12	7.4	0.9	17	4.93	246
10/18/2000	North	Pinto bean	2	0-12	6.9	0.9	18	2.38	224
10/18/2000	Middle	Pinto bean	1	0-12	7.5	1.0	19	3.06	232
10/18/2000	Middle	Pinto bean	2	0-12	7.2	0.9	13	3.06	236
10/18/2000	South	Pinto bean	1	0-12	7.5	1.6	27	5.44	248
10/18/2000	South	Pinto bean	2	0-12	7.2	1.0	21	3.74	226
10/18/2000	North	Pinto bean	1	12-24			15		
10/18/2000	North	Pinto bean	2	12-24			13		
10/18/2000	Middle	Pinto bean	1	12-24			14		
10/18/2000	Middle	Pinto bean	2	12-24			11		
10/18/2000	South	Pinto bean	1	12-24			14		
10/18/2000	South	Pinto bean	2	12-24			13		
Average					**7.3**	**1.1**	**16**	**3.77**	**235**
12/04/2001	Middle	Chickpea	1	0-8	7.3		21	4.08	243
12/04/2001	North	Chickpea	1	0-8	7.5		18	2.72	228
12/04/2001	South	Chickpea	1	0-8	7.5		24	10.37	287
12/04/2001	North	Chickpea	2	0-8	7.1		18	3.4	234
12/04/2001	North	Chickpea	2	0-8	7.2		20	3.74	247
12/04/2001	South	Chickpea	2	0-8	7.1		24	3.91	233
Average					**7.3**		**21**	**4.70**	**245**
12/04/2001	Middle	Pinto bean	1	0-8	7.2		24	3.23	220
12/04/2001	North	Pinto bean	1	0-8	7.1		25	4.08	245
12/04/2001	South	Pinto bean	1	0-8	7.3		34	6.46	263
12/04/2001	Middle	Pinto bean	2	0-8	7.0		20	3.91	229
12/04/2001	North	Pinto bean	2	0-8	6.9		29	2.89	230
12/04/2001	South	Pinto bean	2	0-8	7.2		17	3.74	216
Average					**7.1**		**25**	**4.05**	**234**

Table 8. Soil test results at Yellow Jacket

Average of three replications

Treatment No.	Date	Depth inch	pH	O.M. %	NO_3-N ppm	AB-DTPA P (ppm)	K ppm	Zn ppm
Cropping system/Crop to be planted								
Bean ground								
Rep I	11/04/1998	0-10	7.0	1.0	14.0	4.6	201.0	2.0
Rep II	11/04/1998	0-10	7.0	0.9	17.0	3.6	198.0	0.2
Rep III	11/04/1998	0-10	7.1	0.9	14.0	3.1	189.0	0.2
CT Wheat -Fallow								
Wheat	09/10/1999	0-8	6.9	1.0	12.0	5.3	186.0	
	09/10/1999	8-16			10.0			
	08/23/2000	0-10	7.4		8.0	3.7	172.3	
	08/31/2001	0-10	6.9		13.3	4.0	169.3	
	08/31/2001	10-20			5.0			
MT Wheat - Fallow								
Wheat	09/10/1999	0-8	7.0	0.9	8.0	5.3	185.0	
	09/10/1999	8-16			8.0			
	08/23/2000	0-10	7.3		6.7	4.1	156.0	
	08/31/2001	0-10	7.0		9.7	3.9	161.7	
	08/31/2001	10-20			4.0			
CT Wheat -Bean								
Wheat	09/10/1999	0-10	7.0	0.9	7.0	4.3	158.0	
Wheat	08/23/2000	0-10	7.0		9.0	4.8	220.0	
Wheat	09/19/2001	0-10	7.1		6.3	4.5	185.7	
Bean	04/27/2000	0-12	7.2	0.8	2.0	3.7	172.0	0.2
MT Wheat - Bean								
Wheat	09/10/1999	0-10	7.0	0.9	8.0	5.1	185.0	
Wheat	08/23/2000	0-10	7.0		16.0	4.9	209.0	
Wheat	09/19/2001	0-10	7.0		15.0	6.2	210.7	
Bean	04/27/2000	0-12	7.4	0.9	1.0	3.9	172.0	0.2
Bean	05/22/2001	0-12	7.1	1.0	3.3	4.4	168.0	0.6
Bean	05/22/2001	12-22			3.0			
MT Wheat - Chickpea								
Wheat	09/10/1999	0-10	7.1	1.0	10.0	5.1	184.0	
Wheat	08/23/2000	0-10	7.0		16.0	4.6	195.0	
Wheat	10/05/2001	0-12	7.1		17.3	8.6	254.3	
Chickpea	04/27/2000	0-12	7.3	1.0	1.0	4.1	174.0	
Chickpea	04/30/2001	0-12	7.3	1.0	2.7	5.0	179.3	0.5
Chickpea	04/30/2001	12-22			2.7			
MT Wheat - Safflower - Oat								
Wheat	09/10/1999	0-10	7.2	1.0	3.0	4.9	170.0	
Wheat	08/23/2000	0-10	7.0		19.0	5.3	212.0	
Wheat	09/27/2001	0-10	7.0		12.0	5.3	219.0	
Barley	04/27/2000	0-12	7.3	0.9	1.5	3.7	163.0	
Safflower	04/09/2001	0-12	7.3		3.0	3.9	181.0	
Safflower	04/09/2001	12-20			6.0			
Oat	04/09/2001	0-12	7.1		4.7	4.3	169.7	
Oat	04/09/2001	12-20			7.0			

Table 8. (Continued)

Average of three replications

Treatment No.	Date	Depth inch	pH	O.M. %	NO_3-N ppm	AB-DTPA P (ppm)	K ppm	Zn ppm
Crop rotation/Treatment No.								
MT Wheat -Safflower - Bean								
Wheat	09/10/1999	0-10	7.1	0.9	8.0	5.1	170.0	
Wheat	08/23/2000	0-10	6.9		?	5.1	203.0	
Wheat	09/19/2001	0-10	7.0		7.3	5.6	205.7	
Safflower	04/27/2000	0-12	7.2	0.9	1.0	3.6	163.0	
Safflower	04/09/2001	0-12	7.1		3.0	4.8	177.3	
Safflower	04/09/2001	12-20			3.0			
Bean	05/22/2001	0-12	7.0	0.9	6.7	3.6	165.3	0.3
Bean	05/22/2001	12-22			8.0			
Bean	04/27/2000	0-12	7.3	0.8	2.0	4.1	171.0	0.4
MT Wheat - Corn - Bean								
Wheat	09/10/1999	0-10	7.0	1.0	6.0	4.6	185.0	
Wheat	08/23/2000	0-10	6.9		?	5.6	215.0	
Wheat	09/19/2001	0-10	6.9		8.0	6.9	205.3	
Corn	04/27/2000	0-12	7.3	0.9	1.0	3.6	172.0	
Corn	04/30/2001	0-12	7.2		2.7	3.6	170.7	
Corn	04/30/2001	12-22			3.0			
Bean	05/22/2001	0-12	7.0	0.9	5.7	4.3	170.7	0.3
Bean	05/22/2001	12-22			7.3			
Bean	04/27/2000	0-12	7.1	0.9	3.0	5.3	190.0	0.2

Table 9. Soil test results at Eastland

Average of two replications

Treatment No.	Date	Depth inch	pH	O.M. %	NO_3-N ppm	AB-DTPA P (ppm)	K ppm	Zn ppm
Cropping system/Crop to be planted								
Wheat	09/20/1999	0-6	7.4	1.0	8.5	3.4	246.3	0.5
(was in	09/20/1999	6-12	7.5	1.0	6.2	2.3	217.3	0.4
fallow)	09/20/1999	12-24			4.2			
CT Wheat - Fallow								
Wheat	08/30/2000	0-10	7.7		5.0	3.7	204.5	
	08/31/2001	0-10	7.9		5.5	0.9	202.0	
	08/31/2001	10-20			2.5			
MT Wheat - Fallow								
Wheat	08/30/2000	0-10	7.5		5.0	4.3	198.0	
	08/31/2001	0-10	7.7		6.5	1.1	229.5	
	08/31/2001	10-20			3.0			
CT Wheat - Bean								
Wheat	08/30/2000	0-10	7.7		5.5	3.1	200.5	-
Wheat	09/19/2001	0-10	7.5		3.5	0.6	210.5	
Bean	04/30/2001	0-12		0.8	2.5	4.3	204.0	0.1
Bean	04/30/2001	12-22			2.5			
MT Wheat - Bean								
Wheat	08/30/2000	0-10	7.5		5.0	5.2	218.0	-
Wheat	09/19/2001	0-10	7.6		7.0	1.2	205.0	-
Bean	04/30/2001	0-12		0.7	2.0	2.4	206.0	0.1
Bean	04/30/2001	12-22		0.5	5.0	0.5	165.0	0.1
MT Wheat - Safflower - Fallow								
Wheat	08/30/2000	0-10	7.6		6.0	5.0	219.0	
Wheat	08/31/2001	0-10	7.4		9.5	1.6	191.5	
Wheat	08/31/2001	10-20			8.5			
Safflower	04/01/2001	0-8	7.6		2.5	3.8	219.0	
Safflower	04/01/2001	8-20	7.6		4.0	1.4	163.5	
MT Triticale - Corn - Safflower								
Triticale	10/05/2001	0-12	7.4		27.5!	7.0	263.5	
Corn	04/30/2001	0-12			3.5	3.9	205.5	
Corn	04/30/2001	12-22			5.0			
Safflower	04/01/2001	0-8	7.3		5.0	3.7	197.0	
Safflower	04/01/2001	8-20	7.9		4.5	1.4	174.0	
MT Triticale - Bean								
Triticale	08/30/2000	0-10	7.9		4.5	2.7	204.5	-
Triticale	09/19/2001	0-10	7.5		9.5	1.6	229.5	
Bean	04/30/2001	0-12		0.8	4.5	4.7	225.5	0.2
Bean	04/30/2001	12-22			7.0			

Table 10. Gravimetric soil moisture before planting and after harvest at Yellow Jacket in 2000-01

Cropping system/ crop	Soil moisture before planting				Soil moisture after harvest				Season precipitation in.
	Sampling date	Depth ft.	Moisture* %	AW** in.	Sampling date	Depth ft.	Moisture* %	AW** in.	
CT Wheat - Fallow									
Wheat	09/12/2000	1	12.0	0.0	08/29/2001	1	11.8	0.0	8.3
		2	13.9	0.0		2	9.4	0.0	
		3	11.8	0.0		3	very dry	0.0	
		3.5	12.8	0.0		4	very dry	0.0	
		Total	**12.6**	**0.0**		**Total**	**10.6**	**0.0**	
MT Wheat - Fallow									
Wheat	09/12/2000	1	14.0	0.1	08/29/2001	1	12.1	0.0	8.3
		2	16.2	0.2		2	9.9	0.0	
		3	14.9	0.1		3	very dry	0.0	
		4	14.0	0.1		4	very dry	0.0	
		Total	**14.8**	**0.5**		**Total**	**11.0**	**0.0**	
CT Wheat - Bean									
Wheat	10/16/2000	1	9.7	0.0	08/29/2001	1	10.4	0.0	7.2
		2	10.5	0.0		2	10.8	0.0	
		3	10.0	0.0		3	13.9	0.1	
		4	11.8	0.0		4	13.4	0.1	
		Total	**10.5**	**0.0**		**Total**	**12.1**	**0.2**	
Bean	05/31/2001	1	16.3	0.5	10/02/2001	1	8.8	0.0	4.2
		2	18.0	0.5		2	12.3	0.0	
		3	15.4	0.2		3	13.8	0.1	
		4	15.4	0.3		4	15.6	0.3	
		Total	**16.3**	**1.6**		**Total**	**12.6**	**0.4**	
MT Wheat - Bean									
Wheat	10/16/2000	1	12.3	0.0	08/29/2001	1	10.7	0.0	7.2
		2	15.8	0.2		2	10.1	0.0	
		3	15.4	0.1		3	9.7	0.0	
		4	15.8	0.4		4	11.3	0.0	
		Total	**14.8**	**0.7**		**Total**	**10.5**	**0.0**	
Bean	05/31/2001	1	14.3	0.2	10/02/2001	1	9.3	0.0	4.2
		2	18.2	0.5		2	14.0	0.0	
		3	17.3	0.4		3	15.0	0.1	
		4	16.9	0.6		4	15.5	0.3	
		Total	**16.6**	**1.7**		**Total**	**13.5**	**0.4**	
MT Wheat - Chickpea									
Wheat	09/20/2000	1	8.8	0.0	08/29/2001	1	11.7	0.0	8.1
		2	9.8	0.0		2	10.2	0.0	
		3	9.7	0.0		3	9.3	0.0	
		4	10.1	0.0		4	very dry	0.0	
		Total	**9.6**	**0.0**		**Total**	**10.4**	**0.0**	
Chickpea	05/09/2001	1	16.6	0.6	10/08/2001	1	7.1	0.0	4.6
		2	18.9	0.7		2	10.1	0.0	
		3	17.0	0.4		3	10.9	0.0	
		4	16.5	0.4		4	13.9	0.0	
		Total	**17.2**	**2.1**		**Total**	**10.5**	**0.0**	

*Dry mass water percentage **Availale water

Table 10. (continued)

Cropping system/ crop	Soil moisture before planting				Soil moisture after harvest				Season precipitation in.
	Sampling date	Depth ft.	Moisture* %	AW** in.	Sampling date	Depth ft.	Moisture* %	AW** in.	
MT Wheat - Safflower - Oat									
Barley	04/30/2001	1	16.9	0.6	08/29/2001	1	11.0	0.0	4.6
		2	17.8	0.5		2	10.0	0.0	
		3	12.8	0.0		3	very dry	0.0	
		4	18.2	0.8		4	very dry	0.0	
		Total	**16.4**	**1.9**		**Total**	**10.5**	**0.0**	
Safflower	04/30/2001	1	16.1	0.5	10/02/2001	1	7.1	0.0	4.6
		2	15.5	0.3		2	10.3	0.0	
		3	12.6	0.1		3	very dry	0.0	
		4	13.3	0.0		4	very dry	0.0	
		Total	**14.4**	**0.9**		**Total**	**8.7**	**0.0**	
Oat	04/16/2001	1	17.4	0.7	08/29/2001	1	10.2	0.0	4.8
		2	16.6	0.3		2	10.2	0.0	
		3	13.8	0.2		3	very dry	0.0	
		4	14.4	0.3		4	very dry	0.0	
		Total	**15.5**	**1.5**		**Total**	**10.2**	**0.0**	
MT Wheat - Safflower - Bean									
Wheat	10/16/2000	1	10.9	0.0	08/29/2001	1	10.2	0.0	7.2
		2	13.9	0.2		2	9.7	0.0	
		3	11.4	0.0		3	8.2	0.0	
		4	11.8	0.0		4	very dry	0.0	
		Total	**12.0**	**0.2**		**Total**	**9.3**	**0.0**	
Safflower	04/30/2001	1	16.9	0.6	10/02/2001	1	7.7	0.0	4.6
		2	18.8	0.6		2	10.3	0.0	
		3	17.8	0.5		3	9.1	0.0	
		4	17.8	0.8		4	very dry	0.0	
		Total	**17.8**	**2.5**		**Total**	**9.0**	**0.0**	
Bean	05/31/2001	1	13.0	0.0	10/02/2001	1	8.8	0.0	4.2
		2	16.4	0.2		2	12.2	0.0	
		3	13.2	0.0		3	10.1	0.0	
		4	12.3	0.0		4	10.1	0.0	
		Total	**13.7**	**0.3**		**Total**	**10.3**	**0.0**	
MT Wheat - Corn - Bean									
Wheat	10/16/2000	1	12.0	0.0	08/29/2001	1	12.4	0.1	7.2
		2	14.9	0.1		2	11.0	0.0	
		3	15.5	0.1		3	12.0	0.0	
		4	15.6	0.3		4	13.4	0.1	
		Total	**14.5**	**0.6**		**Total**	**12.2**	**0.2**	
Corn	05/09/2001	1	17.2	0.7	10/22/2001	1	9.1	0.0	5.1
		2	18.7	0.6		2	12.2	0.0	
		3	17.3	0.4		3	12.5	0.0	
		4	17.8	0.7		4	15.5	0.3	
		Total	**17.8**	**2.4**		**Total**	**12.3**	**0.3**	
Bean	05/31/2001	1	14.2	0.2	10/02/2001	1	10.0	0.0	4.2
		2	17.9	0.5		2	14.6	0.1	
		3	16.2	0.3		3	14.9	0.1	
		4	17.1	0.6		4	16.3	0.5	
		Total	**16.4**	**1.6**		**Total**	**13.9**	**0.7**	

*Dry mass water percentage **Availale water

Table 11. Gravimetric soil moisture before planting and after harvest at Goodman Point in 2000-01

	Soil moisture before planting				Soil moisture after harvest			
Location	Sampling date	Depth ft.	Moisture* %	AW** in.	Sampling date	Depth ft.	Moisture* %	AW** in.
Continuous bean								
North	05/30/2001	1	15.8	0.4	10/08/2001	1	10.5	0.0
North		2	14.1	0.0		2	12.6	0.0
North		3	13.5	0.1		3	13.3	0.1
North		4	17.5	0.7		4	15.7	0.3
		Total	**15.2**	**1.3**		**Total**	**13.0**	**0.5**
Middle		1	16.1	0.5		1	11.1	0.0
Middle		2	16.4	0.2		2	13.6	0.0
Middle		3	14.0	0.1		3	12.2	0.0
Middle		4	11.7	0.1		4	13.5	0.0
		Total	**14.6**	**0.9**		**Total**	**12.6**	**0.0**
South		1	16.2	0.5		1	10.9	0.0
South		2	14.2	0.1		2	13.2	0.0
South		3	11.0	0.0		3	12.2	0.0
South		4	12.2	0.2		4	9.9	0.0
		Total	**13.4**	**0.8**		**Total**	**11.5**	**0.0**
Continuous chickpea								
North	05/15/2001	1	15.1	0.3	10/08/2001	1	8.8	0.0
North		2	16.5	0.2		2	9.9	0.0
North		3	12.9	0.0		3	10.0	0.0
North		4	14.4	0.1		4	very dry	0.0
		Total	**14.7**	**0.7**		**Total**	**9.5**	**0.0**
Middle		1	16.2	0.5		1	8.8	0.0
Middle		2	16.3	0.2		2	10.5	0.0
Middle		3	14.9	0.1		3	11.3	0.0
Middle		3.5	12.7	0.1		3.5	9.7	0.0
		Total	**15.0**	**0.9**		**Total**	**10.1**	**0.0**
South		1	15.8	0.4		1	8.6	0.0
South		2	16.3	0.2		2	10.0	0.0
South		3	13.8	0.1		2.5	11.7	0.0
South		4	16.4	0.5		3	very dry	0.0
		Total	**15.6**	**1.3**		**Total**	**10.1**	**0.0**
Wheat - Bean								
North	10/18/2000	1	9.0	0.0	08/07/2001	1	7.9	0.0
North		2	9.4	0.0		2	8.6	0.0
		Total	**9.2**	**0.0**		**Total**	**8.2**	**0.0**
Middle		1	9.1	0.0		1	8.2	0.0
Middle		2	9.4	0.0		2	7.8	0.0
		Total	**9.3**	**0.0**		**Total**	**8.0**	**0.0**
South		1	8.8	0.0		1	8.0	0.0
South		2	9.2	0.0		2	8.9	0.0
		Total	**9.0**	**0.0**		**Total**	**8.4**	**0.0**

Table 11 (Continued)

	Soil moisture before planting				Soil moisture after harvest			
Location	Sampling date	Depth ft.	Moisture* %	AW** in.	Sampling date	Depth ft.	Moisture* %	AW** in.
Wheat - Chickpea								
North	09/15/2000	1	6.7	0.0	08/07/2001	1	8.4	0.0
North		2	7.7	0.0		2	9.2	0.0
		Total	**7.2**	**0.0**		**Total**	**8.8**	**0.0**
Middle		1	7.8	0.0		1	8.0	0.0
Middle		2	7.9	0.0		2	9.1	0.0
		Total	**7.8**	**0.0**		**Total**	**8.5**	**0.0**
South		1	8.5	0.0		1	8.1	0.0
South		2	8.1	0.0		2	8.3	0.0
		Total	**8.3**	**0.0**		**Total**	**8.2**	**0.0**

*Dry mass water percentage **Availale water

Table 12. Gravimetric soil moisture before planting and after harvest at Eastland in 2000-01

Cropping system/ crop	Soil moisture before planting				Soil moisture after harvest				Season precipitation
	Sampling date	Depth ft.	Moisture* %	AW** in.	Sampling date	Depth ft.	Moisture* %	AW** in.	in.
CT Wheat - Fallow									
Wheat	09/12/2000	1	11.4	0.0	08/10/2001	1	8.4	0.0	8.4
		2	15.1	0.5		2	10.4	0.0	
		3	16.2	0.6		3	12.6	0.1	
		4	17.4	0.7		4	14.9	0.3	
		Total	**15.0**	**1.8**		**Total**	**11.6**	**0.4**	
MT Wheat - Fallow									
Wheat	09/12/2000	1	11.0	0.0	08/10/2001	1	7.7	0.0	8.4
		2	13.6	0.3		2	8.5	0.0	
		3	13.3	0.1		3	12.3	0.1	
		4	17.7	0.2		4	14.7	0.2	
		Total	**13.9**	**0.6**		**Total**	**10.8**	**0.3**	
CT Wheat - Bean									
Wheat	09/12/2000	1	10.3	0.0	08/10/2001	1	8.9	0.1	8.4
		2	12.7	0.2		2	8.8	0.0	
		3	14.6	0.3		3	15.5	0.5	
		4	15.2	0.3		4	13.5	0.0	
		Total	**13.2**	**0.8**		**Total**	**11.7**	**0.6**	
Bean	05/29/2001	1	15.2	0.7	10/03/2001	1	9.2	0.0	2.9
		2	15.1	0.5		2	9.4	0.0	
		3	13.3	0.1		3	11.4	0.0	
		4	12.0	0.0		4	12.7	0.0	
		Total	**13.9**	**1.3**		**Total**	**10.7**	**0.1**	
MT Wheat - Bean									
Wheat	09/12/2000	1	9.0	0.0	08/10/2001	1	7.2	0.0	8.4
		2	12.2	0.1		2	7.4	0.0	
		3	14.1	0.2		3	11.9	0.1	
		4	14.9	0.3		4	13.4	0.0	
		Total	**12.5**	**0.5**		**Total**	**10.0**	**0.1**	
Bean	05/29/2001	1	15.7	0.7	10/03/2001	1	10.0	0.0	2.9
		2	16.7	0.8		2	11.5	0.1	
		3	15.6	0.5		3	13.4	0.2	
		4	13.1	0.2		4	13.9	0.2	
		Total	**15.2**	**2.3**		**Total**	**12.2**	**0.5**	
MT Wheat - Safflower - Fallow									
Wheat	09/12/2000	1	NA		08/10/2001	1	7.6	0.0	8.4
		2	NA			2	7.6	0.0	
		3	NA			3	9.6	0.0	
		4	NA			4	13.9	0.2	
		Total				**Total**	**9.7**	**0.2**	
Safflower	04/30/2001	1	16.6	0.9	10/03/2001	1	7.8	0.0	3.4
		2	16.9	0.9		2	9.2	0.0	
		3	15.5	0.4		3	8.7	0.0	
		4	15.4	0.4		4	9.4	0.0	
		Total	**16.1**	**2.6**		**Total**	**8.8**	**0.0**	

*Dry mass water percentage **Availale water

Table 12. (Continued)

Cropping system/ crop	Soil moisture before planting				Soil moisture after harvest				Season precipitation in.
	Sampling date	Depth ft.	Moisture* %	AW** in.	Sampling date	Depth ft.	Moisture* %	AW** in.	
MT Triticale - Corn - Safflower									
Triticale	09/12/2000	1	11.4	0.0	08/10/2001	1	7.9	0.0	8.4
		2	14.4	0.4		2	9.8	0.0	
		3	13.8	0.2		3	10.5	0.0	
		4	15.6	0.3		4	11.7	0.0	
		Total	**13.8**	**0.9**		**Total**	**10.0**	**0.0**	
Corn	05/08/2001	1	17.1	1.0	10/03/2001	1	7.8	0.0	3.0
		2	18.1	1.1		2	9.5	0.0	
		3	17.9	0.9		3	11.0	0.0	
		4	17.5	0.7		4	14.7	0.3	
		Total	**17.7**	**3.7**		**Total**	**10.8**	**0.3**	
Safflower	04/30/2001	1	17.1	1.0	10/03/2001	1	8.1	0.0	3.4
		2	17.5	1.0		2	9.6	0.0	
		3	17.4	0.8		3	very dry	0.0	
		4	16.5	0.6		4	very dry	0.0	
		Total	**17.2**	**3.3**		**Total**	**8.9**	**0.0**	
MT Triticale - Bean									
Triticale	09/12/2000	1	10.1	0.0	08/10/2001	1	8.5	0.0	8.4
		2	14.1	0.4		2	11.0	0.2	
		3	16.3	0.6		3	11.8	0.0	
		4	17.2	0.7		4	16.8	0.6	
		Total	**14.4**	**1.7**		**Total**	**12.0**	**0.8**	
Bean	05/29/2001	1	15.2	0.6	10/03/2001	1	8.7	0.0	2.9
		2	17.0	0.9		2	10.1	0.0	
		3	16.4	0.6		3	10.9	0.0	
		4	17.3	0.7		4	13.3	0.1	
		Total	**16.5**	**2.8**		**Total**	**10.7**	**0.1**	

*Dry mass water percentage **Availale water

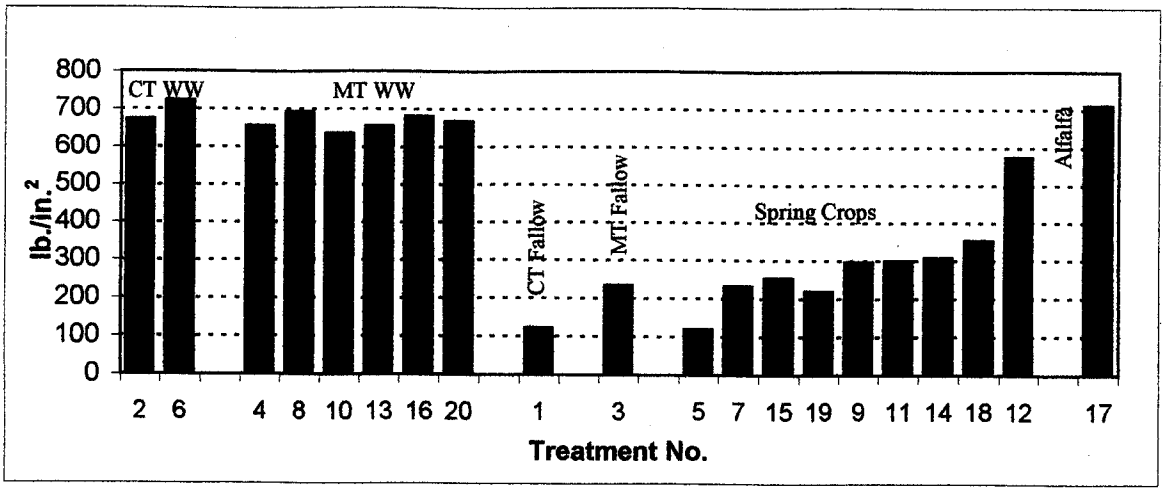

Figure 1. Cone penetration resistance at Yellow Jacket in June 2000 (0-11.8 inches)

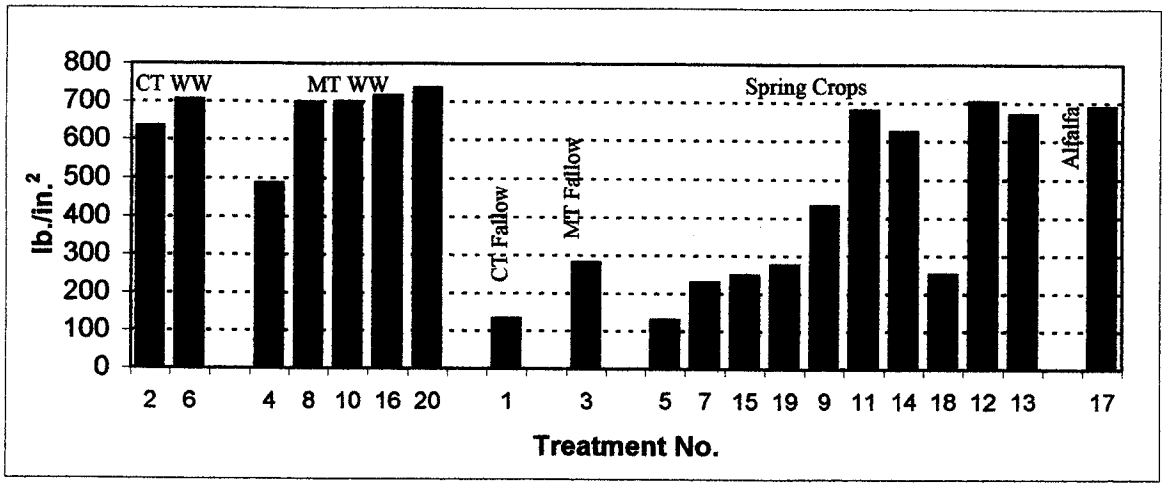

Figure 2a. Cone penetration resistance at Yellow Jacket in June 2001 (0-11.8 inches)

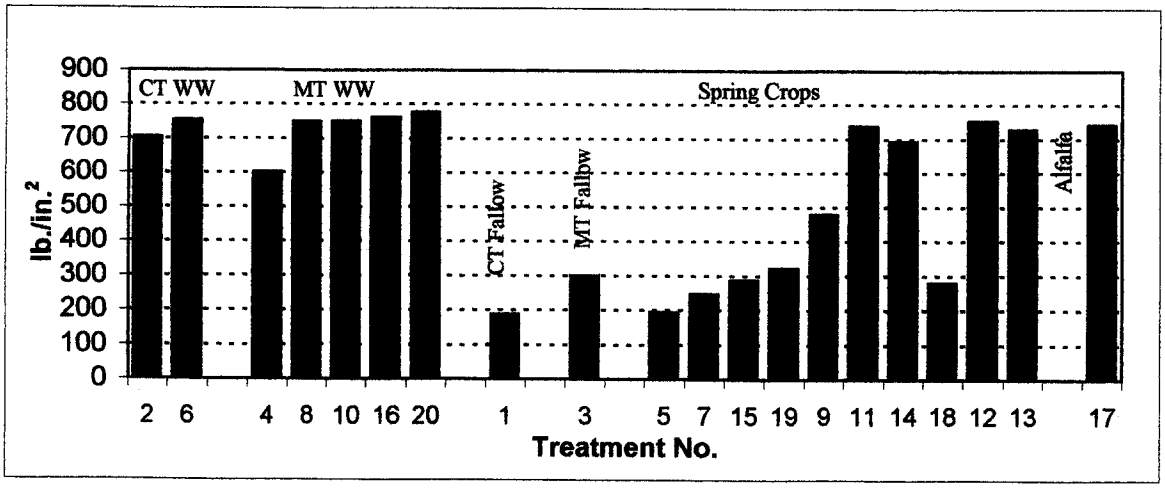

Figure 2b. Cone penetration resistance at Yellow Jacket in June 2001 (0-17.7 inches)

Appendix A

Table 1A. Field operations at Yellow Jacket in 2000-01

Variety/Crop	Date	Operation	Rate Unit/acre	Cost $/acre
CT Wheat-Fallow				
Fairview	9/14/00	Field cultivate		5.00
Winter wheat	9/16/00	Plant		8.00
		seed	47 lb	3.53
	7/27/01*	Combine &		
	8/27/01*	haul		12.30
Fallow	9/19/00	Disk		10.00
	11/8/00	M. Plow		12.00
	5/11/01	Field cultivate		8.00
	6/4/01	Field cultivate		8.00
	7/16/01	Field cultivate		8.00
MT Wheat-Fallow				
Fairview	9/14/00	Fertilize		4.00
Winter wheat		N	50 lb	16.85
		P_2O_5	25 lb	7.05
	9/14/00	Field cultivate		8.00
	9/16/00	Plant		10.00
		seed	47 lb	3.53
	7/27/01*	Combine &		
	8/27/01*	haul		12.30
Fallow	9/20/00	Roundup Ultra	1.8 pt	13.62
		application		6.00
	4/17/01	Roundup Ultra	1 qt	14.89
		application		6.00
	6/7/01	Roundup Ultra	18 oz	8.38
	6/7/01	2,4-D LV Ester	1 pt	1.95
		application		6.00
	7/17/01	Landmaster BW	45 oz	9.56
		application		6.00

*Yield strips were harvested on July 27 and the rest of the plot on Aug. 27.

Table 1A (Continued)

Variety/Crop	Date	Operation	Rate Unit/acre	Cost $/acre
CT Wheat-Bean				
Fairview	10/17/00	Field cultivate		8.00
Winter wheat	10/17/00	Plant		10.00
		seed	47 lb	3.53
	5/17/01	Harmony Extra	0.5 oz	9.62
		2,4-D LV Ester	4 oz	2.50
		application		6.00
	7/27/01*	Combine &		
	8/27/01*	haul		12.30
Cahone	9/20/00	Roundup Ultra**	1.8 pt	13.62
Pinto bean		application		6.00
	11/8/00	M. Plow		12.00
	5/2/01	Field cultivate		8.00
	6/1/01	Field cultivate		8.00
	6/5/01	Plant		10.00
		seed	23.2 lb	4.83
	6/27/01	Cultivate		8.00
	7/19/01	Cultivate		8.00
	9/12/01	Cut beans		10.00
	9/21/01	Combine & haul		12.30
MT Wheat-Bean				
Fairview	10/17/00	Fertilize		4.00
Winter wheat		N	25 lb	8.43
		P_2O_5	20 lb	5.64
	10/17/00	Field cultivate		8.00
	10/17/00	Plant		10.00
		seed	45 lb	3.38
	5/17/01	Harmony Extra	0.5 oz	9.62
		2,4-D LV Ester	4 oz	2.50
		application		6.00
	7/27/01*	Combine &		
	8/27/01*	haul		12.30

*Yield strips were harvested on July 27 and the rest of the plot on Aug. 27.
**Sprayed in lieu of disking.

Table 1A (Continued)

Variety/Crop	Date	Operation	Rate Unit/acre	Cost $/acre
Cahone	9/20/00	Roundup Ultra	1.8 pt	13.62
Pinto bean		application		6.00
	4/17/01	Roundup Ultra	1 qt	14.89
		application		6.00
	5/31/01	Fertilize		4.00
		N	25 lb	8.43
		P_2O_5	20 lb	5.64
		Zn	5 lb	5.90
	6/1/01	Treflan	1 pt	2.40
		application		6.00
	6/1/01	Field cultivate		5.00
	6/5/01	Plant		10.00
		seed	23 lb	4.83
	6/27/01	Cultivate		12.00
	7/19/01	Cultivate		12.00
	9/12/01	Cut beans		10.00
	9/21/01	Combine & haul		12.30
MT Wheat-Chickpea				
Fairview	9/26/00	Fertilize		4.00
Winter wheat		N	25 lb	8.43
		P_2O_5	20 lb	5.64
	9/26/00	Field cultivate		8.00
	9/27/00	Plant		10.00
		seed	45 lb	3.38
	7/27/01*	Combine &		
	8/27/01*	haul		12.30

*Yield strips were harvested on July 27 and the rest of the plot on Aug. 27.

Table 1A (Continued)

Variety/Crop	Date	Operation	Rate Unit/acre	Cost $/acre
Sanford Chickpea	9/20/00	Roundup Ultra	1.8 pt	13.62
		application		6.00
	4/17/01	Roundup Ultra	1 qt	14.89
		application		6.00
	5/14/01	Fertilize		4.00
		N	30 lb	10.11
		P_2O_5	20 lb	5.64
	5/14/01	Field cultivate		8.00
	5/17/01	Plant		10.00
		seed	28 lb	26.60
	6/4/01	Roto till		1.00
	6/27/01	Cultivate		8.00
	7/19/01	Cultivate		8.00
	7/5/01	Hoe (2 hrs)		16.00
	7/19/01	Cultivate		8.00
	10/01/01	Cut peas		10.00
	10/11/01	Combine & haul		12.30
MT Wheat- Safflower-Oat				
Monida Oat	4/17/01	Fertilize		4.00
		N	30 lb	10.11
	4/17/01	Roundup Ultra	1 qt	14.89
		application		6.00
	4/18/01	Plant		10.00
		seed	49 lb	19.60
	6/7/01	2,4-D LV Ester	1 pt	1.95
		application		6.00
	8/27/01	Combine & haul		12.30

Table 1A (Continued)

Variety/Crop	Date	Operation	Rate Unit/acre	Cost $/acre
MT Wheat-Safflower-Oat (continued)				
'96RWA1192' Barley*	9/20/00	Roundup Ultra	1.8 pt	13.62
		application		6.00
	10/-/00	Cultivate		8.00
	4/17/01	Roundup Ultra	1 qt	14.89
		application		6.00
	4/25/01	Plant		10.00
		seed	49 lb	3.92
	5/17/01	Harmony Extra	0.5 oz	9.62
		2,4-D LV	4.0 oz	2.50
		application		6.00
	8/27/01	Combine & haul		12.30
'S-208' Safflower	9/20/00	Roundup Ultra	1.8 pt	13.62
		application		6.00
	4/17/01	Roundup Ultra	1 qt	14.89
		application		6.00
	5/2/01	Fertilize		4.00
		N	30 lb	10.11
		P_2O_5	20 lb	5.64
	5/9/01	Plant		10.00
		seed	29 lb	4.06
	5/14/01	Roundup Ultra	1 pt	7.45
		application		6.00
	9/25/01	Combine & haul		12.30

*Spring barley was planted in lieu of winter wheat.

Table 1A (Continued)

Variety/Crop	Date	Operation	Rate Unit/acre	Cost $/acre
MT Wheat-Safflower-Bean				
Cahone	4/17/01	Roundup Ultra	1 qt	14.89
Pinto bean		application		6.00
	5/31/01	Fertilize		4.00
		P_2O_5	20 lb	5.64
		Zn	5 lb	5.90
	6/1/01	Field cultivate		5.00
	6/5/01	Plant		10.00
		seed	29 lb	6.09
	6/27/01	Cultivate		8.00
	7/19/01	Cultivate		8.00
	9/12/01	Cut beans		10.00
	9/21/01	Combine & haul		12.30
Fairview	10/17/00	Fertilize		4.00
Winter wheat		P_2O_5	20 lb	5.64
	10/17/00	Field cultivate		8.00
	10/17/00	Plant		10.00
		seed	45 lb	3.38
	5/17/01	Harmony Extra	0.5 oz	9.62
		2,4-D LV	4.0 oz	2.50
		application		6.00
	7/27/01*	Combine &		
	8/27/01*	haul		12.30

*Yield strips were harvested on July 27 and the rest of the plot on Aug. 27.

Table 1A (Continued)

Variety/Crop	Date	Operation	Rate Unit/acre	Cost $/acre
S-208 Safflower	9/20/00	Roundup Ultra	1.8 pt	13.62
		application		6.00
	4/17/01	Roundup Ultra	1 qt	14.89
		application		6.00
	5/2/01	Fertilize		4.00
		N	30 lb	10.11
		P_2O_5	20 lb	5.64
	5/7/01	Treflan	1.5 pt	3.60
		application		6.00
	5/7/01	Field cultivate	2x	16.00
	5/9/01	Plant		10.00
		seed	29 lb	4.06
	9/25/01	Combine & haul		12.30
Three-year alfalfa				
Blazer XL Alfalfa	5/29/01	Cut		8.00
	6/1/01	Baled		4.17
MT Wheat-Corn-Bean				
Cahone Pinto bean	4/17/01	Roundup Ultra	1 qt	14.89
		application		6.00
	5/31/01	Fertilize		6.00
		P_2O_5	20 lb	5.64
		Zn	5 lb	5.90
	6/1/01	Treflan	1 pt	2.40
		application		6.00
	6/1/01	Field cultivate		5.00
	6/5/01	Plant		10.00
		seed	23 lb	4.83
	6/27/01	Cultivate		8.00
	7/19/01	Cultivate		8.00
	9/12/01	Cut beans		10.00
	9/21/01	Combine & haul		12.30

Table 1A (Continued)

Variety/Crop	Date	Operation	Rate Unit/acre	Cost $/acre
Fairview	10/17/00	Fertilize		4.00
Winter wheat		N	10 lb	3.37
		P_2O_5	20 lb	5.64
	10/17/00	Field cultivate		8.00
	10/17/00	Plant		10.00
		seed	45 lb	3.38
	5/17/01	Harmony Extra	0.5 oz	9.62
		2,4-D LV	4.0 oz	2.50
		application		6.00
	7/27/01*	Combine &		
	8/27/01*	haul		12.30
Grand Valley	9/20/00	Roundup Ultra	1.8 pt	13.62
SX-115		application		6.00
Corn	4/27/01	Roundup Ultra	1 qt	14.89
		application		6.00
	5/14/01	Fertilize		4.00
		N	40 lb	13.48
		P_2O_5	20 lb	5.64
	5/14/01	Field cultivate		8.00
	5/17/01	Plant		10.00
		seed	131 lb	8.52
	7/6/01	Hoe		4.00
	7/19/01	Cultivate		8.00
	10/12/01	Combine & haul		12.30

*Yield strips were harvested on July 27 and the rest of the plot on Aug. 27.

Table 2A. Field operations at Eastland in 2000-01

Variety/Crop	Date	Operation	Rate Unit/acre	Cost $/acre
CT Wheat-Fallow				
Fallow	11/11/00	M. Plow		12.00
	4/25/01	Field cultivate		8.00
	5/31/01	Field cultivate		8.00
	7/20/01	Field cultivate		8.00
	8/20/01	Field cultivate		8.00
Fairview Winter wheat	8/7/00	Field cultivate		8.00
	9/18/00	Field cultivate		8.00
	9/27/00	Plant		10.00
		seed	55 lb	4.13
	5/18/01	2,4-D LV	1 pt	1.95
		application		6.00
	8/7/01	Combine & haul		12.30
MT Wheat-Fallow				
Fallow	4/25/01	Roundup Ultra	1 qt	14.89
		application		6.00
	6/11/01	2,4-D LV	1pt	1.95
	6/11/01	Roundup Ultra	20 oz	9.31
		application		6.00
	7/20/01	Field cultivate		8.00
Fairview Winter wheat	8/7/01	Field cultivate		8.00
	9/14/00	Inject		7.00
		N	17.7 lb	5.85
		P_2O_5	8.4 lb	2.38
	9/18/00	Field cultivate		8.00
	9/27/00	Plant		10.00
		seed	55 lb	4.13
	4/26/01	Spray		6.00
		N	32.3 lb	10.87
		P_2O_5	11.6 lb	3.27
	5/18/01	2,4-D LV	1.0 pt	1.95
		application		6.00
	8/7/01	Combine & haul		12.30

Table 2A (Continued)

Variety/Crop	Date	Operation	Rate Unit/acre	Cost $/acre
CT Wheat-Bean				
Cahone Pinto bean	11/11/00	M. Plow		12.00
	4/25/01	Field cultivate		8.00
	5/31/01	Field cultivate		8.00
	6/5/01	Plant		10.00
		seed	19 lb	3.99
	6/11/01	Spring tooth harrow		10.00
	7/23/01	Cultivate		8.00
	9/12/01	Cut beans		10.00
	10/1/01	Combine & haul		12.30
Fairview Winter wheat	9/18/00	Field cultivate		8.00
	9/27/00	Plant		10.00
		seed	55 lb	4.13
	5/18/01	2,4-D LV	1 pt	1.95
		application		6.00
	8/7/01	Combine & haul		12.30
MT Wheat-Bean				
Cahone Pinto bean	4/25/01	Roundup Ultra	1 qt	14.89
		application		6.00
	5/29/01	Fertilize		6.00
		N	30 lb	10.11
		P_2O_5	20 lb	5.64
		Zn	5 lb	5.90
	5/31/01	Field cultivate		8.00
	6/1/01	Treflan	1 pt	2.40
		application		6.00
	6/1/01	Field cultivate		8.00
	6/5/01	Plant		10.00
		seed	19 lb	3.99
	6/11/01	Spring tooth harrow		10.00
	7/23/01	Cultivate		8.00
	9/12/01	Cut beans		10.00
	10/1/01	Combine & haul		12.30

Table 2A (Continued)

Variety/Crop	Date	Operation	Rate Unit/acre	Cost $/acre
Fairview Winter wheat	9/12/00	Fertilize (inject)		7.00
		N	17.7 lb	5.98
		P_2O_5	8.4 lb	2.38
	9/18/00	Field cultivate		8.00
	9/27/00	Plant		10.00
		seed	55 lb	4.13
	4/26/01	Fertilize (spray)		6.00
		N	32.3 lb	10.87
		P_2O_5	11.6 lb	3.25
	5/18/01	2,4-D LV	1 pt	1.95
		application		6.00
	8/7/01	Combine & haul		12.30
MT Wheat-Safflower-Fallow				
S-208 Safflower	4/24/01	Fertilize		4.00
		N	25 lb	8.43
		P_2O_5	20 lb	5.64
	4/25/01	Field cultivate		8.00
	5/8/01	Treflan	1.5 pt	3.60
		application		6.00
	5/8/01	Field cultivate	2x	16.00
	5/18/01	Plant		10.00
		seed	20 lb	2.80
	10/1/01	Combine & haul		12.30
Fallow	8/7/00	Field cultivate		8.00
	4/25/01	Roundup Ultra	1 qt	14.89
		application		6.00
	6/11/01	2,4-D LV	1 pt	1.95
	6/11/01	Roundup Ultra	20 oz	9.31
		application		5.00
	7/20/01	Field cultivate		8.00

Table 2A (Continued)

Variety/Crop	Date	Operation	Rate Unit/acre	Cost $/acre
Fairview	8/7/00	Field cultivate		8.00
Winter wheat	9/12/00	Fertilize (inject)		7.00
		N	17.7 lb	5.98
		P_2O_5	8.4 lb	2.38
	9/18/00	Field cultivate		8.00
	9/27/00	Plant		10.00
		seed	55 lb	4.13
	4/26/01	Fertilize (spray)		6.00
		N	32.3 lb	10.87
		P_2O_5	11.6 lb	3.26
	5/18/01	2,4-D LV	1 pt	1.95
		application		6.00
	8/7/01	Combine & haul		12.30
MT Triticale-Corn-Safflower				
Grand Valley	8/7/00	Field cultivate		8.00
'SX-1145'	9/18/00	Field cultivate		8.00
Corn	4/25/01	Roundup Ultra	1 qt	14.89
		application		6.00
	5/14/01	Fertilize		4.00
		N	30 lb	10.11
		P_2O_5	20 lb	5.64
	5/15/01	Field cultivate		8.00
	5/21/01	Plant		10.00
		seed	12 lb	18.24
	7/6/01	Hoe (45 min)		6.00
	9/12/01	Chop & haul		5.00
S-208	4/24/01	Fertilize		4.00
Safflower		N	25 lb	8.43
		P_2O_5	20 lb	5.64
	4/25/01	Field cultivate		8.00
	5/18/01	Plant		10.00
		seed	20 lb	2.80
	10/1/01	Combine & haul		12.30

Table 2A (Continued)

Variety/Crop	Date	Operation	Rate Unit/acre	Cost $/acre
Presto Triticale	8/7/00	Field cultivate		8.00
	9/12/00	Fertilize (inject)		7.00
		N	17.7 lb	5.98
		P_2O_5	8.4 lb	2.38
	9/18/00	Field cultivate		5.00
	9/26/00	Plant		10.00
		seed	32 lb	2.56
	4/26/01	Fertilize (spray)		6.00
		N	32.3 lb	10.87
		P_2O_5	11.6 lb	3.26
	8/7/01	Combine & haul		12.30
MT Triticale - Bean				
Presto Triticale	9/12/00	Fertilize (inject)		7.00
		N	17.7 lb	5.98
		P_2O_5	8.4 lb	2.38
	9/18/00	Field cultivate		8.00
	9/26/00	Plant		10.00
		seed	32 lb	2.56
	4/26/01	Fertilize (spray)		6.00
		N	32.3 lb	10.87
		P_2O_5	11.6 lb	3.26
	8/7/01	Combine & haul		12.30
Cahone Pinto bean	8/7/00	Field cultivate		8.00
	4/25/01	Roundup Ultra	1 qt	14.89
		application		6.00
	5/29/01	Fertilize		6.00
		N	20 lb	6.74
		P_2O_5	20 lb	5.64
		Zn	5 lb	5.90
	5/31/01	Field cultivate		8.00
	6/5/01	Plant		10.00
		seed	19 lb	3.99
	6/11/01	Spring tooth harrow		5.00
	7/23/01	Cultivate		8.00
	9/12/01	Cut beans		10.00
	10/1/01	Combine & haul		12.30

Table 3A. Field operations at Goodman Point in 2000-01

Variety/Crop	Date	Operation	Rate Unit/acre	Cost $/acre
Fairview	10/10/00	Cultivate		8.00
Winter wheat	10/18/00	Plant		10.00
		seed	55 lb	4.13
	5/15/01	2,4-D	1 pt	1.95
		application		6.00
	6/23/01	Combine & haul		12.30
Cahone	5/10/01	Cultivate		8.00
Bill Z	6/02/01	Plant		10.00
Pinto bean		Cahone	20 lb	4.20
	6/20/01	Re-plant		10.00
		Bill Z	20 lb	6.80
	8/13/01	Cultivate		8.00
	9/4/01	Cut beans		10.00
	9/28/01	Combine & haul		12.30
Sanford	5/10/01	Cultivate		8.00
Chickpea	5/25/01	Plant		10.00
		Sanford	30 lb	28.50
	6/24/01	Cultivate		8.00
	9/20/01	Cut peas		10.00
	9/28/01	Combine & haul		12.30

Table 4A. Crop residue at planting and harvest at Yellow Jacket in 2000-01

Cropping system/2001 crop	Before planting Sampling date	Residue lb/acre	After harvest Sampling date	Residue lb/acre	Comments
CT Wheat - Fallow					
Wheat	Fall '00	NA	08/29/2001	2620	Very little residues in Fall '00
Fallow	07/31/2000	2873	Fall'01	NA	
MT Wheat - Fallow					
Wheat	09/25/2000	932	08/29/2001	3509	
Fallow	07/31/2000	2657	Fall'01	NA	
CT Wheat - Bean					
Wheat	10/09/2000	501	08/29/2001	1490	
Bean	07/31/2000	1500	09/25/2001	973	Very little residues in spring '01
MT Wheat - Bean					
Wheat	10/09/2000	955	08/29/2001	2349	
Bean	06/06/2001	370	09/25/2001	570	
	07/31/2000	1448			
MT Wheat - Chickpea					
Wheat	09/25/2000	1019	08/29/2001	3042	
Chickpea	05/20/2001	453	10/16/2001	247	Chickpeas were removed on 10/1 and threshed outside the plots.
	07/31/2000	1265			
MT Wheat - Safflower - Oat					
Barley	04/27/2001	768	08/29/2001	1108	
	Fall '00	1334			
Safflower	05/16/2001	330	09/26/2001	1634	
Oat	04/18/2001	1399	08/29/2001	1470	
MT Wheat - Safflower - Bean					
Wheat	10/09/2000	561	08/29/2001	1873	
Safflower	05/16/2001	352	09/26/2001	1856	
	07/31/2000	1511			
Bean	06/06/2001	869	09/25/2001	1049	
MT Wheat - Corn - Bean					
wheat	10/09/2000	2120	08/29/2001	2710	
Corn	05/20/2001	729	10/16/2001	2339	
	07/31/2000	1528			
Bean	06/06/2001	1000	09/25/2001	876	
	Fall '00	1418			

Table 5A. Crop residue at planting and harvest at Eastland in 2000-01

Cropping system/2001 crop	Before planting Sampling date	Residue lb/acre	After harvest Sampling date	Residue lb/acre	Comments
CT Wheat - Fallow					
Wheat	Fall '00	NA	08/20/2001	902	Was disked in spring '00
Fallow	08/04/2000	695	09/13/2001	115	
MT Wheat - Fallow					
Wheat	Fall '00	NA	08/20/2001	903	Was disked in spring '00
Fallow	08/04/2000	760	09/13/2001	358	
CT Wheat - Bean					
Wheat	Fall '00	NA	08/20/2001	541	Was disked in spring '00
Bean	06/05/2001	145	10/02/2001	320	
MT Wheat - Bean					
Wheat	Fall '00	NA	08/20/2001	716	Was disked in spring '00
Bean	06/05/2001	300	10/02/2001	397	
MT Wheat - Safflower - Fallow					
Wheat	Fall '00	NA	08/20/2001	835	Was disked in spring '00
Safflower	05/30/2001	480	10/02/2001	482	
	08/04/2000	708			
Fallow	Fall '00	NA	09/13/2001	38	Was disked in spring '00
MT Triticale - Corn - Safflower					
Triticale	Fall '00	NA	08/20/2001	1195	Was disked in spring '00
Corn	05/30/2001	43	09/13/2001	359	Was disked in spring '00
Safflower	05/30/2001	205	10/02/2001	460	
MT Triticale - Bean					
Triticale	Fall '00	NA	08/20/2001	820	Was disked in spring '00
Bean	06/05/2001	43	10/02/2001	263	Was seeded to alfalfa in spring '00

Table 6A. Crop residue at planting and harvest at Goodman Point in 2001

Date	Treatment No.	Rep No.	Position	Harvested crop	Residue (lb/acre)
08/02/2001	3	1	South	Wheat	875
08/02/2001	3	1	South	Wheat	960
08/02/2001	3	1	South	Wheat	930
08/02/2001	3	1	South	Wheat	1015
08/02/2001	3	1	South	Wheat	620
08/02/2001	3	2	South	Wheat	875
08/02/2001	3	2	South	Wheat	1385
08/02/2001	3	2	South	Wheat	1590
08/02/2001	3	2	South	Wheat	1205
08/02/2001	3	2	South	Wheat	1505
Average					**1096**
08/02/2001	3	1	Middle	Wheat	985
08/02/2001	3	1	Middle	Wheat	815
08/02/2001	3	1	Middle	Wheat	875
08/02/2001	3	1	Middle	Wheat	1015
08/02/2001	3	2	Middle	Wheat	1080
08/02/2001	3	2	Middle	Wheat	1310
08/02/2001	3	2	Middle	Wheat	1240
08/02/2001	3	2	Middle	Wheat	985
Average					**1038**
08/02/2001	3	1	North	Wheat	1465
08/02/2001	3	2	North	Wheat	1110
Average					**1287**
08/02/2001	4	1	South	Wheat	1505
08/02/2001	4	1	South	Wheat	1275
08/02/2001	4	1	South	Wheat	1275
08/02/2001	4	1	South	Wheat	1205
08/02/2001	4	1	South	Wheat	1205
08/02/2001	4	2	South	Wheat	1175
08/02/2001	4	2	South	Wheat	1240
08/02/2001	4	2	South	Wheat	1590
08/02/2001	4	2	South	Wheat	1545
08/02/2001	4	2	South	Wheat	1350
Average					**1337**
08/02/2001	4	1	Middle	Wheat	1465
08/02/2001	4	1	Middle	Wheat	1015
08/02/2001	4	1	Middle	Wheat	1080
08/02/2001	4	1	Middle	Wheat	1080
08/02/2001	4	2	Middle	Wheat	1465
08/02/2001	4	2	Middle	Wheat	1385
08/02/2001	4	2	Middle	Wheat	1135
08/02/2001	4	2	Middle	Wheat	1385
Average					**1251**
08/02/2001	4	1	North	Wheat	1135
08/02/2001	4	2	North	Wheat	1505
Average					**1320**
10/02/2001	1	1	South	Bean	234
10/02/2001	1	2	South	Bean	234
Average					**234**
10/02/2001	1	1	Middle	Bean	195
10/02/2001	1	2	Middle	Bean	190
Average					**192**
10/02/2001	1	1	North	Bean	122
10/02/2001	1	2	North	Bean	165
Average					**144**
10/02/2001	2	1	South	Garbanzo	249
10/02/2001	2	2	South	Garbanzo	234
Average					**242**
10/02/2001	2	1	Middle	Garbanzo	340
10/02/2001	2	2	Middle	Garbanzo	330
Average					**335**
10/02/2001	2	1	North	Garbanzo	304
10/02/2001	2	2	North	Garbanzo	297
Average					**301**

Appendix B: Information dissemination and outreach activities

Year 2000:

Most of the efforts during the first year of the SARE project focused on:

- Finding appropriate sites for the on-farm trials
- Hiring a project field coordinator, and
- Establishing the field trials

Several meetings were held in Dove Creek, Colorado between July and December 1999 to explain the purpose of the SARE project and seek a cooperator from Dolores County. Meanwhile, progress was being made towards the installation of a field trial at Eastland, Utah and later at Goodman Point in Montezuma County. It was decided to limit the on-farm trials to two (three were planned) due to budgetary constraints and the larger than expected size of the trial at Eastland.

Year 2001:

The SARE project objectives and results to date were discussed at the meetings and outreach activities listed below. The numbers in parentheses indicate the approximate number of participants.

1. Research Center Conference in Fort Collins, CO on 1/10/01 (20)
2. Soil & Crop Science seminar in Fort Collins, CO on 1/18/01 (40)
3. Dryland Farming Workshop in Dove Creek, CO on 2/8/01 (55)
4. Advisory Board Meeting in Cortez, CO on 2/21/01 (33)
5. Colorado Agricultural Experiment Station Managers' Tour on 6/29/01 (15)
6. Field Day and SARE Tour on August 16 and 17, 2001 (124 on Day 1, 12 to 14 on Day 2)
7. 2001 ASA Annual Meetings in Charlotte, NC (poster presentation)

Approximately two-thirds of the participants to activities 3, 4, and 6 were farmers, ranchers, or agricultural business representatives.

Publications:

Popular press:
'Alternative crop management may increase profit, researchers say' by Jim Mimiaga. Page 2B in the Cortez Journal, 12/18/99. Account of the meeting held in Dove Creek on 12/9/99 to discuss the SARE project with area producers.

Published abstract:
Berrada, A. and G. A. Peterson. 2000. Development of Sustainable Dryland Cropping Systems in SW Colorado and SE Utah. Agron. Abstracts p. 132, Amer. Soc. of Agron., Madison, WI.

Berrada, A, G.A. Peterson, and R.W. Hammon. 2001. Evaluation of alternative cropping systems in SW Colorado and SE Utah. ASA, CSSA, SSSA Annual Meetings Abstracts, Oct. 21-25, 2001. Charlotte, NC.

Colorado Agricultural Experiment Station Annual Report. 2001. Fresh ideas for dryland farming: Using conservation tillage and crop diversification for better soil. p.18-19 (features the SARE project).

Progress reports: 2000 and 2001 Annual Reports submitted to western SARE.