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

2002 and 2003 Results

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By

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SARE Project No. SW99-56

Abstract

A Sustainable Agriculture Research and Education (SARE) project was initiated 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. Field trials were established at Yellow Jacket and Goodman Point in Colorado and at Eastland in Utah. Treatments consisted of two- and three-year crop rotations managed using conventional- (CT) or minimum-till (MT) practices. No-till (NT) was substituted for MT in MT Wheat-Fallow, in 2002 and 2003, at Yellow Jacket. The 2002 and 2003 results are reported here.

Crop yields were extremely low in 2002, with the exception of Wheat-Fallow at Yellow Jacket. Winter wheat (*Triticum aestivum*) in Wheat-Fallow was planted earlier and had more available soil moisture at planting, particularly with NT management, than wheat in the more intensive crop rotations. No-till Wheat-Fallow out produced CT Wheat-Fallow by 7.5 bu/a. Wheat after fallow at Eastland performed better than wheat after dry bean (*Phaseolus vulgaris*), but the highest yield was only 13 bu/a.

The generally poor crop yields in 2002 were indicative of the exceptionally dry conditions during the 2001-02 growing season (35% of normal precipitation). The fall of 2002 had near normal precipitation, which boosted wheat production in 2003. Wheat-Bean (CT & MT), Wheat-Chickpea, and Wheat-Corn (*Zea mays*)-Bean produced significantly more wheat than CT Wheat-Fallow and Wheat-Safflower (*Carthamus tinctorius*)-Bean in 2003 at Yellow Jacket. Conventional-till Wheat-Fallow and NT Wheat-Fallow had similar yields, although NT Wheat-

Fallow had more available soil moisture at planting. No-till Wheat-Fallow could have benefited from N fertilization as indicated by the low grain protein concentration and the low soil test NO_3-N level at planting. There were no significant differences in wheat yield, among treatments, at Eastland or Goodman Point, in 2003.

Dry bean production in 2003 averaged 382 lb/a at Yellow Jacket, 412 lb/a at Goodman Point, and 191 lb/a at Eastland; with no significant differences among treatments. Beans at Eastland were cut late, resulting in substantial shattering and harvest losses. Wheat-Safflower-Fallow produced 236 lb/a more safflower than Triticale (*x Triticosecale* Wittmack)-Corn-Safflower at Eastland.

In dry years, such as was the case in 2000 through 2003, continuous non-irrigated crop production (one crop each year) may not be sustainable in the project area. A long fallow period, i.e., 14 months every few years may be necessary to improve soil moisture availability. More research is needed to determine the optimum cropping intensity in the project area. Enough time—several crop rotation cycles—should be allowed for the full expression of the soil-climate-cropping systems interactions.

Introduction

The project area includes Dolores, Montezuma, and San Miguel counties in southwestern Colorado and San Juan County in southeastern Utah. Approximately two-thirds of the cropland (350,000 acres total) in the project area is non-irrigated. Crop yields are limited by the low and erratic precipitation (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) produce an average of 20 bu/acre and 400 lb/acre, respectively (http://www.nass.usda.gov/co/, http://www.nass.usda.gov/ut/) (verified 13 Sept. 2004).

The combination of fine, weakly structured, silty soils and relatively steep sloping terrain (predominant slopes are 1 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 and occasional high intensity rains in late summer or early spring. Wind erosion is not as serious a threat as water erosion but can be severe in the springtime on bare ground, particularly in dry years.

One way to minimize soil erosion is through MT and NT practices. No-till management leaves the maximum amount of crop residues on the soil surface, which acts as a barrier to runoff, soil displacement, and evaporation. There are numerous reports of substantial increases in precipitation storage efficiency due to NT, as compared to CT or MT. The increased soil-water availability with NT management has led to greater cropping intensity in the central Great Plains of the U.S. (Peterson et al., 1996; Dhuyvetter et al., 1996; Norwood, 2000; Nielson et al., 2002; Kaan et al., 2002).

The adoption of MT and NT practices in the project area is lagging compared to other regions in the U.S., based on reports published by the Conservation Technology Information Center (http://www.ctic.purdue.edu/CTIC/CRM.html) (verified 13 Sept. 2004). 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 show that winter wheat can be grown successfully with NT and MT management in either the wheat-bean or the wheat-fallow sequence (Berrada et al., 1995). By contrast, NT dryland dry bean production was not successful. Dry bean seed production was significantly less with NT than with CT management, even though soil-water storage had been improved with NT. Surface soil compaction appeared to be the primary constraint in NT beans.

Minimum-till bean management would compete better with CT than NT but the use of herbicides should be minimized to make the system profitable. 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 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 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.).

Wheat-bean rotation should be preferable to wheat-fallow since it produces a crop each year. Residual N from the bean crop should enhance wheat yield and its protein concentration. A positive wheat yield response to up to 60 lb N/a was observed at the Southwestern Colorado Research Center but only 20 lb N/a was profitable (Stack and Fisher, 1992). The primary objective of fallowing in semi-arid environments is to allow as much soil moisture storage (availability) as possible to minimize crop failure. Dry beans obtain most of their water from the upper two feet of soil, which leaves the bulk of any available subsoil moisture to the succeeding crop such as wheat (Brengle et al., 1970; Yonts, 1996). Winter wheat after dry bean is usually not planted until early to mid October but a September planting is more desirable. 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 (Hammon et al., 1999).

Most of the cropland in the project area is in the Conservation Reserve Program (CRP), alfalfa (*Medicago sativa*), winter wheat, dry bean, or pasture. Minor crops include oat (*Avena sativa*), safflower, corn, and chickpea (*Cicer arietinum*). Chickpea can be grown using similar equipment and production practices as with dry bean. Chickpea is more frost tolerant than dry bean and, thus can be planted earlier. Competitive chickpea yields and good seed quality have 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). Little information is available on how chickpea and other minor crops fit in rotation with winter wheat, dry bean, and other crops in the project area.

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 and experimental design:

One field trial was established in 1999 at the Southwestern Colorado Research Center at Yellow Jacket, CO and two on farmers' fields in 2000. The on-farm trials were located at Eastland, UT and Goodman Point, CO. The choice of cropping systems was based on previous research results and growers' interests. Conventional tillage was compared to MT management in winter wheat-fallow and winter wheat-dry bean rotations, at Yellow Jacket and Eastland. Alternative crop rotations at these two locations were managed using MT only. Cropping systems tested at each location are listed below.

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 (Wheat-Safflower-Oat). This treatment was changed to Wheat-Safflower-Fallow in 2002.
6. Minimum Tillage Winter Wheat-Safflower-Dry Bean (Wheat-Safflower-Bean)
7. Minimum Tillage Winter Wheat-Chickpea (Wheat-Chickpea)
8. Minimum Tillage Winter Wheat-Corn-Dry Bean (Wheat-Corn-Bean)
9. Three-year alfalfa (Alfalfa)

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 (Wheat-Safflower- Fallow)
6. Minimum Tillage Winter Triticale-Corn-Safflower (Triticale-Corn-Safflower)
7. Minimum Tillage Winter Triticale-Dry Bean (Triticale-Bean)

Goodman Point, CO

1. Three-year chickpea monoculture
2. Three-year dry bean monoculture
3. Winter Wheat-Chickpea rotation
4. Winter Wheat-Dry Bean rotation

The elevation at the three sites ranges from 6800 to 6900 ft. above sea level. The frost-free season is 100 to 120 days for summer crops such as dry bean. Normal precipitation (1971-2000 average) at Yellow Jacket is 15.9 inches per year, of which approximately 40% comes from snow (http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?coyell) (verified 13 Sept. 2004). Monthly average precipitation ranges from 0.6 to 1.9 in., 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 number of blocks (replications) was three at Yellow Jacket and two at Eastland and Goodman Point. 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.

Plot management:

The staff at the Southwestern Colorado Research Center managed the field trial at Yellow Jacket. The farm owner managed the trial at Goodman Point. Three farmers and the research staff were involved in the management of the trial at Eastland. The farm owner and his assistant planted and harvested wheat and safflower and did most of the tillage. Another farmer planted and harvested pinto beans and a third farmer planted and harvested corn. The farm owner at Eastland received half of the bean and corn crops as cash. This arrangement was made because the farm owner did not have the equipment to grow beans or corn. The principle investigator and the project field coordinator assisted with fertilizer and herbicide application and other field operations at Eastland, on an 'as needed' basis.

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 Southwestern Colorado Research Center, 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.

All the plots at Goodman Point were managed conventionally with heavy reliance on tillage to control weeds. No fertilizer was applied to any of the treatments, throughout the duration of the experiment (2000-2003). The whole plot area was in alfalfa in 1993 to 1999. No fertilizer was applied to the CT treatments at Yellow Jacket and Eastland. Nitrogen, P, or Zn fertilizer was applied to the MT treatments based on soil test results. None of the treatments were fertilized in 2002-03 due to drought. Field operation records are listed in Appendix A.

Measurements:

Climatic data*:* Precipitation and temperature data were obtained from the Yellow Jacket weather station, which is fairly representative of the climatic conditions at the other two sites. On-site measurements of rainfall were made with a rain gauge (data not shown).

Soil testing: Composite soil samples were taken prior to fall and spring plantings at each site and in December 2003 in selected treatments at Yellow Jacket. Sampling depth was generally 0 to 1 ft. and 1 to 2 ft. except when the soil was too dry, in which case only the top foot was sampled. The soil was analyzed for pH, organic matter, and available N, P and Zn. Soil test results are listed in Appendix B.

Soil water availability: Soil samples were taken with a hydraulic probe before planting and after harvest of each crop, in one-foot increments, down to 4 ft., depending on soil conditions. No measurements were made at Goodman Point in the fall of 2001 or 2002. The soil samples were weighed, dried for 48 hours at 105^{o}C, and re-weighed to determine their water content. Bulk density values used to convert soil water content by weight to soil water content by volume were obtained from previous measurements at Yellow Jacket (unpublished data). The wilting point of representative soil samples was determined with the pressure plate extractor method (Dane and Hopmans, 2002). Available water is the difference between total soil water content at field capacity and water content at wilting point. When the difference was < 0.0 available water was set to zero. Soil water measurements are listed in Appendix C.

Crop yield: Seed yield at Eastland and Goodman Point was estimated from the whole-plot weight. The harvest from each plot was loaded into a truck and weighed with a commercial scale at the nearest grain elevator. A sample was taken from each plot to determine test weight, percent moisture, and/or percent protein. Corn at Eastland was chopped for silage and weighed in the same manner as the grain crops were. Its moisture content was determined by drying three samples in an oven at 80^{o} C, for 48 hours.

Wheat, oat, safflower, and corn at Yellow Jacket were harvested with a plot combine in two 4 ft. x 140 ft. strips. The seed was cleaned and weighed. Seed test weight, percent moisture, and percent protein (wheat and triticale) were measured as well. Chickpea and pinto bean were undercut with knives mounted on a tractor, raked with a bean rake, and left in the field to dry for one to two weeks. A 40- to 60-ft. section of a representative windrow was threshed with a plot combine. The seeds were cleaned and weighed and a sample was saved for test weight, moisture, and protein measurements.

Alfalfa at Yellow Jacket was cut once a year, usually by mid June, and baled (small bales) after it was sufficiently dry (≤18% moisture). The bales were counted and weighed and samples taken from a few bales to determine alfalfa hay percent moisture and relative feed value (RFV).

Pest evaluation: Pheromone traps were used to monitor pale western (*Agrotis orthogonia* Morrison) and army cutworm [*Euxoa auxiliaris* (Grote)] moth population at Yellow Jacket and Eastland in the summer and early fall of 2002 and 2003. This was part of a Western Region IPM project (http://www.cutworm.org/) (verified 13 Sept. 2004).

Results and Discussion

2002 Results

Climatic conditions:

The 2001-02 crop season was one of the driest on record in the Four Corners area, following two years of below-average precipitation (http://www.wrcc.dri.edu/climsum.html) (verified 13 Sept. 2004). Cumulative precipitation at Yellow Jacket, from October 2001 through August 2002, was 3.5 in. or 24% of normal (Table 1). September rainfall was above normal (2.7 in. vs. 1.6 in.) but came too late for most of the 2002 crops. Average monthly temperature was above normal in April through September (Fig. 1). Similar conditions prevailed at Goodman Point and Eastland (data not shown).

Table 1. Monthly precipitation at Yellow Jacket in 1999-2003

Month	1971-2000	1999	2000	2001	2002	2003
January	1.2	0.2	1.2	0.7	0.0	0.2
February	1.3	0.5	0.6	1.0	0.0	2.0
March	1.4	0.0	1.6	0.1	0.5	1.7
April	0.9	2.7	0.4	1.1	0.2	0.2
May	1.3	1.7	0.4	0.5	0.1	0.7
June	0.6	1.1	0.1	0.2	0.0	0.1
July	1.5	1.7	0.6	1.2	0.1	0.6
August	1.7	2.5	2.3	2.8	0.8	1.2
September	1.5	0.9	0.8	0.2	2.7	2.2
October	2.0	0.0	2.0	0.6	1.8	1.2
November	1.5	0.1	0.7	0.5	1.3	0.8
December	1.0	0.1	0.4	0.9	0.6	0.3
Total	15.9	11.5	10.9	9.6	8.1	11.1
% Normal	**100**	**72**	**69**	**60**	**51**	**70**
Oct.-Aug.	15.9	-	7.3	10.6	3.7	10.2
% Normal	**100**	**-**	**50**	**74**	**26**	**71**
Apr.-Aug.*	6.0	-	3.8	5.7	1.2	2.7
% Normal	**100.0**	**-**	**62**	**96**	**21**	**44**

*Same year

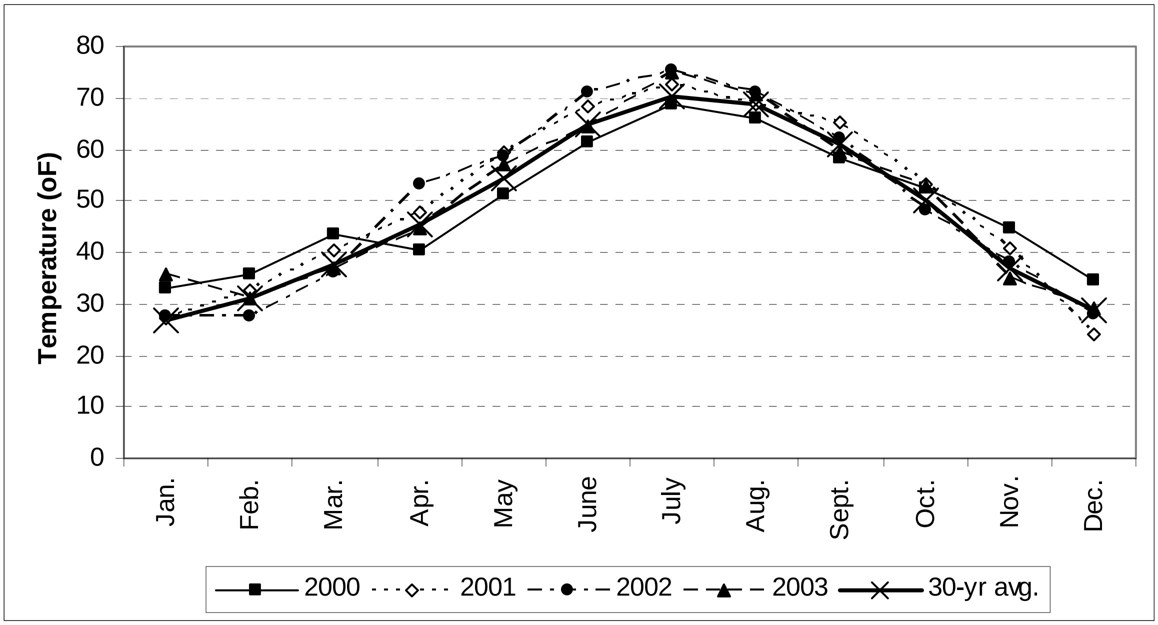

Figure 1. Monthly average temperature at Yellow Jacket in 2000-2003

Wheat production at Yellow Jacket:

Winter wheat in Wheat-Fallow averaged 21 bu/a compared to 4 bu/a (0 to 8.7 bu/a) after pinto bean, chickpea, corn, oat, or safflower (Table 2). Wheat in CT and MT Wheat-Fallow was planted on 12 Sept. 2001 (Table A1). Wheat in the other treatments was planted on 12 Oct. 2001 but did not come up until the spring of 2002, resulting in poor germination, particularly in blocks 1 and 2. Wheat plots in those blocks were re-seeded to 'Sylvan' spring wheat in early April.

There was substantially more available soil moisture at wheat planting time in Wheat-Fallow than in the more intensive crop rotations (Table C1). This, along with earlier planting may explain the large difference in wheat yield between Wheat-Fallow and the other crop rotations (Table 2). Minimum-till Wheat-Fallow produced 24 bu/a, significantly more than CT Wheat-Fallow, probably due to more available soil moisture at planting (Table C1) and N and P fertilization (Table A1).

Wheat and triticale production at Eastland:

Wheat after fallow produced significantly more grain than wheat after dry bean (Table 3). Triticale produced less that 1 bu/a after safflower and approximately 6 bu/a after dry bean. There was more available soil moisture before planting in Wheat-Fallow and Wheat-Safflower-Fallow than in Wheat-Bean, Triticale-Bean, and Triticale-Corn-Safflower (Table C2). Valuable moisture was lost during re-seeding of wheat in Wheat-Fallow and Wheat-Safflower-Fallow. Wheat after fallow was re-seeded twice due to soil crusting and did not emerge until spring e.g., at the same time as wheat after pinto bean.

Table 2. Winter wheat yield at Yellow Jacket in 2002 and 2003

Cropping system	2002	2003	2000-2003	2003
	bu/a	bu/a	bu/a	% Protein
MT Wheat-Fallow	24.7	24.8	26.7	11.3
CT Wheat-Fallow	17.2	21.7	21.6	12.8
Wheat-Corn-Bean	4.6	27.4	19.6	14.3
MT Wheat-Bean	6.0	27.7	19.1	15.0
CT Wheat-Bean	3.2	29.8	17.4	13.5
Wheat-Safflower-Bean	2.2	22.1	16.3	15.2
Wheat-Chickpea	0.0	26.0	15.1	14.5
Wheat-Safflower-Fallow	-	23.4	-	15.3
Average	**8.3**	**25.4**	**19.4**	**14.0**
$LSD_{0.10}$	2.9	3.5	6.7	1.0

Table 3. Winter wheat yield at Eastland in 2002 and 2003

Cropping system	2002	2003	2000-2003	2003
	bu/a	bu/a	bu/a	% Protein
MT Wheat-Fallow	13.2	21.3	20.3	11.5
Wheat-Safflower-Fallow	10.0	13.5	18.2	11.5
MT Wheat-Bean	3.6	18.5	16.3	11.3
CT Wheat-Fallow	11.0	15.7	15.8	10.3
CT Wheat-Bean	5.0	16.2	13.9	11.3
Triticale-Bean	6.1	17.4	13.1*	12.6
Triticale-Corn-Safflower	0.6	18.0	12.4*	13.4
Average	**7.1**	**17.2**	**16.9****	**11.7**
$LSD_{0.10}$	3.3	4.2	NS	1.1

*Average of 2001, 2002, and 2003
**Average of wheat yield only, from 2000 through 2003.

Wheat production at Goodman Point:

Wheat after dry bean produced 4.7 bu/a and less than one bushel per acre after chickpea (Table 4). The plots were disked in mid-September and wheat was seeded on 11 Oct. 2001 (Table A3). Soil moisture content at planting was extremely low (data not shown) as was precipitation throughout most of the growing season. In addition to drought, wheat suffered from grasshopper damage at this site.

Table 4. Crop yield at Goodman Point in 2002 and 2003

Current Crop	Previous crop	Crop yield				% Protein
		2002	2003	2001-2003*	Unit	2003
Winter wheat	Dry bean	4.7	18.9	10.3	bu/a	16.6
Winter wheat	Chickpea	0.3	19.1	8.9	bu/a	16.3
Dry bean	Winter wheat	0	396	-	lb/a	24.2
Dry bean	Dry bean	0	427	271	lb/a	24.5
Chickpea	Winter wheat	0	296	-	lb/a	26.3
Chickpea	Chickpea	0	348	253	lb/a	26.4

*Crops were not harvested in 2000, except chickpea (138 lb/a).

Wheat protein concentration:

Wheat protein averaged 19% at Goodman Point, 17% at Yellow Jacket, and 15% at Eastland. (data not shown). Soil test NO_3-N concentrations in the fall of 2001 were generally low to medium at Yellow Jacket (Table B1), low at Eastland (Table B2), and high at Goodman Point (Table B3).

Spring crops:

At Yellow Jacket, oat, safflower, and corn had good emergence and stand establishment but ran out of water quickly. Chickpeas and pinto beans were planted in dry soil (Table C3) resulting in poor emergence and growth since there was very little precipitation through July. Similar conditions existed at Eastland and Goodman Point. None of the spring crops were harvested at any of the experimental sites. Safflower production at Eastland was estimated at 150 lb/acre in Wheat-Safflower-Fallow and 400 lb/acre in Triticale-Safflower-Corn.

Cutworm activity:

Cutworm activity was monitored at Yellow Jacket and Eastland as part of the Western Region IPM Cutworm Regional Survey and Forecast Project (http://www.cutworm.org/) (verified 13 Sept. 2004). Cutworm outbreaks represent serious but sporadic events in southwestern Colorado and southeastern Utah. The main crops that are attacked are winter wheat and alfalfa. The two main species of concern are the army cutworm and the pale western cutworm. Adult cutworm moth totals (average of two traps) for Eastland were 484 pale western cutworms and 213 army cutworms during an 11-week period in August through October. This corresponds to a high risk for potential damage in 2003 from pale western cutworms and a low risk for potential damage from army cutworms. The moth totals for Yellow Jacket were 369 pale western cutworms and 1473 army cutworms in 13 weeks (20 Aug. to 12 Nov.). These numbers correspond to a high risk for potential damage in 2003 from both species. The threshold for potential damage the following spring is 200 moths for pale western cutworm and 800 moths for army cutworm. Little or no cutworm activity (larvae stage) or crop damage was observed during the growing season in 2002.

2003 Results

Climatic conditions:

Cumulative precipitation at Yellow Jacket from October 2002 through September 2003 was 12.8 in. or 80% of normal (Table 1). Precipitation in April through August 2003 was 44% of normal. May, July, and August were warmer than average (Fig. 1).

Wheat production at Yellow Jacket:

Wheat averaged 25.4 bu/a, with significant differences among treatments (Table 2). Wheat after pinto beans or chickpeas produced the highest yield (26 to 30 bu/a). Wheat after fallow and wheat after bean after safflower (Wheat-Safflower-Bean) produced the lowest yield (22 to 25 bu/a). Wheat grain protein concentration was highest in MT Wheat-Bean and in Wheat-Safflower-Fallow, and lowest in MT Wheat-Fallow (Table 2).

Winter wheat was planted on 26 Sept. 2002 in all the treatments, unlike in previous years when wheat was planted earlier after fallow than after spring crops. Spring crops in 2002 were not harvested due to extremely low production; therefore, it was possible to plant wheat the same day in all the treatments (Table A1).

There was very little soil moisture (0-4 ft) at planting, except in MT Wheat–Fallow and MT Wheat-Corn-Bean (Table C1). Minimum-till Wheat-Fallow was managed as NT in 2002 and 2003 (Table A1). No fertilizer was applied to any of the treatments in the fall of 2002 or spring of 2003 due to drought. Soil test results (Table B1) and grain protein concentration (Table 1) indicate that NT Wheat-Fallow would have benefited from N fertilization. Soil test NO_3-N levels in the fall of 2002 were low in MT and CT Wheat-Fallow and adequate in the other treatments based on a yield goal of 30 to 40 bu/a (Davis et al., 2002). The reason for the high soil NO_3-N in

Wheat-Safflower-Fallow is unknown. Soil test P levels were in the medium range in all the treatments (Table B1).

Wheat and triticale production at Eastland:

There were no significant differences in wheat or triticale yield among the treatments at $P \leq 0.10$ (Table 3). Differences between Wheat-Safflower-Fallow, which had the lowest yield (13.5 bu/a) and MT Wheat-Fallow, which had the highest yield (21.3 bu/a); and between MT Wheat-Fallow and CT Wheat-Fallow (15.7 bu/a) were significant at $P = 0.13$. The coefficient of variation was 14.9%. Wheat grain protein concentration was low (10.3 to 11.5%) compared to that of triticale (12.6 and 13.4 %) (Table 3).

Wheat at Eastland was planted on 20 Sept. 2002 in all the wheat plots, at 75 lb/a. Triticale was planted on 27 Sept. at 51 lb/a (Table A2). Equipment availability dictated the planting date at Eastland. Wheat seeding rate was somewhat high for this environment; 50 to 60 lb/a is more common. Soil moisture content on 19 Sept. was very low (Table C2). All the treatments could have benefited from N and P fertilizer (Table B2), but none was applied due to the perception that the fertilizer would not be economical and could be detrimental to the crop in a drought situation. In addition, soil test results were not available prior to wheat or triticale planting.

Wheat production at Goodman Point:

Winter wheat at Goodman Point was planted on 2 Oct. 2002 (Table A3) in dry conditions but was followed with 0.7 in. of rain. Wheat yield averaged 19 bu/a, with no significant difference between Wheat-Bean and Wheat-Chickpea (Table 4). Wheat grain protein concentration averaged 16.5%. Soil NO_3-N level in the fall of 2001 and 2002 was high (21 to 25 ppm), while P level was low (Table B3).

Spring crops:

Spring crop production was poor at all three sites (Tables 3 & 5) due to dry conditions during the growing season. Soil moisture at planting was adequate (Tables C3-C5) but precipitation in April through July was substantially below average (Table 1). There were no significant differences in dry bean yield at Yellow Jacket or Eastland. Chickpea at Goodman Point produced 52 lb/a more grain after chickpea than after winter wheat, but the average yield was only 322 lb/a (Table 3). More chickpea was produced at Yellow Jacket (653 lb/a) than at Goodman Point, although seed quality at Yellow Jacket was poor (high percentage of green and stained seeds). Safflower averaged 437 lb/a at Yellow Jacket and 653 lb/a at Eastland. Safflower produced 236 lb/a more seeds after winter wheat in Wheat-Safflower-Fallow than after corn in Triticale-Corn-Safflower (Table 5). Safflower at Eastland may have benefited from a low plant population (low seeding rate and poor emergence), given the dry conditions in the spring and summer of 2003.

No fertilizer was applied to any of the spring crops in 2003, even though soil test N, P, and Zn levels were very low (Tables B3-B5). There was a big drop in soil NO_3-N concentration at Goodman Point in the spring of 2003 compared to the fall of 2002 (Table B3). A decline in NO_3-N concentration would be expected over the years since no N fertilizer was applied but the magnitude of the decline could not be explained, unless it had something to do with the difference in the sampling date between 2002 and 2003. The high soil NO_3-N levels at Goodman Point in 2000 through 2002 were likely due to the residual effect of alfalfa (Berrada et al., 2002).

Table 5. Spring crop yield at Yellow Jacket and Eastland in 2003¶

Cropping system	Yellow Jacket		Eastland	
	lb/a	% Protein	lb/a	% Protein
CT Wheat-**Bean**	398	23.8	223	20.8
MT Wheat-**Bean**	383	23.9	173	23.2
Wheat-Safflower-**Bean**	366	23.2	NA	NA
Wheat-Corn-**Bean**	381	23.4	NA	NA
Triticale-**Bean**	NA	NA	177	22.2
Wheat-**Chickpea**	653	25.0	NA	NA
Wheat-**Safflower**-Bean	458	18.0	NA	NA
Wheat-**Safflower**-Fallow	416	17.9	771	17.1
Triticale-Corn-**Safflower**	NA	NA	535	22.2
Wheat-**Corn**-Bean	1442*	10.0	NA	NA
Triticale-**Corn**-Safflower	NA	NA	5740**	NA
Alfalfa	1570	18.2	NA	NA

¶ Highlighted crop
*Corn grain yield
**Corn dry matter yield

Cutworm damage:

The high moth counts in August-October 2002, coupled with favorable climatic conditions (good precipitation and mild temperature) in the fall and winter of 2002-03 resulted in an outbreak of army cutworm. Damage to winter wheat and alfalfa was severe in the fields that were not sprayed, until approximately mid-May when the larvae pupated. Larvae feeding destroyed most of the above-ground growth during the winter (winter wheat) and mid-spring (alfalfa) in these fields. Damage to winter wheat was extensive at all three sites, prior to the application of 2.5 to 3.5 oz/acre of Mustang [S-Cyano(3-phonoxyphenyl)methyl(±)cis/trans3-(2,2-dichloroethenyl)-2,2dimethylcyclopropane carboxylate]. Spraying was completed on 20 February, 22 March, and 4 April 2003 at Yellow Jacket, Goodman Point, and Eastland, respectively.

Moth activity was monitored in 2003 (August-October) at Yellow Jacket only. Cumulative army cutworm moth count was 1277. Pale western army cutworm moth count was 90. Very little, if any cutworm activity was observed in January through April 2004, probably because of good snow cover and record low temperatures.

Conclusions

Wheat and triticale production was extremely low in 2002, with the exception of Wheat-Fallow at Yellow Jacket. Wheat in Wheat-Fallow, at Yellow Jacket, was planted one month earlier than wheat in the more intensive crop rotations. There was more available soil moisture at planting in Wheat-Fallow, particularly with NT management. No-Till Wheat-Fallow out produced CT Wheat-Fallow by 7.5 bu/a. The difference could be due to more available moisture with NT and the fact that NT plots were fertilized and CT plots were not.

Wheat after fallow at Eastland also produced more than wheat after bean, but the highest yield was only 13 bu/a. Valuable soil moisture and growth potential were lost in Wheat-Fallow and Wheat-Safflower-Fallow, since wheat was re-seeded twice.

Spring crops produced very little or no seeds in 2002. The generally poor crop yields in 2002 were indicative of the exceptionally dry conditions during most of the growing season. Precipitation from October 2001 through September 2002 was 35% of normal and that from April through August 2002 was 21% of normal. Precipitation for the same periods in 2002-03 was 80 and 44% of normal, respectively. Consequently, crop yields were generally higher in 2003 than in 2002.

At the Yellow Jacket site, Wheat-Bean (CT and NT), Wheat-Chickpea, and Wheat-Corn-Bean produced the highest wheat yields in 2003. No-Till and CT Wheat-Fallow produced similar yields, even though there was more available soil moisture at planting in NT than in CT. No-Till Wheat-Fallow had lower soil test NO_3-N at planting and lower grain protein concentration than CT Wheat-Fallow. It could have benefited from N fertilization. Wheat at Yellow Jacket was planted the same day in all the treatments, unlike in 1999-2001.

There were no significant differences in wheat yield, among treatments, at Eastland or Goodman Point, in 2003.

Dry bean production in 2003 averaged 382 lb/a at Yellow Jacket, 412 lb/a at Goodman Point, and 191 lb/a at Eastland; with no significant differences among treatments. Beans at Eastland were cut late, resulting in substantial shattering and harvest losses.

Overall conclusions and recommendations based on the 2000-3 results

Winter wheat after a 14-month fallow (Wheat-Fallow) produced the best seed yield at Yellow Jacket in 2000 (Berrada et al., 2002) and 2002 and at Eastland in 2002; probably due to earlier planting and/or more available soil moisture at planting, compared to the more intensive crop rotations. Hammon et al. (1999) showed a significant decrease in winter wheat yield at

Yellow Jacket, as planting was delayed past the optimum date of mid- to late September. Wheat after dry bean is usually not planted until early to mid-October, in the project area. In dry years, such as was the case in 1999-00 and 2001-02, a long fallow period may be necessary to ensure that there is enough moisture at planting for adequate wheat seed germination and stand establishment. Minimum till (2001) and NT (2002 & 2003) management enhanced soil water storage and wheat yield in Wheat-Fallow at Yellow Jacket.

A confounding factor when comparing CT Wheat-Fallow to MT Wheat-Fallow is the fact that MT Wheat-Fallow benefited from N and P fertilization, except in 2003. Conventional Till Wheat-Fallow and CT Wheat-Bean were intended to represent typical farming practices in the project area, which rarely include the application of any fertilizer.

The economics of fertilization may be marginal in this environment (Stack and Fisher, 1992); nevertheless, sound nutrient management is essential to the viability of dryland cropping systems, particularly with MT and NT, given the often better water availability and higher C/N ratio compared to CT (Westfall et al., 1996).

Another confounding factor is the fact that winter wheat after fallow was planted earlier than wheat after a spring crop, except in the fall of 1999 and fall of 2002. We did this because we were more interested in comparing cropping systems than individual cropping practices. Ideally, separate experiments should be conducted to compare CT and MT with and without fertilizer addition and to compare Wheat-Fallow to other crop rotations by varying wheat planting date e.g., 15 Sept., 1 Oct., and 15 Oct.; to match field conditions.

Spring crops did poorly throughout the study period but particularly in 2000 and 2002. Corn appears to be a good crop in rotation with winter wheat and dry bean, for reasons yet to be determined. However, corn yields were low compared to other areas with similar annual precipitation amounts. The short growing season and rainfall distribution (low rainfall in May through mid-July) are not conducive to high corn yields. Producing corn for silage is probably a better alternative than producing corn for grain in the area. With little corn acreage in the project area, corn plots were easy targets for birds, rodents, and game.

Chickpeas did not do as well as expected in rotation with winter wheat. They were planted earlier than pinto beans but often matured later. Uniformity of chickpea seed maturity was a concern when emergence was non-uniform. Chickpeas performed well in other trials at Yellow Jacket but a number of challenges need to be addressed before they can be recommended for large-scale production in the project area (Berrada et al., 1999).

Safflowers produced around 800 lb/a in Wheat-Safflower-Bean in 2001 at Yellow Jacket and in Wheat-Safflower-Fallow in 2003 at Eastland. Safflower production potential in the project area is 1200 to 1500 lb/a with no irrigation. Chemical weed control (Treflan PPI) was beneficial to safflower at Yellow Jacket, but the net receipts per acre were negative (data not shown). Safflowers, because of their deep root system tend to deplete soil moisture more than other crops such as pinto beans or corn. Our data suggest that Wheat-Safflower-Fallow is preferable to Wheat-Safflower-Bean or Wheat-Safflower-Oat in the project area. Growing safflower and dry bean back-to-back on the same field is not recommended due to disease concerns such as bacterial blight, which infects both crops (Berglund et al., 1998).

Residual soil NO_3-N (from alfalfa) at Goodman Point was high, and could have sustained average wheat and bean production for a couple years. However, the combination of dried up soil profile at the end of the alfalfa production cycle (7 years) and below average precipitation in 2000 through 2003 was detrimental to crop production.

The alfalfa-based cropping system at Goodman Point merits more testing, for it offers a potentially viable system for organic bean production. Alfalfa is one of the major crops in the project area and provides several benefits: protection against soil erosion, N fixation, and soil quality enhancement. There is also a good market for alfalfa hay produced in southwestern Colorado, as well as for organically produced pinto beans and chickpeas.

The field trial at Goodman Point provided little information about the feasibility of the alfalfa-(3-yr) bean and alfalfa-(3-yr) chickpea rotations, due to drought. Disease infestation was minimal in either continuous bean or continuous chickpea. The producer has been practicing this system—7 years of alfalfa, followed by 3 or 4 years of pinto beans and 3 or 4 years of chickpeas—for many years and hasn't experienced any major pest problems.

The dry conditions that prevailed throughout the study period (2000-2003) did not allow for a meaningful evaluation of the economic feasibility of the cropping systems tested. There was also not enough time for the expression of the soil-climate-cropping systems interactions and their impact on soil fertility and pest dynamics in particular. A proposal to continue and expand this project is summarized in Appendix D.

Outreach in 2002-03

One workshop was organized on Feb. 20, 2002; in conjunction with the Southwestern Colorado Research Annual Advisory Committee meeting to discuss the project results to date and explore new avenues for research and education in the project area, such as organic farming and crop rotations involving a cover crop. A total of 34 people attended the workshop. The Principal Investigator (PI) later visited with several farmers and current and prospective project cooperators and made presentations at Soil Conservation District meetings in Monticello, UT and Dove Creek and Cortez, CO to discuss the SARE project and present a proposal for its continuation beyond 2003. Tours of the field trials and other outreach activities were planned for 2002 and 2003 but were cancelled due to drought (2002) and changes in programs and personnel at the Southwestern Colorado Research Center. A limited survey was conducted to find out more about cropping systems, challenges, and farming trends in the project area. This information along with the project and other research results was used in an oral presentation made by the PI at the ASA/CSSA/SSSA Annual Meetings in Indianapolis, IN on November 13, 2002. The production of a video featuring the SARE project was scheduled for the spring and summer of 2003 but was cancelled due to personnel changes at the Southwestern Colorado Research Center.

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Appendix A

Field Operation Records

Table A1. Field operations at Yellow Jacket from the fall of 2001 through the fall of 2003

Date	Treatment (Plot No.) / Operation	Date	Treatment (Plot No.) / Operation
1. CT **Wheat**-Fallow (114, 209, 302)		2. CT Wheat-**Fallow** (101, 220, 318)	
09-04-01	Disk	08-31-01	Field cultivate
11-04-01	Plow	09-12-01	Plant 'Fairview' wheat at 50 lb/a
04-11-02	Field cultivate	07-18-02	Harvest wheat
09-24-02	Field cultivate	09-24-02	Field cultivate
09-26-02	Plant 'Fairview' wheat at 50 lb/a	10-25-02	Plow
07-24-03	Harvest wheat	05-20-03	Field cultivate
08-19-03	Disk	06-23-03	Field cultivate
10-08-03	Disk	10-16-03	Field cultivate
Nov.'03	Plow	10-17-03	Plant 'Fairview' wheat at 50 lb/a
3. MT Wheat-**Fallow** (117, 204, 308)		4. MT **Wheat**-Fallow (110, 212, 314)	
09-11-01	Spray w/Roundup Max @ 26 oz/a + 2,4-D at 10 oz/a	09-11-01	Spray w/Roundup Max @ 26 oz/a + 2,4-D at 10 oz/a
05-07-02	Spray w/Roundup RT Master @ 20 oz/a	09-11-01	Fertilize w/N @ 40-50 lb/a + P_2O_5 @ 20 lb/a
09-26-02	Spray w/Roundup RT @ Master 20 oz/a	09-11-01	Field cultivate
09-26-02	Plant 'Fairview' wheat at 50 lb/a	09-12-01	Plant 'Fairview' wheat at 50 lb/a
07-24-03	Harvest wheat	07-18-02	Harvest wheat
10-08-03	Spray w/Roundup Max @ 24 oz/a	09-26-02	Spray w/Roundup RT Master @ 20 oz/a
		06-02-03	Spray w/Roundup Max @ 16 oz/a + 2,4-D @ 16 oz/a
		08-04-03	Spray w/Roundup Max @ 16 oz/a + 2,4-D @ 16 oz/a
		10-08-03	Spray w/Roundup Max @ 24 oz/a
		10-17-03	Plant 'Fairview' wheat at 50 lb/a
5. CT Wheat-**Bean** (111, 207, 320)		6. CT **Wheat**-Bean (106, 206, 303)	
09-04-01	Disk	10-11-01	Field cultivate
11-14-01	Plow	10-12-01	Plant 'Fairview' wheat at 50 lb/a
04-11-02	Field cultivate	04-05-02	Plant 'Sylvan' wheat @ 51 lb/a
06-06-02	Cultipacker	07-18-02	Harvest wheat
06-14-02	Plant 'Cahone' pinto beans @ 15.2 lb/a	09-24-02	Field cultivate
09-24-02	Field cultivate	10-25-02	Plow
09-26-02	Plant 'Fairview' wheat at 50 lb/a	06-02-03	Field cultivate
07-24-03	Harvest wheat	06-03-03	Plant 'Cahone' pinto beans @ 15.2 lb/a
08-19-03	Disk	06-26-03	Cultivate beans
10-08-03	Disk	09-16-03	Cut beans
Nov.'03	Plow	09-29-03	Thresh beans
		10-16-03	Field cultivate
		10-17-03	Plant 'Fairview' wheat at 50 lb/a
7. MT Wheat-**Bean** (103, 210, 315)		8. MT **Wheat**-Bean (113, 217, 317)	
09-11-01	Spray w/Roundup Max @ 26 oz/a + 2,4-D at 10 oz/a	10-11-01	Field cultivate
04-30-02	Field cultivate	10-12-01	Plant 'Fairview' wheat at 50 lb/a
06-14-02	Plant 'Cahone' pinto beans @ 15.2 lb/a	04-05-02	Plant 'Sylvan' wheat @ 51 lb/a
09-24-02	Field cultivate	07-18-02	Harvest wheat
09-26-02	Plant 'Fairview' wheat at 50 lb/a	09-24-02	Field cultivate
07-24-03	Harvest wheat	05-20-03	Field cultivate
10-08-03	Spray w/Roundup Max @ 24 oz/a	06-02-03	Field cultivate
		06-03-03	Plant 'Cahone' pinto beans @ 15.2 lb/a
		06-26-03	Cultivate beans
		09-16-03	Cut beans
		09-29-03	Thresh beans
		10-16-03	Field cultivate
		10-17-03	Plant 'Fairview' wheat at 50 lb/a

Table A1 (Continue)

Date	Treatment (Plot No.) / Operation	Date	Treatment (Plot No.) / Operation
9. MT Wheat-**Chickpea** (102, 218, 310)		10. MT **Wheat**-Chickpea (115, 214, 311)	
09-11-01	Spray w/Roundup Max @ 26 oz/a + 2,4-D at 10 oz/a	10-11-01	Field cultivate
04-30-02	Field cultivate	10-12-01	Plant 'Fairview' wheat at 50 lb/a
05-14-02	Fertilize w/N @ 20 lb/a + P_2O_5 @ 20 lb/a	04-05-02	Plant 'Sylvan' wheat @ 51 lb/a
05-14-02	Field cultivate	07-18-02	Harvest wheat
05-15-02	Plant 'Sanford' chickpea @ 36 lb/a	09-05-02	Field cultivate
09-24-02	Field cultivate	09-24-02	Field cultivate
09-26-02	Plant 'Fairview' wheat at 50 lb/a	04-28-03	Field cultivate
07-24-03	Harvest wheat	05-20-03	Field cultivate
10-08-03	Spray w/Roundup Max @ 24 oz/a	05-21-03	Plant 'Sanford' chickpea @ 41 lb/a
		05-22-03	Tooth harrow
		06-03-03	Field cultivate
		06-03-03	Re-plant chickpea @ 32.2 lb/a
		06-26-03	Cultivate
		10-01-03	Cut chickpeas
		10-14-03	Thresh chickpeas
		10-16-03	Field cultivate
		10-17-03	Plant 'Fairview' wheat @ 50 lb/a
11. MT **Wheat** -Safflower-Fallow (116, 202, 307)		12. MT Wheat-**Safflower**-Fallow (112, 216, 316)	
10-11-01	Field cultivate	09-11-01	Spray w/Roundup Max @ 26 oz/a + 2,4-D at 10 oz/a
10-12-01	Plant 'Fairview' wheat at 50 lb/a	04-11-02	Fertilize w/ N @ 29 lb/a
04-05-02	Plant 'Sylvan' wheat @ 51 lb/a	04-22-02	Spray Treflan @ 10 oz/a
07-18-02	Harvest wheat	04-22-02	Field cultivate
09-05-02	Field cultivate	05-07-02	Plant S-208 safflower @ 19 lb/a
09-24-02	Field cultivate	09-24-02	Field cultivate
04-28-03	Field cultivate	04-28-03	Field cultivate
04-29-03	Plant S-208 safflower @ 19 lb/a	05-20-03	Field cultivate
04-29-03	Harvest safflower	06-23-03	Field cultivate
10-08-03	Spray w/Roundup Max @ 24 oz/a	08-04-03	Spray w/Roundup Max @ 16 oz/a + 2,4-D at 16 oz/a
		10-16-03	Field cultivate
		10-17-03	Plant 'Fairview' wheat @ 50 lb/a
13. MT Wheat-Safflower-Fallow (**Oat**) (104, 219, 313)		14. MT **Wheat**-Safflower-Bean (109, 208, 305)	
04-11-02	Fertilize w/N @ 20 lb/a	10-11-01	Field cultivate
04-11-02	Spray Roundup RT Master @ 20 oz/a	10-12-01	Plant 'Fairview' wheat at 50 lb/a
04-12-02	Field cultivate	04-5-02	Plant 'Sylvan' wheat @ 51 lb/a
04-12-02	Plant 'Monida' oat at 44 lb/a	07-18-02	Harvest wheat
08-06-02	Disk	09-24-02	Field cultivate
09-24-02	Field cultivate	04-28-03	Field cultivate
09-26-02	Plant 'Fairview' wheat at 50 lb/a	04-29-03	Plant S-208 safflower @ 19 lb/a
07-24-03	Harvest wheat	09-24-03	Harvest safflower
10-08-03	Spray w/Roundup Max @ 24 oz/a	10-08-03	Spray w/Roundup Max @ 24 oz/a

Table A1 (Continued)

Date	Treatment (Plot No.) / Operation	Date	Treatment (Plot No.) / Operation
15. MT Wheat-**Safflower**-Bean (118, 205, 309)		16. MT Wheat-Safflower-**Bean** (107, 211, 312)	
09-11-01	Spray w/Roundup Max @ 26 oz/a + 2,4-D at 10 oz/a	04-30-02	Field cultivate
04-11-02	Fertilize w/N @ 29 lb/a	06-14-02	Plant 'Cahone' pinto beans @ 15.2 lb/a
04-11-02	Spray Roundup RT Master @ 20 oz/a	09-24-02	Field cultivate
04-12-02	Field cultivate	09-26-02	Plant 'Fairview' wheat @ 50 lb/a
05-07-02	Plant S-208 safflower @ 22.5 lb/a	07-24-03	Harvest wheat
09-5-02	Field cultivate	10-08-03	Spray w/Roundup Max @ 24 oz/a
09-24-02	Field cultivate		
06-02-03	Field cultivate		
06-03-03	Plant 'Cahone' pinto beans @ 15.2 lb/a		
06-26-03	Cultivate beans		
09-16-03	Cut beans		
09-29-03	Thresh beans		
10-16-03	Field cultivate		
10-17-03	Plant 'Fairview' wheat at 50 lb/a		
17. Alfalfa (120, 213, 306)		18. MT **Wheat**-Corn-Bean (105, 203, 301)	
04-15-02	Spring tooth harrow	10-11-01	Field cultivate
09-05-02	Mow	10-12-01	Plant 'Fairview' wheat at 50 lb/a
06-12-03	Cut	04-05-02	Plant 'Sylvan' wheat @ 51 lb/a
06-17-03	Bale	07-18-02	Harvest wheat
		09-24-02	Field cultivate
		04-28-03	Field cultivate
		05-20-03	Field cultivate
		05-22-03	Plant SX 115 corn @ 13.8 lb/a
		05-22-03	Spring tooth harrow
		06-28-03	Cultivate corn
		10-15-03	Harvest corn
		10-20-03	Spray w/Roundup max @ 24 oz/a
19. MT Wheat-**Corn**-Bean (108, 215, 319)		20. MT Wheat-Corn-**Bean** (119, 201, 304)	
09-11-01	Spray w/Roundup Max @ 26 oz/a + 2,4-D at 10 oz/a	04-30-02	Field cultivate
04-30-02	Field cultivate	06-14-02	Plant 'Cahone' pinto beans @ 15.2 lb/a
05-14-02	Fertilize w/N @ 20-40 lb/a + P_2O_5 @ 20 lb/a	09-24-02	Field cultivate
05-14-02	Field cultivate	09-26-02	Plant 'Fairview' wheat at 50 lb/a
05-15-02	Plant SX 115 corn @ 13.8 lb/a	07-24-03	Harvest wheat
09-05-02	Mow	10-08-03	Spray w/Roundup Max @ 24 oz/a
09-24-02	Field cultivate	**Notes**	• Fairview is hard red winter wheat
04-28-03	Field cultivate		• Sylvan is hard red spring wheat
06-02-03	Field cultivate		• Wheat planted in the fall of 2001 in reps I and II failed except in the Wheat-Fallow rotation and was consequently re-seeded in the spring of 2002.
06-03-03	Plant 'Cahone' pinto beans @ 15.2 lb/a		• Roundup RT (Master) was mixed with Sticker spreader at 10 oz/a and ammonium sulfate at 2 lb/a.
06-26-03	Cultivate beans		• The whole plot area was sprayed with Mustang at 3.0 oz/a on 19 Feb. 2003 to control army cutworm.
09-16-03	Cut beans		• Bean, chickpea, and corn plots were hoed on 24-25 July 2003.
09-29-03	Thresh beans		
10-16-03	Field cultivate		
10-17-03	Plant 'Fairview' wheat at 50 lb/a		

Table A2. Field operations at Eastland from the fall of 2001 through the fall of 2003

Date	Treatment (Plot No.) / Operation	Date	Treatment (Plot No.) / Operation
	1. CT **Wheat**-Fallow (110, 203)		2. CT Wheat-**Fallow** (103, 205)
9-13-01	Field Cultivate	09-04-01	Disk
9-14-01	Plant 'Fairview' wheat at 55 lb/a	11-14-01	Plow
9-26-01	Re-plant 'Fairview' wheat at 55 lb/a	04-16-02	Field cultivate
10-11-01	Re-plant 'Fairview' wheat at 68 lb/a	07-08-02	Field cultivate
07-19-02	Harvest wheat	08-03-02	Field cultivate
08-13-02	Disk	09-19-02	Field cultivate
10-15-02	Plow	09-20-02	Plant 'Fairview' wheat @ 75 lb/a
05-13-03	Field Cultivate	08-01-03	Harvest wheat
06-05-03	Field Cultivate		
	3. MT **Wheat**-Fallow (101, 210)		4. MT Wheat-**Fallow** (116, 212)
9-10-01	Fertilize w/N @ 50 lb/a + P_2O_5 @ 20 lb/a	08-24-01	Spray Roundup Max @ 32 oz/a + 2,4-D @ 10 oz/a
9-13-01	Field Cultivate		
9-14-01	Plant 'Fairview' wheat at 55 lb/a	04-24-02	Spray Roundup RT Master @ 20 oz/a
9-26-01	Re-plant 'Fairview' wheat at 55 lb/a	07-08-02	Field cultivate
10-11-01	Re-plant 'Fairview' wheat at 68 lb/a	08-03-02	Field cultivate
07-19-02	Harvest wheat	09-19-02	Field cultivate
08-13-02	Disk	09-20-02	Plant 'Fairview' wheat @ 75 lb/a
09-19-02	Field cultivate	08-01-03	Harvest wheat
05-13-03	Field Cultivate		
06-05-03	Field Cultivate		
	5. CT **Wheat**-Bean (114, 209)		6. CT Wheat-**Bean** (115, 202)
10-9-01	Fertilize	08-24-01	Spray Roundup Max @ 32 oz/a + 2,4-D @ 10 oz/a
10-10-01	Field Cultivate		
10-11-01	Plant 'Fairview' wheat at 68 lb/a	04-16-02	Field cultivate
07-19-02	Harvest wheat	06-11-02	Plant 'Cahone' pinto beans @ 20 lb/a
08-13-02	Disk	08-03-02	Field cultivate. Beans worked under.
10-15-02	Plow	09-19-02	Field cultivate
05-13-03	Field Cultivate	09-20-02	Plant 'Fairview' wheat @ 75 lb/a
06-05-03	Field Cultivate	08-01-03	Harvest wheat
06-07-03	Plant 'Cahone' pinto beans @ 20 lb/a		
	Cultivate beans		
09-24-03	Cut beans		
10-20-03	Thresh beans		
	7. MT **Wheat**-Bean (107, 215)		8. MT Wheat-**Bean** (112, 213)
10-9-01	Fertilize	08-24-01	Spray Roundup Max @ 1 qt/a + 2,4-D @ 10 oz/a
10-10-01	Field Cultivate		
10-11-01	Plant 'Fairview' wheat at 68 lb/a	04-23-02	Spray Roundup RT Master @ 20 oz/a
07-19-02	Harvest wheat	06-11-02	Plant 'Cahone' pinto beans @ 20 lb/a
08-13-02	Disk	08-03-02	Field cultivate. Beans worked under.
09-27-02	Spray Roundup RT Master @ 20 oz/a	09-19-02	Field cultivate
05-13-03	Field Cultivate	09-20-02	Plant 'Fairview' wheat @ 75 lb/a
06-05-03	Field Cultivate	08-01-03	Harvest wheat
06-07-03	Plant 'Cahone' pinto beans @ 20 lb/a		
	Cultivate beans		
09-24-03	Cut beans		
10-20-03	Thresh beans		

Notes:

1. The highlighted crop (fallow) represents the 2002 treatment.
2. The whole plot area was sprayed with Mustang at 3.0 oz/a on 31 March and 14 Apr. 2003 to control army cutworm.

Table A2 (Continued)

Date	Treatment (Plot No.) / Operation	Date	Treatment (Plot No.) / Operation
9. MT Wheat -Safflower-**Fallow** (109, 214)		10. MT **Wheat**-Safflower-Fallow (108, 208)	
10-01-01	Harvest safflower	9-10-01	Fertilize w/N @ 40 lb/a + P_2O_5 @ 25 lb/a
04-24-02	Spray Roundup RT Master @ 20 oz/a	9-13-01	Field Cultivate
08-03-02	Field cultivate	9-14-01	Plant 'Fairview' wheat at 55 lb/a
09-19-02	Field cultivate	9-26-01	Re-plant 'Fairview' wheat at 55 lb/a
09-20-02	Plant 'Fairview' wheat @ 75 lb/a	10-11-01	Re-plant 'Fairview' wheat at 68 lb/a
08-01-03	Harvest wheat	07-19-02	Harvest wheat
		08-13-02	Disk
		09-19-02	Field cultivate
		05-13-03	Field cultivate
		05-16-03	Plant safflower @ 15 lb/a
		09-27-03	Harvest safflower
11. MT Wheat-**Safflower**-Fallow (102, 211)		12. MT Triticale-Corn-**Safflower** (105, 206)	
08-07-01	Harvest wheat	09-12-01	Corn chopped for silage
04-16-02	Field cultivate	04-16-02	Field cultivate
05-06-02	Fertilize w/N @ 25 lb/a + P_2O_5 @ 20 lb/a	05-06-02	Fertilize w/N @ 10 & 20 lb/a + P_2O_5 @ 20 lb/a
05-06-02	Plant safflower @ 15 lb/a		
10-15-02	Safflower disked under	05-06-02	Plant safflower @ 15 lb/a
05-13-03	Field cultivate	09-27-02	Field cultivate
06-05-03	Field cultivate	09-27-02	Plant 'Presto' triticale @ 51 lb/a
		08-01-03	Harvest triticale
13. MT **Triticale**-Corn-Safflower (104, 216)		14. MT Triticale-**Corn**-Safflower (106, 207)	
10-9-01	Fertilize w/P_2O_5 @ 22 lb/a (Rep I)	04-23-01	Spray Roundup RT Master @ 20 oz/a
10-10-01	Field Cultivate	05-10-02	Fertilize wN @ 10 & 40 lb/a + P_2O_5 @ 20 lb/a
10-11-01	Plant 'Presto' winter triticale at 50 lb/a	05-14-02	Field cultivate
07-19-02	Harvest triticale	05-22-02	Plant SX 1145 corn hybrid @ 20 lb/a
08-13-02	Disk	June '02	Cultivate corn
05-13-03	Field cultivate	10-15-02	Disk
05-30-03	Plant SX 1145 corn hybrid @ 20 lb/a	05-13-03	Field cultivate
10-01-03	Chop corn	05-16-03	Plant safflower @ 15 lb/a
		09-27-03	Harvest safflower
15. MT Triticale-**Bean** (111, 201)		16. MT **Triticale**-Bean (113, 204)	
08-24-01	Spray Roundup Max @ 1 qt/a + 2,4-D @ 10 oz/a	10-9-01	Fertilize w/N @ 44 lb/a + P_2O_5 @ 22 lb/a
		10-10-01	Field Cultivate
04-23-02	Spray Roundup RT Master @ 20 oz/a	10-11-01	Plant 'Presto' winter triticale at 50 lb/a
06-05-02	Spray Roundup RT Master @ 20 oz/a	07-19-02	Harvest triticale
06-11-02	Plant 'Cahone' pinto beans @ 20 lb/a	08-13-02	Disk
08-03-02	Field cultivate. Worked beans under.	09-19-02	Field cultivate
09-19-02	Field cultivate	05-13-03	Field Cultivate
09-27-02	Plant 'Presto' winter triticale @ 51 lb/a	06-05-03	Field Cultivate
08-01-03	Harvest triticale	06-07-03	Plant 'Cahone' pinto beans @ 20 lb/a
		July '03	Cultivate beans
		09-24-03	Cut beans
		10-20-03	Thresh beans

Notes (continued):

3. Roundup RT Master was mixed with Sticker spreader at 10 oz/a and ammonium sulfate at 2 lb/a.
4. Plots that were in wheat or triticale in 2003 were disked by early September. Once all the crops were harvested, the whole plot area was disked and plowed. The Eastland trial was terminated at the end of the cropping season in 2003.
5. The safflower plots were hoed in late June to early July; the bean plots (plots 111, 112, and 115) in mid-July, and corn (plot 104) in early August.

Table A3. Field operations at Goodman Point from the fall of 2001 through the fall of 2003

Crop rotations:

1. Continuous pinto bean cropping
2. Continuous chickpea cropping
3. Pinto bean – winter wheat rotation
4. Chickpea – winter wheat rotation

Crop (crop rotation no.)	Date	Operation
Pinto bean (1, 3)	09-28-01	Threshed beans
	04-15-02	Worked bean and chickpea plots with the field cultivator.
	05-20-02	Worked bean and chickpea plots with the field cultivator.
	06-01-02	Planted 'Cahone' pinto beans at about 15 lb/a
	Fall '02	No harvest in 2002
	May '03	Worked bean and chickpea plots with the field cultivator.
	06-04-03	Planted 'Cahone' pinto beans at about 15 lb/a
	07-21-03	Cultivated bean plots
	09-26-03	Cut beans
	10-20-03	Threshed beans
Chickpea (2, 4)	09-28-01	Threshed chickpeas
	04-15-02	Worked bean and chickpea plots with the field cultivator.
	05-20-02	Worked bean and chickpea plots with the field cultivator.
	Fall '02	Planted 'Sanford' chickpeas at about 30 lb/a
	05-23-02	No harvest in 2002
	May '03	Worked bean and chickpea plots with the field cultivator.
	05-25-03	Planted 'Sanford' chickpeas at 20 to 30 lb/a
	07-21-03	Cultivated bean plots
	09-26-03	Cut beans
	10-20-03	Threshed chickpeas
Winter wheat (3, 4)	09-14-01	Disked wheat plots
	10-11-01	Planted 'Fairview' winter wheat at 50 to 60 lb/a
	07-26-02	Harvested wheat
	10-02-02	Planted 'Fairview' wheat after pinto bean or chickpea
	08-07-03	Harvested wheat
	08-27-03	Disked wheat plots

Notes:

1. All the plots were plowed on 9 July 2002, except the ones that were to be planted to wheat in the fall of 2002.
2. The wheat plots were sprayed with Mustang at 3.0 oz/a on 22 March 2003 to control army cutworm. Damage was already extensive.
3. Bean and chickpea plots were hoed once in July 2003.

Appendix B

Soil Test Results

Table B1. Soil test results at Yellow Jacket in the fall of 2001 and 2002*

Cropping system	Sampling date	NO_3-N ppm	AB-DTPA P (ppm)
CT Wheat-Fallow	Fall '01	13.3	4.0
	Fall '02	9.3	4.3
MT Wheat-Fallow	Fall '01	9.7	3.9
	Fall '02	7.3	4.7
CT Wheat-Bean	Fall '01	6.3	4.5
	Fall '02	14.7	4.9
MT Wheat-Bean	Fall '01	15.0	6.2
	Fall '02	12.7	5.0
MT Wheat-Chickpea	Fall '01	17.3	8.6
	Fall '02	16.0	5.0
MT Wheat-Safflower-Fallow	Fall '01	12.0	5.3
	Fall '02	22.7!	5.1
MT Wheat-Safflower-Bean	Fall '01	7.3	5.6
	Fall '02	14.7	5.7
MT Wheat-Corn-Bean	Fall '01	8.0	6.9
	Fall '02	17.0	4.2

* Treatments to be planted to winter wheat. Sampling depth: 0-12 in.

Table B2. Soil test results at Eastland in the fall of 2001 and 2002*

Cropping system	Sampling date	NO_3-N ppm	AB-DTPA P (ppm)
CT Wheat-Fallow	Fall '01	5.5 (2.5)**	0.9
	Fall '02	5.0	3.4
MT Wheat-Fallow	Fall '01	6.5 (3.0)	1.1
	Fall '02	8.0	3.6
CT Wheat-Bean	Fall '01	3.5	0.6
	Fall '02	10.5	3.3
MT Wheat-Bean	Fall '01	7.0	1.2
	Fall '02	11.5	5.0
MT Wheat-Safflower-Fallow	Fall '01	9.5 (8.5)	1.6
	Fall '02	12.0	3.5
MT Triticale-Corn-Safflower	Fall '01	?	7.0
	Fall '02	11.5	3.2
MT Triticale-Bean	Fall '01	9.5	1.6
	Fall '02	8.0	2.9

* Treatments to be planted to winter wheat. Sampling depth: 0-12 in.
** Number in parenthesis: Soil NO_3-N test level at the 12- to 24 in. depth

Table B3. Soil test results at Goodman Point in 2001-2003*

Cropping system	Sampling date	NO_3-N ppm	AB-DTPA P (ppm)	Zn ppm
Continuous Bean	Spring '02	22.0	5.1	0.5
	Spring '03	3.5 (6.5)**	4.3	0.5
Continuous Chickpea	Spring '02	21.2	4.0	0.3
	Spring '03	3.0 (4.0)	4.0	0.3
Wheat-Bean				
Wheat	Fall '01	25.0	4.1	-
	Fall '02	22.5	5.3	-
Bean	Spring '02	16.5	5.6	0.5
	Spring '03	3.5 (4.0)	4.0	0.5
Wheat-Chickpea				
Wheat	Fall '01	21.0	4.7	-
	Fall '02	24.0	4.2	-
Chickpea	Spring '02	20.0	3.5	0.3
	Spring '03	3.0 (5.0)	4.4	0.3

* Sampling depth: 0-12 in.

** Number in parenthesis: Soil NO_3-N test level at the 12- to 24 in. depth

Table B4. Soil test results at Yellow Jacket in the spring of 2002 and 2003*

Cropping system	Sampling date	NO_3-N ppm	AB-DTPA P (ppm)	Zn ppm
CT Wheat-**Bean**	Spring '02	8.3[1]	5.3[1]	0.2[1]
	Spring '03	3.7 (4.0)**	4.6	0.5
MT Wheat-**Bean**	Spring '02	10.5	5.0	0.6
	Spring '03	2.7 (2.7)	5.8	1.8!
MT Wheat-**Chickpea**	Spring '02	9.7	4.2	0.4
	Spring '03	2.0 (3.7)	5.4	0.6
MT Wheat-Safflower-Fallow				
Safflower	Spring '02	12.0	4.8	-
Safflower	Spring '03	2.0 (4.3)	4.6	0.4
MT Wheat-Safflower-Bean				
Safflower	Spring '02	8.3	4.7	-
	Spring '03	1.7 (3.3)	4.6	0.6
Bean	Spring '02	12.7	5.3	0.6
	Spring '03	2.3 (2.7)	5.0	0.5
MT Wheat-Corn-Bean				
Corn	Spring '02	7.5	5.2	-
	Spring '03	3.3 (3.3)	4.6	0.7
Bean	Spring '02	14.7	4.0	0.6
	Spring '03	3.0 (4.0)	5.8	0.9

* Sampling depth: 0-12 in. except where indicated ([1] 0 to 6 in.)
** Number in parenthesis: Soil NO_3-N test level at the 12- to 24 in. depth

Table B5. Soil test results at Eastland in the spring of 2002 and 2003*

Cropping system	Sampling date	NO3-N ppm	AB-DTPA P (ppm)	Zn ppm
CT Wheat-Bean				
	Spring '02	7.8	3.3	0.1
	Spring '03	2.0 (2.5)**	4.8	0.2
MT Wheat-Bean				
	Spring '02	9.0	5.8	0.2
	Spring '03	2.5 (9.5)	3.7	0.6
MT Wheat-Safflower-Fallow				
Safflower	Spring '02	6.5	5.6	-
Safflower	Spring '03	2.0 (6.5)	3.7	0.3
MT Triticale-Corn-Safflower				
Corn	Spring '02	9.5	3.9	-
	Spring '03	2.0 (4.0)	4.0	0.3
Safflower	Spring '02	10.0	4.6	-
	Spring '03	2.0 (8.5)	4.5	0.3
MT Triticale-Bean				
Bean	Spring '02	9.8	3.4	0.1
	Spring '03	2.5 (4.0)	6.0	0.6

* Sampling depth: 0-12 in.
** Number in parenthesis: Soil NO_3-N level at the 12- to 24 in. depth

Table B6. Soil test results at Yellow Jacket in December 2003*

Cropping System	Depth In.	pH	Sol Salts dS/m	O.M. %	NO3-N ppm	AB-DTPA P (ppm)	K ppm	Zn ppm	S ppm
CT Wheat-Fallow									
Wheat	0-6	7.2	0.2	1.0	3.3	4.5	185	0.3	3.7
	6-12	7.3	0.2	0.9	2.7	2.8	172	0.3	3.0
	12-24				1.3	0.6			
	Average	**7.3**	**0.2**	**0.9**	**2.4**	**2.6**	**179**	**0.3**	**3.3**
Fallow	0-6	6.9	0.3	1.0	19.0	5.1	186	0.3	5.3
	6-12	6.9	0.2	0.9	12.0	3.1	172	0.2	4.0
	12-24				4.3	0.5			
	Average	**6.9**	**0.3**	**0.9**	**11.8**	**2.9**	**179**	**0.3**	**4.7**
MT Wheat-Fallow									
Wheat	0-6	7.2	0.2	1.0	3.3	5.0	183	0.3	4.0
	6-12	7.1	0.2	0.8	3.7	3.1	154	0.2	4.0
	12-24				1.3	0.5			
	Average	**7.2**	**0.2**	**0.9**	**2.8**	**2.9**	**169**	**0.3**	**4.0**
Fallow	0-6	7.1	0.2	1.0	11.3	5.5	191	0.2	3.7
	6-12	7.0	0.2	0.8	7.0	3.9	158	0.2	2.7
	12-24				4.7	0.6			
	Average	**7.1**	**0.2**	**0.9**	**7.7**	**3.3**	**175**	**0.2**	**3.2**
CT Wheat-Bean									
Wheat	0-6	7.1	0.2	1.0	4.3	5.2	189	0.3	4.3
	6-12	7.2	0.2	0.9	2.3	3.1	169	0.2	3.3
	12-24				2.0	0.6			
	Average	**7.2**	**0.2**	**1.0**	**2.9**	**3.0**	**179**	**0.2**	**3.8**
Bean	0-6	7.0	0.2	0.9	14.7	5.3	186	0.6	4.0
	6-12	7.1	0.2	0.8	8.0	2.8	168	0.4	3.3
	12-24				4.3	0.5			
	Average	**7.1**	**0.2**	**0.9**	**9.0**	**2.9**	**177**	**0.5**	**3.7**
MT Wheat-Bean									
Wheat	0-6	7.1	0.2	1.0	4.0	6.3	192	0.8	2.7
	6-12	7.0	0.2	0.9	4.0	4.3	165	0.3	3.3
	12-24				2.0	0.5			
	Average	**7.1**	**0.2**	**1.0**	**3.3**	**3.7**	**178**	**0.6**	**3.0**
Bean	0-6	7.0	0.2	1.1	12.0	7.4	186	2.0	4.7
	6-12	6.9	0.2	0.9	6.0	2.9	157	0.3	2.3
	12-24				5.0	0.5			
	Average	**7.0**	**0.2**	**1.0**	**7.7**	**3.6**	**171**	**1.2**	**3.5**
MT Wheat-Chickpea									
Wheat	0-6	7.0	0.2	0.9	12.0	6.4	187	0.7	4.3
	6-12	7.1	0.2	0.9	7.0	3.1	148	0.3	2.7
	12-24				1.7	0.7			
	Average	**7.0**	**0.2**	**0.9**	**6.9**	**3.4**	**168**	**0.5**	**3.5**

Table B6 (Continued)

Cropping System	Depth In.	pH	Sol Salts dS/m	O.M. %	NO3-N ppm	AB-DTPA P (ppm)	K ppm	Zn ppm	S ppm
MT Wheat-Safflower-Fallow									
Safflower	0-6	7.0	0.2	1.0	9.0	5.8	191	0.4	4.7
	6-12	7.1	0.2	0.8	7.7	2.9	155	0.2	3.0
	12-24				3.0	0.6			
	Average	**7.0**	**0.2**	**0.9**	**6.6**	**3.1**	**173**	**0.3**	**3.8**
Fallow	0-6	7.0	0.2	1.1	14.0	5.9	189	0.4	4.7
	6-12	7.1	0.2	0.9	7.7	2.4	160	0.2	3.3
	12-24				8.0	0.5			
	Average	**7.1**	**0.2**	**1.0**	**9.9**	**2.9**	**175**	**0.3**	**4.0**
Wheat	0-6	7.0	0.2	1.1	3.3	7.1	202	0.3	3.3
	6-12	7.0	0.2	0.9	3.3	3.7	154	0.2	3.3
	12-24				2.7	0.6			
	Average	**7.0**	**0.2**	**1.0**	**3.1**	**3.8**	**178**	**0.3**	**3.3**
MT Wheat-Safflower-Bean									
Wheat	0-6	7.0	0.2	1.0	13.3	6.3	187	0.7	5.0
	6-12	7.1	0.2	0.8	7.0	2.8	153	0.3	4.0
	12-24				3.7	0.5			
	Average	**7.1**	**0.2**	**0.9**	**8.0**	**3.2**	**170**	**0.5**	**4.5**
Alfalfa									
Alfalfa	0-6	7.3	0.3	1.0	9.3	3.9	191	0.2	5.3
	6-12	7.2	0.2	0.9	2.3	2.4	156	0.2	3.0
	12-24				1.3	0.6			
	Average	**7.3**	**0.2**	**1.0**	**4.3**	**2.3**	**173**	**0.2**	**4.2**
MT Wheat-Corn-Bean									
Corn	0-6	6.9	0.2	1.0	10.0	7.2	195	1.1	4.3
	6-12	7.0	0.2	0.9	6.0	2.9	160	0.2	3.7
	12-24				3.7	0.5			
	Average	**7.0**	**0.2**	**0.9**	**6.6**	**3.5**	**177**	**0.6**	**4.0**
Bean	0-6	6.8	0.2	1.1	13.0	8.7	198	0.6	4.7
	6-12	7.0	0.2	0.9	5.0	2.9	156	0.2	4.0
	12-24				4.3	0.5			
	Average	**6.9**	**0.2**	**1.0**	**7.4**	**4.0**	**177**	**0.4**	**4.3**
Wheat	0-6	7.2	0.2	0.9	3.7	5.4	182	0.7	4.0
	6-12	7.2	0.1	0.7	3.0	1.9	154	0.1	4.0
	12-24				1.7	0.5			
	Average	**7.2**	**0.2**	**0.8**	**2.8**	**2.6**	**168**	**0.4**	**4.0**

* Sampling depth: 0-12 in.

Appendix C

Soil Moisture Measurements

Table C1. Gravimetric soil moisture prior to winter wheat planting at Yellow Jacket in 2001 and 2002

Cropping system	Soil depth (ft.)	Sampling date	Soil water content by weight (%)	Available soil water* (in.)	Sampling date	Soil water content by weight (%)	Available soil water* (in.)
CT	0-1	09/05/01	15.5	0.8	09/24/02	14.5	0.6
Wheat-	1-2	09/05/01	17.1	0.4	09/24/02	11.0	0.0
Fallow	2-3	09/05/01	15.3	0.6	09/24/02	10.0	0.0
	3-4	09/05/01	13.6	0.2	09/24/02	11.7	0.0
Average			**15.4**	**2.0**		**11.8**	**0.6**
MT	0-1	09/05/01	14.3	0.5	09/24/02	16.6	0.9
Wheat-	1-2	09/05/01	17.8	0.6	09/24/02	15.8	0.2
Fallow	2-3	09/05/01	17.3	0.9	09/24/02	10.9	0.0
	3-4	09/05/01	17.3	0.9	09/24/02	.	.
Average			**16.6**	**2.9**		**14.4**	**1.1**
CT	0-1	10/02/01	8.8	0.0	09/24/02	12.7	0.3
Wheat-	1-2	10/02/01	12.3	0.0	09/24/02	11.1	0.0
Bean	2-3	10/02/01	13.8	0.3	09/24/02	12.1	0.0
	3-4	10/02/01	15.6	0.6	09/24/02	13.7	0.3
Average			**12.6**	**0.9**		**12.4**	**0.6**
MT	0-1	10/02/01	9.3	0.0	09/24/02	14.4	0.6
Wheat-	1-2	10/02/01	14.0	0.0	09/24/02	12.1	0.0
Bean	2-3	10/02/01	15.0	0.5	09/24/02	11.3	0.0
	3-4	10/02/01	15.5	0.6	09/24/02	13.0	0.1
Average			**13.5**	**1.1**		**12.7**	**0.7**
MT	0-1	10/08/01	7.1	0.0	09/24/02	14.0	0.5
Wheat-	1-2	10/08/01	10.1	0.0	09/24/02	10.8	0.0
Chickpea	2-3	10/08/01	10.9	0.0	09/24/02	10.2	0.0
	3-4	10/08/01	13.0	0.2	09/24/02	11.3	0.0
Average			**10.3**	**0.2**		**11.6**	**0.5**
MT	0-1	10/02/01	7.1	0.0	09/24/02	12.5	0.3
Wheat-	1-2	10/02/01	10.3	0.0	09/24/02	9.9	0.0
Safflower-	2-3	10/02/01	-	-	09/24/02	-	-
Fallow (oat)	3-4	10/02/01	-	-	09/24/02	-	-
Average			**8.7**	**0.0**		**11.2**	**0.3**
MT	0-1	10/02/01	8.8	0.0	09/24/02	13.1	0.3
Wheat-	1-2	10/02/01	12.3	0.0	09/24/02	10.7	0.0
Safflower-	2-3	10/02/01	10.4	0.0	09/24/02	10.2	0.0
Bean	3-4	10/02/01	10.6	0.0	09/24/02	8.4	0.0
Average			**10.5**	**0.0**		**10.6**	**0.3**
MT	0-1	10/02/01	10.0	0.0	09/24/02	15.0	0.7
Wheat-	1-2	10/02/01	14.6	0.0	09/24/02	13.7	0.0
Corn-	2-3	10/02/01	14.5	0.4	09/24/02	12.9	0.1
Bean	3-4	10/02/01	16.3	0.7	09/24/02	14.3	0.4
Average			**13.8**	**1.1**		**14.0**	**1.2**

* If the calculated available soil water content (AW) is a negative number, AW is set to zero.

Table C2. Gravimetric soil moisture prior to winter wheat planting at Eastland in 2001 and 2002

Cropping system	Soil depth (ft.)	Sampling date	Soil water content by weight (%)	Available soil water* (in.)	Sampling date	Soil water content by weight (%)	Available soil water* (in.)
CT	0-1	09/05/01	14.3	0.5	09/19/02	10.4	0.0
Wheat-	1-2	09/05/01	14.4	0.4	09/19/02	11.3	0.0
Fallow	2-3	09/05/01	13.8	0.1	09/19/02	12.3	0.0
	3-4	09/05/01	14.6	0.2	09/19/02	14.5	0.2
Average			**14.3**	**1.2**		**12.1**	**0.2**
MT	0-1	09/05/01	13.2	0.4	09/19/02	11.9	0.1
Wheat-	1-2	09/05/01	15.3	0.6	09/19/02	13.2	0.2
Fallow	2-3	09/05/01	15.4	0.4	09/19/02	13.6	0.1
	3-4	09/05/01	14.8	0.2	09/19/02	13.4	0.0
Average			**14.7**	**1.5**		**13.0**	**0.4**
CT	0-1	10/03/01	9.2	0.0	09/19/02	11.1	0.0
Wheat-	1-2	10/03/01	9.4	0.0	09/19/02	12.8	0.1
Bean	2-3	10/03/01	11.3	0.0	09/19/02	14.6	0.3
	3-4	10/03/01	12.5	0.0	09/19/02	16.3	0.5
Average			**10.6**	**0.0**		**13.7**	**0.9**
MT	0-1	10/03/01	10.0	0.0	09/19/02	10.0	0.0
Wheat-	1-2	10/03/01	11.5	0.0	09/19/02	10.7	0.0
Bean	2-3	10/03/01	13.4	0.1	09/19/02	11.8	0.0
	3-4	10/03/01	13.8	0.0	09/19/02	11.5	0.0
Average			**12.2**	**0.1**		**11.0**	**0.0**
MT	0-1	09/05/01	14.6	0.6	09/19/02	10.4	0.0
Wheat-	1-2	09/05/01	16.0	0.7	09/19/02	9.3	0.0
Safflower-	2-3	09/05/01	16.5	0.6	09/19/02	9.8	0.0
Fallow	3-4	09/05/01	16.4	0.5	09/19/02	10.1	0.0
Average			**15.9**	**2.4**		**9.9**	**0.0**
MT	0-1	10/03/01	8.3	0.0	09/19/02	9.6	0.0
Triticale-	1-2	10/03/01	9.6	0.0	09/19/02	9.7	0.0
Corn-	2-3	10/03/01	-	-	09/19/02	10.8	0.0
Safflower	3-4	10/03/01	-	-	09/19/02	11.9	0.0
Average			**9.0**	**0.0**		**10.5**	**0.0**
MT	0-1	10/03/01	8.7	0.0	09/19/02	10.8	0.0
Triticale-	1-2	10/03/01	10.1	0.0	09/19/02	12.0	0.0
Bean	2-3	10/03/01	10.9	0.0	09/19/02	11.5	0.0
	3-4	10/03/01	13.2	0.0	09/19/02	13.1	0.0
Average			**10.7**	**0.0**		**11.8**	**0.0**

* If the calculated available soil water content (AW) is a negative number, AW is set to zero.

Table C3. Gravimetric soil moisture prior to spring crop planting at Yellow Jacket in 2002 and 2003¶

Cropping system (**crop**)	Soil depth (ft.)	Sampling date	Soil water content by weight (%)	Available soil water* (in.)	Sampling date	Soil water content by weight (%)	Available soil water* (in.)
CT	0-1	05/31/02	9.0	0.0	05/30/03	17.4	1.1
Wheat-	1-2	05/31/02	11.6	0.0	05/30/03	18.2	0.6
Bean	2-3	05/31/02	13.8	0.3	05/30/03	17.6	1.0
	3-4	05/31/02	12.7	0.1	05/30/03	17.1	0.9
Average			**11.8**	**0.4**		**17.6**	**3.6**
MT	0-1	05/31/02	12.3	0.2	05/30/03	15.9	0.8
Wheat-	1-2	05/31/02	11.2	0.0	05/30/03	18.3	0.6
Bean	2-3	05/31/02	12.0	0.0	05/30/03	17.2	0.9
	3-4	05/31/02	11.0	0.0	05/30/03	17.1	0.9
Average			**11.7**	**0.2**		**17.1**	**3.3**
MT	0-1	05/09/02	13.3	0.4	04/25/03	16.4	0.9
Wheat-	1-2	05/09/02	10.9	0.0	04/25/03	18.3	0.6
Chickpea	2-3	05/09/02	-	-	04/25/03	17.7	1.0
	3-4	05/09/02	-	-	04/25/03	16.1	0.7
Average			**12.1**	**0.4**		**17.1**	**3.3**
MT	0-1	04/09/02	12.8	0.3	04/25/03	17.2	1.0
Wheat-	1-2	04/09/02	11.2	0.0	04/25/03	18.4	0.7
Safflower-	2-3	04/09/02	9.9	0.0	04/25/03	17.0	0.9
Fallow	3-4	04/09/02	9.7	0.0	04/25/03	15.3	0.6
Average			**10.9**	**0.3**		**17.0**	**3.1**
MT	0-1	04/09/02	13.9	0.5	04/25/03	16.6	0.9
Wheat-	1-2	04/09/02	10.6	0.0	04/25/03	18.0	0.6
Safflower-	2-3	04/09/02	9.8	0.0	04/25/03	17.1	0.9
Bean	3-4	04/09/02	9.3	0.0	04/25/03	15.5	0.6
Average			**10.9**	**0.5**		**16.8**	**3.0**
MT	0-1	05/31/02	10.7	0.0	05/30/03	16.7	1.0
Wheat-	1-2	05/31/02	10.4	0.0	05/30/03	18.5	0.7
Safflower-	2-3	05/31/02	-	-	05/30/03	17.0	0.9
Bean	3-4	05/31/02	-	-	05/30/03	16.8	0.8
Average			**10.6**	**0.0**		**17.2**	**3.3**
MT	0-1	05/09/02	13.6	0.4	04/25/03	17.1	1.0
Wheat-	1-2	05/09/02	12.4	0.0	04/25/03	18.3	0.6
Corn-Bean	2-3	05/09/02	12.1	0.0	04/25/03	17.3	0.9
	3-4	05/09/02	13.5	0.2	04/25/03	17.2	0.9
Average			**12.9**	**0.7**		**17.5**	**3.5**
MT	0-1	05/31/02	13.5	0.4	05/30/03	16.3	0.9
Wheat-	1-2	05/31/02	13.0	0.0	05/30/03	18.5	0.7
Corn-**Bean**	2-3	05/31/02	12.8	0.1	05/30/03	18.2	1.1
	3-4	05/31/02	14.5	0.4	05/30/03	17.6	1.0
Average			**13.4**	**1.0**		**17.6**	**3.6**

* If the calculated available soil water content (AW) is a negative number, AW is set to zero.

Table C4. Gravimetric soil moisture prior to spring crop planting at Eastland in 2002 and 2003¶

Cropping system (**crop**)	Soil depth (ft.)	Sampling date	Soil water content by weight (%)	Available soil water* (in.)	Sampling date	Soil water content by weight (%)	Available soil water* (in.)
CT	0-1	06/01/02	12.7	0.3	05/28/03	14.8	0.6
Wheat-	1-2	06/01/02	12.0	0.0	05/28/03	15.3	0.6
Bean	2-3	06/01/02	14.5	0.2	05/28/03	14.3	0.2
	3-4	06/01/02	15.5	0.3	05/28/03	14.6	0.2
Average			**13.7**	**0.9**		**14.7**	**1.6**
MT	0-1	06/01/02	9.6	0.0	05/28/03	15.8	0.8
Wheat-	1-2	06/01/02	10.8	0.0	05/28/03	16.7	0.8
Bean	2-3	06/01/02	12.9	0.0	05/28/03	16.1	0.5
	3-4	06/01/02	13.0	0.0	05/28/03	-	-
Average			**11.6**	**0.0**		**16.2**	**2.1**
MT	0-1	04/01/02	13.6	0.4	04/24/03	16.6	0.9
Wheat-	1-2	04/01/02	11.9	0.0	04/24/03	17.0	0.9
Safflower-	2-3	04/01/02	13.2	0.0	04/24/03	16.2	0.6
Fallow	3-4	04/01/02	14.1	0.1	04/24/03	16.6	0.6
Average			**13.2**	**0.6**		**16.6**	**2.9**
MT	0-1	04/01/02	13.0	0.3	04/24/03	17.2	1.0
Triticale-	1-2	04/01/02	11.3	0.0	04/24/03	17.8	1.0
Corn-	2-3	04/01/02	11.3	0.0	04/24/03	16.7	0.7
Safflower	3-4	04/01/02	14.5	0.2	04/24/03	-	-
Average			**12.5**	**0.5**		**17.3**	**2.7**
MT	0-1	05/09/02	12.2	0.2	04/24/03	16.1	0.8
Triticale-	1-2	05/09/02	9.8	0.0	04/24/03	17.5	1.0
Corn-	2-3	05/09/02	10.1	0.0	04/24/03	16.7	0.6
Safflower	3-4	05/09/02	13.8	0.0	04/24/03	13.9	0.1
Average			**11.4**	**0.2**		**16.1**	**2.5**
MT	0-1	06/01/02	11.3	0.0	05/28/03	14.5	0.6
Triticale-	1-2	06/01/02	11.9	0.0	05/28/03	15.9	0.7
Bean	2-3	06/01/02	11.9	0.0	05/28/03	14.8	0.3
	3-4	06/01/02	14.8	0.2	05/28/03	14.5	0.2
Average			**12.5**	**0.3**		**15.0**	**1.7**

* If the calculated available soil water content (AW) is a negative number, AW is set to zero.

Table C5. Gravimetric soil moisture prior to spring crop planting at Goodman Point in 2002 and 2003

Cropping system (**crop**)	Soil depth (ft.)	Sampling date	Soil water content by weight (%)	Available soil water* (in.)	Sampling date	Soil water content by weight (%)	Available soil water* (in.)
	0-1	05/08/02	11.1	0.0	05/01/03	17.2	1.0
Continuous	1-2	05/08/02	10.3	0.0	05/01/03	17.5	0.5
Dry Bean	2-3	05/08/02	11.6	0.1	05/01/03	16.9	0.9
	3-4	05/08/02	11.2	0.0	05/01/03	17.7	1.0
Average			**11.0**	**0.2**		**17.3**	**3.4**
	0-1	05/08/02	12.2	0.2	05/01/03	17.6	1.1
Continuous	1-2	05/08/02	10.2	0.0	05/01/03	17.9	0.5
Chickpea	2-3	05/08/02	11.2	0.0	05/01/03	17.3	0.9
	3-4	05/08/02	-	-	05/01/03	-	-
Average			**11.2**	**0.2**		**17.6**	**2.6**
	0-1	05/08/02	11.1	0.0	05/01/03	17.5	1.1
Wheat-	1-2	05/08/02	10.3	0.0	05/01/03	17.8	0.5
Bean	2-3	05/08/02	11.6	0.1	05/01/03	17.3	0.9
	3-4	05/08/02	11.2	0.0	05/01/03	16.6	0.8
Average			**11.0**	**0.2**		**17.3**	**3.4**
	0-1	05/08/02	12.2	0.2	05/01/03	17.7	1.1
Wheat-	1-2	05/08/02	10.2	0.0	05/01/03	18.1	0.6
Chickpea	2-3	05/08/02	11.2	0.0	05/01/03	17.1	0.9
	3-4	05/08/02	-	-	05/01/03	17.7	1.0
Average			**11.2**	**0.2**		**17.7**	**3.6**

* If the calculated available soil water content (AW) is a negative number, AW is set to zero.
Bean and chickpea plots were sampled indiscriminately in 2002.

APPENDIX D

A proposal to continue and expand SARE project SW99-056 was prepared in 2002 and refined in 2003. A summary of the proposal is presented here.

PROJECT TITLE

Development and Promotion of Sustainable Dryland Cropping Systems in SW Colorado and SE Utah.

PROPOSAL SUMMARY

Relevance:

Project SW99-056 identified promising crop rotations and soil management practices but because of the drought that prevailed in 2000 to 2002, it is too early to make valid recommendations. We propose to continue to evaluate alternative dryland cropping systems in the project area (PA) and promote those that conserve soil and improve its quality, optimize the use of natural precipitation, and minimize the use of external inputs and the financial risks to the producer. This will be achieved through reduced tillage, increased crop diversification, and crop rotations that are adapted to the soil and climatic conditions in the PA. Given the increased interest in organic farming and the poor soil fertility in the PA, an emphasis will be put on enhancing soil fertility and productivity. Two approaches will be tested; one based on crop rotations involving a legume, and the other on soil amendments such as organic fertilizers and cover crops. We will partner with National Center for Appropriate Technology (NCAT) and the Kellogg-funded Southwest Marketing Network, to extend the benefits of this project to small and minority farmers and to explore marketing opportunities for alternative and organically produced crops.

Objectives:

The research objectives will be to identify crop rotations and management practices that will maintain or enhance soil fertility and soil productivity, particularly in organic winter wheat and dry bean production systems; conserve water and use it efficiently; and minimize soil erosion. The agronomic and economic feasibility of each cropping system will be evaluated. The outreach efforts will be focused on getting convincing information out to producers who will ultimately adopt specific findings and adapt them to their own farming operation. With the increased emphasis on alternative and organically produced crops in the new project, training will be provided on how to utilize niche markets.

Methods:

The field trial in Yellow Jacket, CO will be continued for another three years. It consists of nine crop rotations and two tillage systems (minimum tillage and conventional tillage). Measurements are made on a regular basis and analyzed statistically to evaluate available soil moisture at planting and crop water use, crop yield, crop residue maintenance, soil fertility, winter wheat grain protein content, pest dynamics, and the costs and returns of each cropping system. The field trial at Eastland, UT will be concluded at the end of 2003 and replaced with a replicated trial to evaluate organic fertilizers. A similar experiment will be established in the fall of 2004 at Squaw Point, CO and on leased land at Yellow Jacket. Three OMRI-certified organic fertilizers and cow manure will be applied to winter wheat in the fall of each year in winter wheat-fallow, winter wheat-safflower-fallow, and winter wheat-bean rotations and compared to an unfertilized check. These treatments will be compared to inorganic N and P fertilizer and two to three cover crops such as Austrian peas and hairy vetch at Yellow Jacket. Available soil nitrate nitrogen and phosphorus will be assessed in the fall (winter wheat) and spring (spring crops) of each year in 0 to 1 ft. (N and P) and 1 to 2 ft. (NO_3-N) soil depths. The effect of the various fertilizers and soil amendments (cover crops) on crop yield, grain N content, and soil fertility will be measured and analyzed statistically. An analysis of the cost/benefit ratio of each treatment will be conducted. Soil moisture content at planting will be measured at Yellow Jacket to assess the effect of cover crops on moisture availability. Alfalfa-based cropping systems will continue to be evaluated at Goodman Point, CO. Several fields that have been in continuous bean production for up to four years after seven years of alfalfa will be monitored using GPS and statistical sampling techniques to quantify the effect of alfalfa on soil fertility, soil moisture availability, and bean yield over time. Alfalfa appears to be an excellent crop for maintaining soil quality in the PA but its residual effects are not known.

Expected outcomes:

a. **Increasing producer knowledge, awareness, attitudes, and skills**: The information generated by this project will increase producers' knowledge and adoption of dryland farming practices that will (i) enhance soil fertility and soil water storage and utilization, (ii) minimize soil erosion and the degradation of soil quality and productivity, and (iii) optimize resource utilization with the judicious choice of crops and crop rotations, soil and crop management, and soil amendments. It is anticipated that the acreage in alternative crops and organic farming will increase as a result of this project and that producers will become skilled at marketing alternative and organically produced crops.

b. **Information dissemination**: This project will address major constraints to crop production in SW Colorado and SE Utah (Project Area or PA) and will generate research-based information that will directly benefit producers. A field day and/or community workshop will be organized each year to address topics of interest such as organic farming, crop rotations, alternative crops, and soil and water conservation and management. Training on marketing will be provided by the Southwest Marketing Network. A video featuring sustainable dryland cropping systems in the PA will be created in collaboration with producers and Cooperative Extension in Dolores (CO), Montezuma (CO), and San Juan (UT) Counties. Printed information on the project will be published on a regular basis in local and regional newspapers, on websites, and in annual progress reports and technical bulletins.

c. **Resources impacted**: Potentially up to 150,000 acres of cropland will be impacted by this project. More land would be impacted as it comes out of CRP.

d. **Economic and quality of life impacts**: Crop rotations and farming practices that optimize land and water use and minimize the use of external inputs such as synthetic pesticides and fertilizers will result in increased productivity and income and a healthier environment. The adoption of minimum tillage and intensive crop rotations will lead to reduced soil erosion, more efficient utilization of available moisture, and increased crop yield and return. Other economic and environmental benefits will be derived from enhanced soil fertility management and increased acreage in organic crop production. In excess of $2,000,000 of additional income could be generated annually with the adoption of sustainable dryland cropping systems in the PA.

Producer involvement:

Members of the Soil Conservation Districts (SCD) of Montezuma, Dolores and San Juan Counties have and will continue to provide input into the planning of field trials and outreach activities. Producers will manage the field trials at Goodman Point, Squaw Point, and Eastland. Innovative producers will be featured in printed and audiovisual materials and will be involved in panel discussions at annual community workshops. A committee made up of the Project Coordinator, a representative from each SCD and Cooperative Extension service in the PA, and the NCAT Coordinator for the Four Corners region will be formed in 2004. It will meet in the spring and fall of each year to set the dates and design the agenda of each educational and outreach activity.