2000

SUSTAINABLE DRYLAND AGROECOSYSTEM MANAGEMENT[1]

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A Cooperative Project

of the

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Fort Collins, Colorado

and the

USDA - Agriculture Research Service
Natural Resources Research Center
Great Plains Systems Research Unit
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RESEARCH APPLICATION SUMMARY

We established the Dryland Agroecosystem Project in the fall of 1985, and 1986 was the first crop year. Grain yields, stover yields, crop residue amounts, soil water measurements, and crop nutrient content were reported annually in previously published technical bulletins. This summary updates our findings for the 14-year period.

Average Yields:

Annual yield fluctuations concern growers because they increase risk. Stable yields translate into stable income levels in their operations. Figure 1 provides a summary of 13 years' average yield history for wheat, corn, sorghum, and proso millet at our three study locations. Wheat has been grown all 14 years at all sites, corn every year at Sterling, and sorghum every year at Walsh. Other crops have been grown for shorter periods of time. Complete data for each crop are available in previously published bulletins (see reference section). We included yields in Figure 1 from all years, even those where yield losses occurred due to hail, early and late freezes, insect pests, winter kill of wheat, and herbicidal carryover.

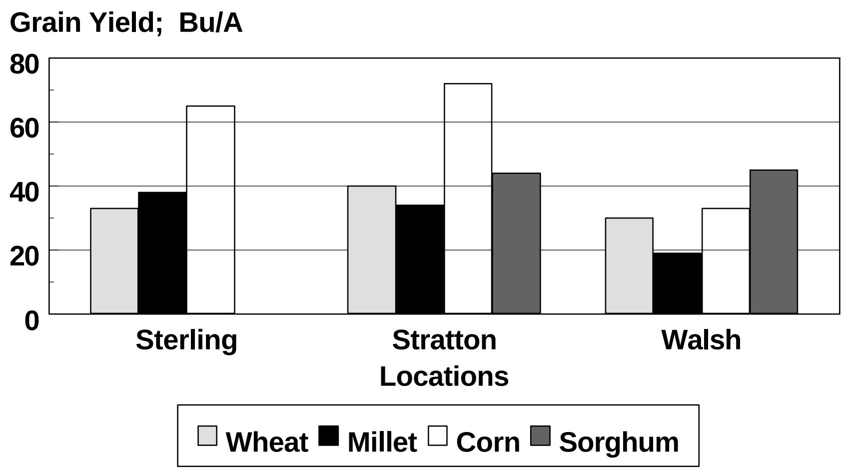


Figure 1. Grain yields averaged over soil positions and 13 years of production for each location.

Corn and Sorghum Yields:

Fluctuations in corn and sorghum yields are of most interest because they represent the highest input crops.

1) Corn yields at Sterling averaged 65 bu/A (range = 14 to 107 bu/A).

2) Corn yields at Stratton averaged 76 bu/A (range = 37 to 112 bu/A).
(Includes disastrous yields recorded in 1994 caused by drought, and low yields caused by early frost in 1995.)

3) Corn yields at Walsh, using Bt varieties, averaged 57 bu/A from1997-1999.

4) Grain sorghum yields at Stratton (4 years) averaged 44 bu/A (range = 20 to 63 bu/A).

5) Grain sorghum yields at Walsh averaged 48 bu/A (range = 27 to 75 bu/A).
(Includes the results from the very dry 1995 season and severe hail in 1996.)

Cropping Systems:

The 3- and 4-year systems like wheat-corn(sorghum)-fallow and wheat-corn-millet-fallow or wheat-sorghum-sorghum-fallow have increased average annualized grain production by 74% compared to the 2-year wheat-fallow system (Figure 2). Yields are annualized to account for the nonproductive fallow year in rotation comparisons. Economic analyses show this to be a 25-40% increase in net annual income for the three-year rotation in northeastern Colorado. However, in southeastern Colorado the three year wheat-sorghum-fallow rotation, using stubble mulch tillage in the fallow prior to wheat planting, netted about the same amount of return as reduced till wheat-fallow. New herbicide programs with fewer residual materials have shown promise and are less expensive.

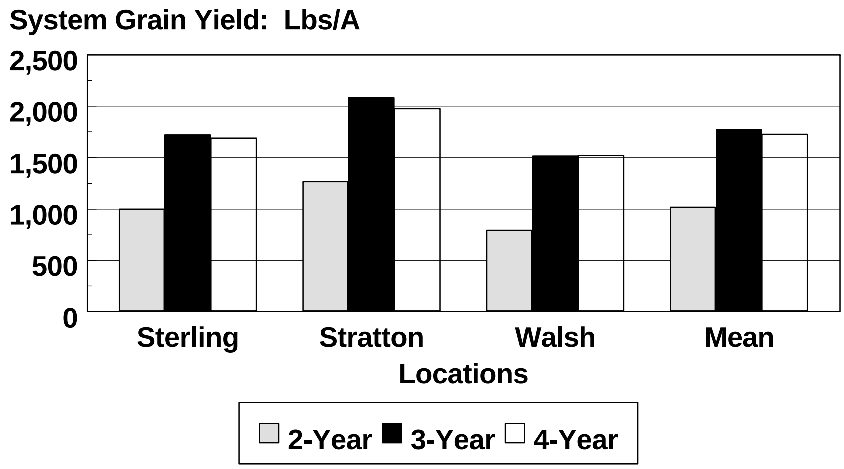


Figure 2. System grain yield for each location.

Our data show that cropping intensification is certainly possible in the central Great Plains. More intensive rotations like wheat-corn(sorghum)-fallow and wheat-corn(sorghum)-millet-fallow have more than doubled grain water use efficiency. Water conserved in the no-till systems has been converted into increased grain production.

Our opportunity cropping systems have maximized production at all sites relative to all other rotations, but have not been the most profitable. The 3-year rotations have been most profitable. Based on our findings with the intensive systems from 1985 to 1997 (12 cropping seasons), we altered the systems in 1998 to reflect the new knowledge. More intensive cropping systems have been added and wheat-fallow has been omitted from the experiments. We now consider the 3-year (wheat-corn or sorghum-fallow) system as the standard of comparison.

New Research Sites:

The dryland agroecosystem project also has a new linkage with the Department of Bioagricultural Sciences and Pest Management. We are now evaluating the interactions of cropping systems with both pest and beneficial insects at three new experimental sites. The new sites at Briggsdale, Akron, and Lamar also allow us to test our most successful intensive cropping systems at three new combinations of precipitation and evaporative demand. The new sites have much larger experimental units, enabling us to study insect dynamics as influenced by cropping system. We want to know if the presence of multiple crops in the system will alter populations of beneficial insects and provide new avenues of pest insect control. Details of cropping system changes at the old sites and the treatments at the new sites are explained in the methods section of this report.

Adoption of Intensive Cropping Systems:

Producers in northeastern Colorado have been adopting the more intensive cropping systems at an increasing rate since 1990. Corn is one of the principal crops used in more intensive systems, and we use its acreage as an index of adoption rate by producers (see Table below). Area planted to dryland corn in northeastern CO increased from about 20,000 acres per year in years previous to 1990 to 220,000 acres in 1999. Total dryland corn acreage in Colorado increased from 23,700 historically to 290,000 in 1999.

Dryland Corn Acreage in Eight Northeastern Colorado Counties and state total from 1971 to 1998.

Year	Eight NE Counties*	Total for State
	Acres	
1971-1988	21,200	23,700
1989	27,000	28,000
1990	26,000	26,000
1991	32,500	33,000
1992	48,500	50,000
1993	79,000	90,000
1994	92,500	100,000
1995	95,500	100,000
1996	104,000	110,000
1997	138,500	150,000
1998	191,000	240,000
1999	220,000	290,000

*Data from Colorado Agricultural Statistics (Adams, Kit Carson, Logan, Morgan, Phillips, Sedgewick, Washington, Yuma)

Corn acreage is expanding into areas once thought to be too dry for corn production as exemplified in Lincoln county where corn acreage increased from1500 in 1996, to 4000 in 1997, to 8000 in 1998, and to 18,000 in 1999. Adoption of the new systems also is reflected in sunflower and proso millet acreage increases. For example, sunflower acreage increased from 63,000 in 1991 to 270,000 in 1999 in Colorado.

Producers wishing to get started in dryland rotation farming may consult bulletins published in previous years and/or the publication by Croissant et al. (1992).

CONCURRENT RESEARCH PROJECTS

Triticale-Corn-Forage Soybean Rotation at Sterling: {Established in fall 1993}

Objective:

Maximize time in crop, provide both a cash crop (corn) and forage crops for a mixed livestock-grain farm. Land preparation costs would also be minimized. From 1993 - 1998 this rotation was triticale-corn-hay millet. Forage soybean replaced hay millet in 1999 in attempt to grow a sandbur free, higher protein forage.

Procedure:

i) Winter triticale is planted in September into the hay millet stubble.

ii) Harvest winter triticale for forage in June before heading, leaving a 8-10 inch stubble. Roundup and Atrazine, applied after harvest.

iii) Corn planted no-till into triticale stubble the following May.

iv) Corn is harvested in late September.

v) Forage soybean, Roundup-Ready is planted into corn stalks the following May and is harvested in August. Weeds controlled with Roundup if necessary.

Results:

i) Corn yields have averaged 52 Bu/A including 1994, when no grain was produced due to dry weather, and including 1995, when the corn froze before maturity. In 1998 and 1999 Roundup Ready, Dekalb, DK493 RR, was grown to aid in sandbur control.

ii) Hay millet yields were non-harvestable in all years except 1997. The failures were primarily due to heavy sandbur infestations. We had to destroy the crop because sandbur populations were equal to the millet populations in most years.

iii) Forage soybean yields in 1999 averaged 1.38 T/A over all soils.

iv) Triticale "Harvested" yields have averaged 2.0 T/A over the past 5 years, even though we left a 10-12" stubble remaining in the field for cover (Following table), but were 0.5 T/A below the long-term average in 1999.

Summary:

Winter triticale seems to be a well adapted cool season forage crop. Corn following triticale should be equivalent to corn after wheat, which has a good record at this site over a 14 year period. The forage soybean yielded relatively well, 1.4 T/A, even though July precipitation was 2" less than the long-term average.

Triticale and corn grain yields by soil for 1998 and 1999.

Year	Crop	Production	Soil Positions			
			Summit	Sideslope	Toeslope	Average
			---------------Tons/A or Bu/A-----------------			
1998	Triticale	Total	0.94	1.13	1.36	1.14
		Harvested[1]	0.77	1.00	1.05	0.94
	Corn	Grain	64	64	88	72
	Hay Millet	Total	0	0	0	0
1999	Triticale	Total	(Not measured in 1999)			
		Harvested[1]	1.64	1.17	1.92	1.58
	Corn	Grain	43	82	69	65
	Soybean	Forage @ 15% moisture	1.17	1.26	1.72	1.38

[1] Harvested leaving 10" stubble;

Experiment Managers:

G.A. Peterson, G. Lindstrom, and D.G. Westfall

Soybean Variety Trials at Sterling and Stratton

Background:

Our interest in soybeans stems from our search for a crop we could harvest and immediately plant winter wheat, thus avoiding fallow. Soybean has the potential to be one of the crops that might fit the system. It has the following attributes:

1. Local market probable
2. Broadleaf plant for rotation
3. Roundup Ready (sandbur control)
4. Fits rotation (plant wheat after soybean harvest)
5. Use same planting and harvesting equipment as wheat
6. Economic potential good (Expected yields 20-25 bu/A and low fertilizer cost)

Objectives:

1) To determine the yield potential of dryland soybean varieties in eastern Colorado
2) To observe growth characteristics and potential harvest dates.
3) To compare drilled versus row planted soybeans

Procedure:

Planting Method:

Drilled with 12" row spacing

Row planted in 30" row spacing

Varieties:

Asgrow 2001, 2101, 2301, 3303

Pioneer 91B91,

Population:

85,000 to 90,000 seeds/A

(3000 seeds/pound)

Seed cost: Roundup Ready seed = $24 per 50 lbs; Planted @ 30#/A = $14.40/A

Planting and Harvesting Dates:

Stratton = 18 May and 4 October 1999

Sterling = 25 May and 6 October 1999

Results:

The drill planted soybeans were not harvested in 1999 because the stands were too erratic. The drill planted the seed too deep and emergence was very poor. Therefore our only variety comparisons are for the row planted soybean. Yield losses due to shattering were a problem at both sites because the low humidity air encourages pod drying and splitting just after maturity. Furthermore the low pod set above the ground also makes combine losses high.

Yields at Sterling ranged from 13 to 20 bu/A with a tendency for higher yields with the longer maturity varieties. Yields at Stratton ranged from 9 to 19 bu/A, and the highest yields were achieved with Group 2 varieties.

Soybean variety trial yields at Sterling and Stratton in 1999.

Variety	Yield	
	Sterling	Stratton
	---------------------Bu/A---------------------	
Asgrow 2001	13	9
Asgrow 2101	16	19
Asgrow 2301	17	18
Asgrow 3303	20	15
Pioneer 91B91	14	11
Mean	16	14

Experiment Managers: D. Poss, G.A. Peterson, D.G. Westfall.

Wheat-Corn-Pea Rotation at Sterling and Stratton:

Objective:

Grow winter or spring legumes, after corn harvest and before wheat in the wheat-corn-fallow rotation to evaluate amount of cover produced, water requirement, potential of peas as a forage, N contribution from the legumes to the subsequent crops in the rotation, and yields of subsequent crops in the rotation.

Procedure:

i) Austrian Winter Pea planted no-till in fall after corn harvest. Spring legumes planted no-till in March after corn harvest.

ii) Late June to early July peas are harvested. Treatments are: 100% vegetation removed; 50% removed; 0% removed; and a control with no peas. After harvest peas are killed with Roundup to stop water use.

iii) Winter wheat is planted in September. Herbicides are same as in the wheat-corn-fallow rotation.

iv) Corn is planted in wheat stubble each spring. Herbicides used are same as in the wheat-corn-fallow rotation.

Results:

The following table reports our experience with Austrian winter pea yields from 1995 - 1999. It also reports the wheat yields following pea production and wheat yields after fallow. Pea crop failure at Sterling in 1995 was due to hail, and failure at Stratton in 1996 was due to winter dessication of the germinated seedlings. From 1997 to 1999 we planted the peas 2 to 3" below the surface which prevented further crop loss to seedling dessication.

Wheat yields following peas were less than wheat after fallow in all situations except 1997 at Stratton. Averaged over years and sites, wheat after peas yielded about 6% less than after fallow. Economic analyses showed that if the pea forage was valued at the price of alfalfa hay the loss in wheat yield was compensated for by the value of the pea forage produced.

Pea dry matter yields, wheat yield after pea, and wheat yield after fallow from 1995 - 1999.						
Pea/Wheat Year	Site	Pea	Wheat Yield after Pea	Wheat Yield after Fallow	Wheat Yield Gain or Loss	Wheat Yield % Change
		Lb/A	Bu/A	Bu/A	Bu/A	%
1995/96						
	Sterling	0	48	49	1.0	-2
	Stratton	3540	26	30	4.0	-13
1996/97						
	Sterling	3130	28	30	2.0	-7
	Stratton	0	10	17	7.0	-41
1997/98						
	Sterling	3490	38	39	1.0	-3
	Stratton	1930	38	36	-2.0	6
1998/99						
	Sterling	2250	33	36	3.0	-8
	Stratton	2880	44	46	2.0	-4
Mean						
	Sterling	2220	37	39	2.0	-5
	Stratton	2090	30	32	2.0	-6

Experiment Managers: D. Poss, G.A. Peterson, D.G. Westfall.

INTRODUCTION

Colorado agriculture is highly dependent on precipitation from both snow and rainfall. Dryland acreage exceeds irrigated acreage by more than two fold, and each unit of precipitation is critical to production. At Akron each additional inch (25 mm) of water above the initial yield threshold translates into 4.5 bu/A of wheat (12 kg/ha/mm), consequently profit is highly related to water conservation (Greb et al., 1974).

A research project was established in 1985 to address efficient water use under dryland conditions in Eastern Colorado. A more comprehensive justification for its initiation has been reported previously (Peterson, et al.,1988). The general objective of the project is to identify dryland crop and soil management systems that will maximize water use efficiency of the total annual precipitation and economic return.

Specific objectives are to:

1. Determine if cropping sequences with fewer and/or shorter summer fallow periods are feasible.
2. Quantify the relationships among climate (precipitation and evaporative demand), soil type and cropping sequences that involve fewer and/or shorter fallow periods.
3. Quantify the effects of long-term use of no-till management systems on soil structural stability, micro-organisms and faunal populations, and the organic C, N, and P content of the soil, all in conjunction with various crop sequences.
4. Identify cropping or management systems that will minimize soil erosion by crop residue maintenance.
5. Develop a data base across climatic zones that will allow economic assessment of entire management systems.

Peterson, et al.(1988) document details of the project in regard to the "start up" period and data from the 1986-87 crop year. Results from the 1988 - 1997 crop years were reported by Peterson, et al. (1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, and 1999). As in previous bulletins, only annual results are presented. Cropping system research is highly time and weather dependent, and therefore we do not draw major conclusions on an annual basis. Other publications, such as Wood, et al. (1990), Croissant, et al. (1992), Peterson, et al. (1993a & 1993b) and Nielsen, et al. (1996) summarize and draw conclusions based on a combination of years.

Long-term averages of summer crops, corn and sorghum, are 65, 76 and 48 bu/A for Sterling(corn), Stratton(corn) and Walsh(sorghum), respectively. These means include years of near crop failure due to drought, hail, and early frost. Our research has shown that cropping intensification is certainly possible and profitable in the central Great Plains. More intensive rotations like wheat-corn(sorghum)-fallow have more than doubled grain water use efficiency in our three study environments when compared over years. Water conserved in the no-till systems has been converted into increased grain production. Furthermore, our opportunity cropping systems have maximized production at all sites relative to all other rotations. Based on findings from1985 to 1997, we altered the systems being studied to reflect the new knowledge. Wheat-fallow was omitted from the experiments, and we consider the 3-year (wheat-corn or sorghum-fallow) system as the standard of comparison.

The dryland agroecosystem project established a linkage with the Department of

Bioagricultural Sciences and Pest Management, in 1998. We are evaluating the interactions of cropping systems with both pest and beneficial insects at three new experimental sites, Briggsdale, Akron, and Lamar, CO. This also allows us to test our most successful intensive cropping systems at three additional combinations of precipitation and evaporative demand. Compared with the original three experiments, they have much larger experimental units enabling us to study insect dynamics as influenced by cropping system. We want to know if the presence of multiple crops in the system will alter populations of beneficial insects and provide new avenues of biological pest management of Russian Wheat Aphid in wheat and insect pests in other crops. Details of cropping system changes at the original sites and the treatments at the new sites are explained in the methods section of this report.

MATERIALS AND METHODS

From 1986 - 1997 we studied interactions of climate, soils and cropping systems at three sites, located near Sterling, Stratton, and Walsh, in Eastern Colorado, that represent a gradient in potential evapotranspiration (PET) (Fig. 3). Elevation, precipitation and evaporative demand are shown in Table 1. All sites have long-term precipitation averages of approximately 16-18 inches (400-450 mm), but increase in PET from north to south. Open pan evaporation is used as an index of PET for the cropping season.

Table 1. Elevation, long-term average annual precipitation, and evaporation characteristics for each site.

Site	Elevation	Annual Precipitation[1]	Growing Season Open Pan Evaporation[2]	Deficit (Precip. - Evap.)
	--Ft. (m) --	---In. (mm) ---	---In. (mm) ---	---In. (mm) ---
Nunn (Briggsdale)	4850 (1478)	13.7 (350)	61 (1550)	- 48 (- 1220)
Sterling	4400 (1341)	17.4 (440)	63 (1600)	- 45 (- 1140)
Akron	4540 (1384)	16.0 (405)	63 (1600)	- 47 (- 1185)
Stratton	4380 (1335)	16.3 (415)	68 (1725)	- 52 (- 1290)
Lamar	5250 (1600)	14.7 (375)	76 (1925)	- 62 (- 1555)
Walsh	3720 (1134)	15.5 (395)	78 (1975)	- 61 (- 1555)

[1]Annual precipitation = 1961-1990 mean [2]Growing season = March - October

Each of the original three sites (Sterling, Stratton, Walsh) was selected to represent a catenary sequence of soils common to the geographic area. Textural profiles for each soil at each location are shown in Figures 4a, 4b, and 4c. There are dramatic differences in soils across slope position at a given site and from site to site. We will contrast the summit soils at the three sites to illustrate how different the soils are. Each profile was described by NRCS personnel in summer 1991. Note first how the summit soils at the three sites differ in texture and horizonation. The surface horizons of these three soils (Ap) present a range of textures from loam at Sterling, to silt loam at Stratton, to sandy loam at Walsh. Obviously the water holding capacities and infiltration rates differ. An examination of the horizons below the surface reveals even more striking differences.

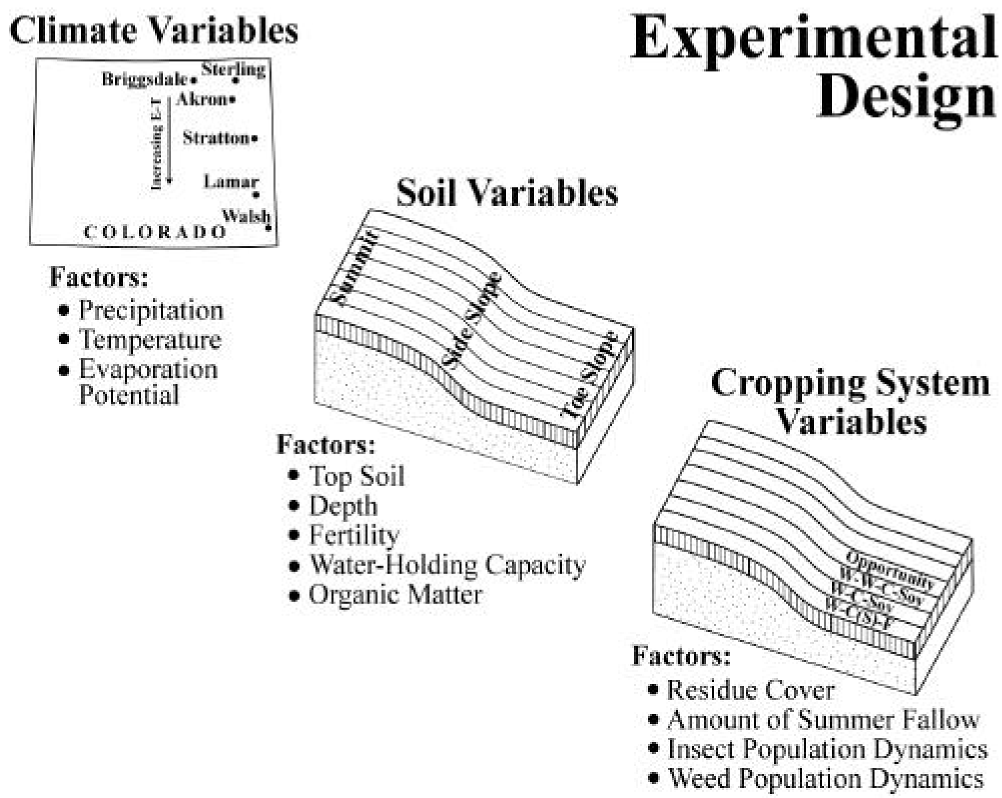
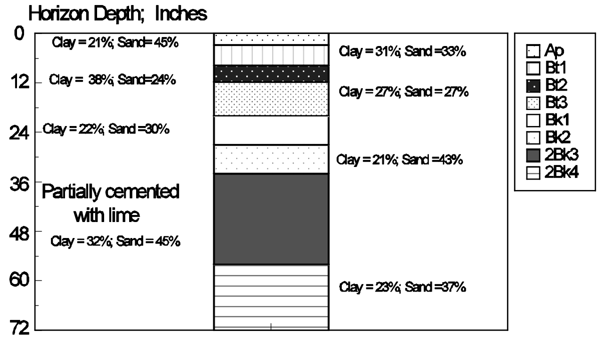


Figure 3. Experimental design with climate, soil, and cropping system variables.

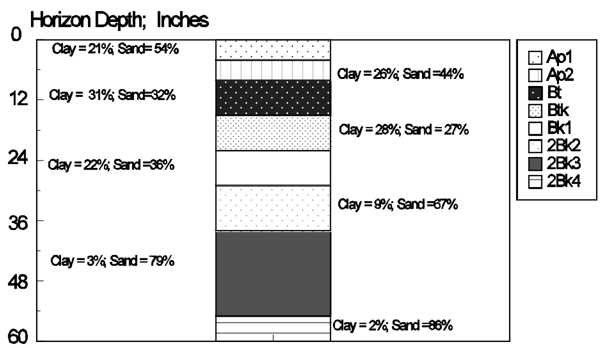
The summit soil profile at Sterling (Figure 4a) changes from a clay content of 21% at the surface(Ap) to 31% in the 3-8" depth (Bt1) to a clay content of 38% in the layer between the 8-12" depth (Bt2). At the 12" depth the clay content drops abruptly to 27%. The water infiltration in this soil is greatly reduced by this fine textured layer (Bt2). At about the 36" depth (2Bk3) there is an abrupt change from 21% clay to 32% clay in addition to a marked increase in lime content. The mixture of 32% clay and 45% sand with lime creates a partially cemented zone that is slowly permeable to water, but relatively impermeable to roots. Profile plant available water holding capacity is 9" in the upper 36 inches of the profile.

At Stratton the summit soil profile (Figure 4b) is highest in clay at the surface, 34% in the Ap horizon, and then decreases steadily to 14% clay (Bk3) below the 40" depth. There are few restrictions to water infiltration at the surface nor to roots anywhere in the profile compared to summit soil at Sterling.   Profile plant available water holding capacity is 12" in the upper 72 inches of soil.

Sterling Summit Soil Profile



Sterling Sidelope Soil Profile



Sterling Toeslope Soil Profile

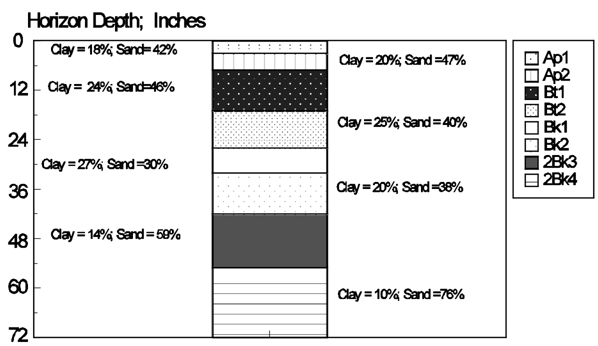


Figure 4a. Soil profile textural characteristics for soils at the Sterling site.

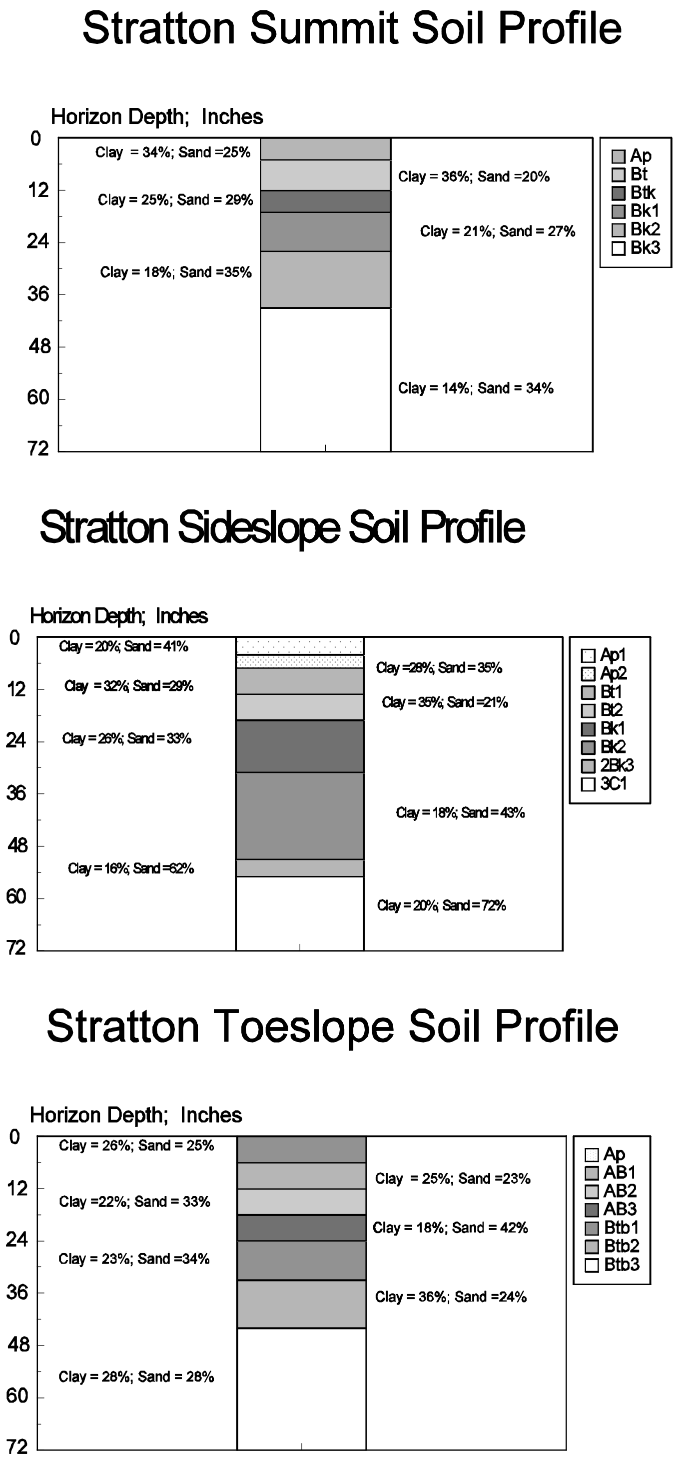


Figure 4b. Soil profile textural characteristics for soils at the Stratton site.

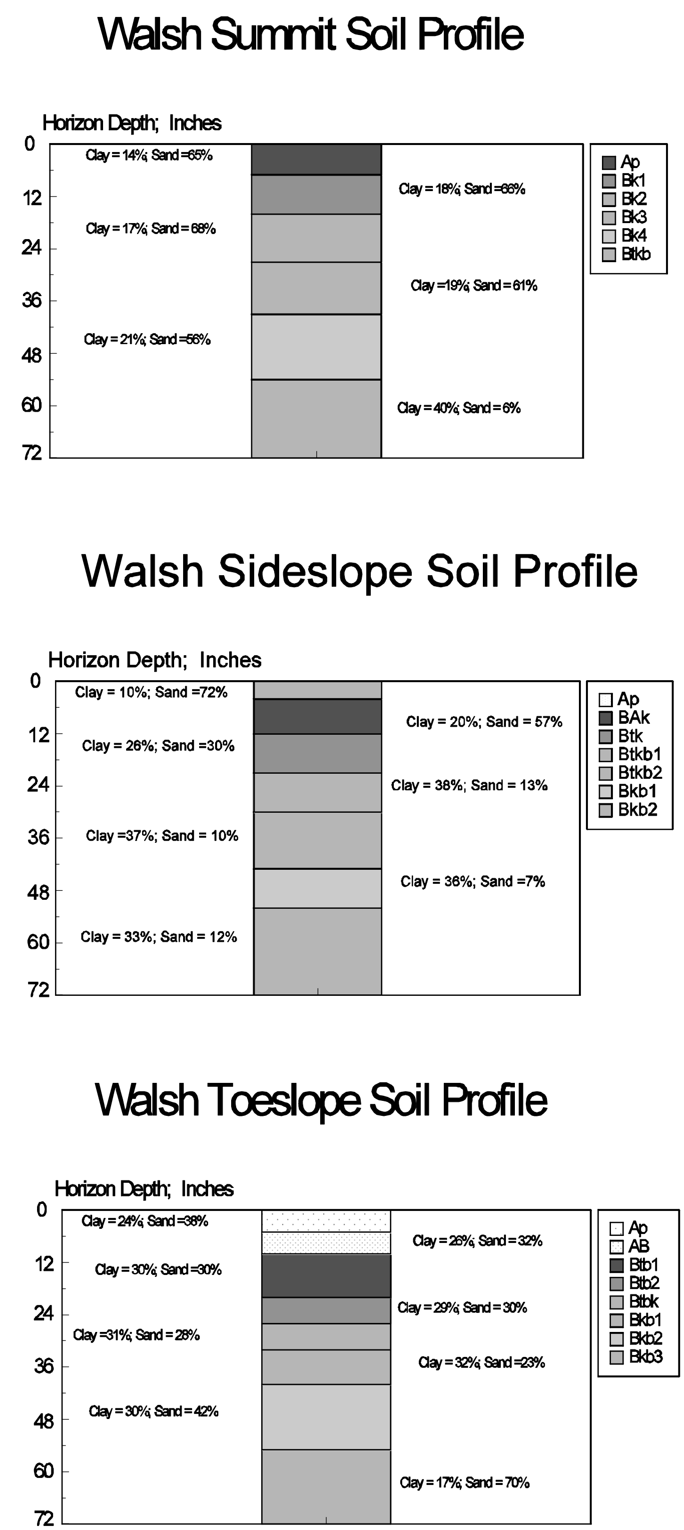


Figure 4c. Soil profile textural characteristics for soils at the Walsh site.

The summit soil at Walsh (Figure 4c) has very sandy textures above 54" compared to either summit soil at the other sites. No restrictions to water infiltration nor root penetration occurs in the profile. In this soil the abrupt increase in clay content at 54", 40% in the Btkb horizon, represents a type of "plug" in the soil profile. Water can infiltrate rapidly in the coarse-textured surface horizons, but does not drain rapidly beyond the root zone due to the high clay content of the deepest horizon at 54". This makes this soil more productive than a similar soil with no clay "plug". The profile plant available water holding capacity is 11". About 2" of the total is in the 5-6' depth, leaving only a 9" storage capacity in the upper 5' of soil.

Many other soil contrasts can be observed by the reader, both within and across sites. All of these soils had been cultivated for more than 50 years, and all exhibit the effects of both wind and water erosion damage. The toeslopes are the recipients of soil materials from the summit and sideslope positions because of their landscape location relative to the others. Hence they also have the highest organic matter content in their surface horizons.

Soil profile characteristics for the three new locations are only available on a general basis. The soil type at Briggsdale and Akron is Platner loam and at Lamar it is a Wiley silt loam.

The cropping system during the previous 50 years had been primarily dryland wheat-fallow with some inclusion of grain sorghum at Walsh and corn at Sterling. At the original sites we placed cropping system treatments over the soil sequence (Fig.3) to study the interaction of systems and soils. At the three new sites we have only one soil type at each. Systems being studied at each site are listed in Tables 2a & 2b. Each system is managed with no-till techniques, and herbicide programs are reported in Appendix Tables 1 - 6. Complete details on measurements being made and reasons for treatment choices are given by Peterson, et al.(1988). Crop variety, planting rate, and planting date for each crop at each site is given in Table 3.

Nitrogen fertilizer is applied annually in accordance with the NO_3-N content of the soil profile (0-6 ft or 0-180 cm) before planting, and expected yield on each soil position at each site. Therefore, N rate changes by year, crop grown, and soil position (Table 4). Nitrogen fertilizer for wheat, corn, and sunflower was dribbled on the soil surface over the row at planting time at Sterling and Stratton. Nitrogen on wheat at Walsh was topdressed in the spring, and N was sidedressed on corn and sorghum. We made all N applications as a 32-0-0 solution of urea-ammonium nitrate.

We band applied P (10-34-0) at planting of all crops near the seed. Phosphorus was applied on one-half of each corn and proso millet plot over all soils at the original sites, but applied to the entire wheat plot. The rate of P is determined by the lowest soil test on the catena, which is usually found on the sideslope position. This rate has been 20 lbs P_2O_5/A (9.5 kg/ha of P) at each site each year thus far. We changed the P fertilization treatment for wheat in fall 1992, so that the half plot that had never received P fertilizer in previous years is now treated when planted to wheat. Other crops in the rotation only receive P on the half plot designated as NP. Zinc (0.9 lbs/A or 1 kg/ha) is banded near the seed at corn planting at Sterling, Stratton, and Briggsdale to correct a soil Zn deficiency.

Table 2a. Cropping systems for each of the original sites in 1999.

Site	Rotations
Sterling	1) Wheat-Corn-Fallow (WCF)
	2) Wheat-Corn-Soybean (WCSb)
	3) Wheat-Wheat-Corn-Soybean (WWCSb)
	4) Opportunity Cropping*
	5) Perennial Grass
Stratton	1) Wheat-Corn-Fallow (WCF)
	2) Wheat-Corn-Soybean (WCSb)
	3) Wheat-Wheat-Corn-Soybean (WWCSb)
	4) Opportunity Cropping*
	5) Perennial Grass
Walsh	1) Wheat-Sorghum-Fallow (WSF)
	2) Wheat-Corn-Soybean (WCSb)
	3) Wheat-Wheat-Sorghum-Soybean (WWSSb)
	4) Continuous Row Crop (Alternate corn & sorghum)
	5) Opportunity Cropping*
	6) Perennial Grass

*Opportunity cropping is designed to be continuous cropping without fallow, but not monoculture.

Opportunity Cropping History

Year	Site: Sterling	Stratton	Walsh
1985	Wheat	Fallow	Sorghum
1986	Wheat	Wheat	Sorghum
1987	Corn	Sorghum	Millet
1988	Corn	Sorghum	Sudex
1989	Attempted Hay Millet	Attempted Hay Millet	Sorghum
1990	Wheat	Wheat	Attempted Sunflower
1991	Corn	Corn	Wheat
1992	Hay Millet	Hay Millet	Corn
1993	Corn	Corn	Fallow
1994	Sunflower	Sunflower	Wheat
1995	Wheat	Wheat	Wheat
1996	Corn	Corn	Fallow
1997	Hay Millet	Hay Millet	Corn
1998	Wheat	Wheat	Sorghum
1999	Corn	Corn	Corn

We measure soil water with the neutron-scatter technique. Aluminum access tubes were installed, two per soil position, in each treatment at each original site in 1988. These tubes are not removed for any field operation and remain in the exact positions year to year. Precautions are taken to prevent soil compaction around each tube. By not moving the tubes over years we get the best possible estimates of soil water use in each rotation. Soil water measurements are made on all soils and rotations at planting and harvest of each crop, which also represents the beginning and end of non-crop or fallow periods. At the new sites soil samples are taken for gravimetric water measurements at crop planting.

Table 2b. Cropping systems for the new sites in 1999.

Site	Rotations
Briggsdale	1) Wheat-Fallow (WF) 2) Wheat-Hay Millet-Fallow (WHF) 3) Wheat-Wheat-Corn-Soybean-Sunflower-Pea (WWCSbSnPea) 4) Opportunity
Akron	1) Wheat-Fallow (WF) 2) Wheat-Corn-Fallow (WCF) 3) Wheat-Corn-Proso-Fallow (WCPF) 4) Wheat-Corn-Proso (WCP)
Lamar	1) Wheat-Fallow (WF) 2) Wheat-Sorghum-Fallow (WSF)

Table 3. Crop variety, seeding rate, and planting date for each site in the 1998-1999 season.

Site	Crop	Variety	Seeding Rate	Planting Date
Briggsdale (Nunn)	Wheat (fallow)	Akron & Halt	60 lbs/A	9/13/98
	Hay Millet	Golden German	10 lbs/A	6/23/99
	Sunflower	Cargill SF187	21,000 seeds/A	5/26/99
	Soybean	Asgrow 2301	90,000 seeds/A	5/26/99
Sterling	Wheat	Halt	60 lbs/A	9/28/98
	Corn	Dekalb 493RR	18,000 seeds/A	5/10/99
	Soybean	Asgrow 2301 RR	90,000 seeds/A	5/25/99
Akron	Wheat	Halt & Tam 107	60 lbs/A	9/30/98
	Corn	Dekalb DK 493RR	16,100 seeds/A	5/19/98
	Proso	Sunup	12 lbs/A	6/8/98 & 7/1/98
	Sunflower	-------------------	-----------------	-----------------
Stratton	Wheat	Halt	60 lbs/A	9/15/98
	Corn	Pioneer 3752	18,000 seeds/A	5/18/99
	Soybean	Asgrow 2301 RR	90,000 seeds/A	5/19/99
Lamar	Wheat	Lamar & Prowers	45 lbs/A	9/22/98
	Sorghum	Cargill 770Y	42,600 seeds/A	6/3/99
Walsh	Wheat	Prowers	45 lbs/A	10/798
	Sorghum	Cargill 627	43,000 seeds/A	6/8/99
	Corn	Asgrow RX686 RR/YG	19,000 seeds/A	5/18/99
	Soybean	Asgrow 3303 RR	110,000 seeds/A	5/18/99

RESULTS AND DISCUSSION

Climatic Data

Precipitation and its distribution in relationship to plant growth stages controls grain and forage yields. Rarely do the precipitation amounts and distributions match the long-term normals. Precipitation in the last six months of 1998, the period prior to wheat planting and the fall growth period, was above the normals by 2.7 in. (69 mm) at Sterling, by 1.7 in. (43 mm) at Stratton, and by 4.5 in. (114 mm) at Walsh (Table 5a). The first half of 1999 was slightly below normal at Sterling (-1.1 in. or -28 mm) , 2.0 in. (51 mm) above normal at Stratton, and 4.0 in. (102 mm) above normal at Walsh. Precipitation was near normal to above during the second half of 1999 at all sites (Table 5a).

Precipitation at the newest sites in the last six months of 1998, the period prior to wheat planting and the fall growth period, was above the normals by 2.7 in. (69 mm) at Briggsdale, by 1.4 in. (36 mm) at Akron, and by 8.9 in. (226 mm) at Lamar (Table 5b). The first half of 1999 was above normal at Briggsdale (2.4 in. or 61mm) , near normal at Akron, and 5.1 in. (130 mm) above normal at Lamar. During the second half of 1999 precipitation was above normal at Briggsdale (2.2 in. or 56 mm) and Akron (5.1 in. or 130 mm), but 2.1 in. (53 mm) below normal at Lamar (Table 5b).

July and August rainfall are critical for production of corn, sorghum, and soybean. At Sterling, Stratton, Briggsdale, and Lamar July rainfall was below normal, but then August rainfall exceeded the normal (Table 5a). This distribution stressed the summer crops in July, but because of excellent stored soil water reserves, the plants maintained their turgor until the August rains came. Thus corn yields were near average or above at these sites. Akron experienced normal July rainfall and then received 4.4 in (112 mm) above normal rain in August. At Walsh the sum of the July and August rainfall exceeded the long-term normal by 2.2 in. (56 mm), and the distribution was more favorable than at the northern sites.

Tables 5c-5h show the precipitation distribution as related to crop growing season at each of the six sites.

Wheat

Wheat yields in the WCF and WSF systems are our new standards of comparison because wheat-fallow has been eliminated from the experiment. We altered our experiment in fall 1997 to to prepare for the new systems in 1998. We converted previous wheat-fallow to WCP and previous wheat-corn-sunflower-fallow to WWCP at Sterling and Stratton and to WWSSa at Walsh. These changes required the addition of two new plots at each site, which had not been in the experiment. By the 2000 crop year we should be getting results that reflect cropping system effects.

The 1999 crop year is still a transition year, and except for the WCF and WSF systems, do not represent wheat yields that are necessarily indicative of that system.. Wheat yields after fallow in 1999, WCF or WSF, (Tables 6a & 6b) exceeded the long-term averages by 9, 9, and 13 bu/A (605, 605, and 870 kg/ha) for Sterling, Stratton, and Walsh, respectively (Peterson et al. 1999). The excellent precipitation during fallow before wheat seeding provided an excellent subsoil water supply. Rainfall during the spring season (April-June) was somewhat above normal at the three original sites, which further enhanced wheat yield potential.

Wheat yields in WCSb and first year wheat in the(W)WCSb systems actually followed proso millet at Sterling and Stratton and followed safflower at Walsh because of the changes we made between 1998 and 1999. It is interesting to compare wheat after proso (Sterling and Stratton) and safflower (Walsh) to wheat after fallow at those sites, even though the systems have only been in place one year. Wheat yields in the continuously cropped WCSb and first year wheat in the(W)WCSb yielded 72%, 67% and 77% as much as wheat after fallow at Sterling, Stratton, and Walsh, respectively. Soil position had less influence on wheat grain yield (Tables 6a & 6b) in 1999 than in previous years (Peterson et al. 1999) because the excellent spring rainfall from April-June lessened crop dependence on stored soil water.

Tables 7, 8 and 9 are summaries of wheat yields by rotation, soil, and year. Average wheat yields in the continuous systems like WCSb, etc. have yielded about 85% of yields after fallow in the WCF and WSF systems. These values are probably very high compared to what we will experience in the long run and the reader should regard with skepticism until we get past the transition years.

Wheat yields at the Briggsdale-Nunn site were exceptionally high (Table 10). The Nunn location was terminated with the 1999 wheat harvest because of a land ownership change, and was restarted on a farm near Briggsdale. All other 1999 crop yield data are from the Briggsdale site. All wheat production at the three new sites followed a summer fallow period, and therefore would be expected to be independent of cropping system. Wheat yields were near the long-term county averages at both the Akron, and Lamar sites. At Lamar the wheat was not grazed in 1999, but still showed some yield reduction from grazing in the previous wheat cycle (spring 1998); about 3 bu/A (200 kg/ha) less yield on previously grazed treatments.

Cultivar effects at the new sites were small and the nonresistant cultivars yielded the same or more than their resistant counterparts (Table 10). Note that at the Lamar site the nonresistant variety (Lamar) was sprayed with an insecticide to control Russian wheat aphid, which it allowed it to compete favorably with the resistant variety.

Wheat yields that followed a summer fallow period at any of the six sites are the only ones that can be expected to reflect the effects of cropping system in 1999. This crop year was still a transition year with yields reflecting both the effects of the new and old cropping systems. Therefore the reader should interpret the results with caution.

Corn and Sorghum

Corn yields following wheat averaged 61, 87, and 49 bu/A (3825, 5455, 3070 kg/ha) at Sterling, Stratton, and Walsh, respectively (Tables 11a & 11b). The above average August rainfall was critical, especially at Sterling and Stratton, where July rainfall was only about a third of the long-term normal. Corn yields at Sterling were near the 14-year average, 65 bu/A (4075 kg/ha), but were 11 bu/A (690 kg/ha) above the average at Stratton (Peterson et al. 1999). Corn production at Walsh was a failure from 1993-1996. In 1997 we planted a Bt corn to combat the Southwestern corn borer and were able to delay planting until mid-May. With this new technology corn yields have averaged 57 bu/A (3575 kg/ha) from 1997-1999.

As in all years, the toeslope soil position produced the highest corn yields at both sites (Tables 11a & 11b), except at Walsh where corn yields were basically the same on all soil positions. The favorable and well distributed precipitation in both July and August, 2.2 in.(56 mm) above normal, at Walsh compensated for the differences in stored soil water on the various positions.

Phosphorus fertilization had no effect on corn grain yield on any soil at any site (Tables 11a & 11b). Soil tests indicate that responses to P fertilizer are expected on the sideslopes, but are not likely on the summit positions. Recall that the entire experimental plot now receives P fertilizer when planted to wheat. Thus it appears that the carryover P to the corn from the fertilized wheat crop has diminished the chance for a response to P fertilizer applied to the corn crop at planting. However, a vegetative growth response usually is evident on the summit and sideslope positions. This "starter - P" response usually does not result in an increase in grain yields.

Corn yields at Briggsdale averaged 54 bu/A (3385 kg/ha) and 78 bu/A (4890 kg/ha) at Akron (Table 10). Excellent August rainfall at these sites was a significant factor at both sites. We have little experience with corn production in the Briggsdale area, but based on long-term July plus August precipitation records, we would expect that the 55 bu/A (3450 kg/ha) yield level is attainable over a period of years. Experience at Akron would indicate the long-term corn yield average will be near 70 bu/A (4390 kg/ha).

Sorghum yields at Walsh ranged from 40 to 73 bu/A (2500 to 4580 kg/ha) (Tables 11a & 11b). Sorghum following wheat averaged 62 bu/A (3890 kg/ha) which is 16 bu/A (1000 kg/ha) above the long-term average (Peterson et al. 1999). As with the corn the favorable July and August rainfall enhanced yields. Sorghum yields in the continuous row-crop system at Walsh (Tables 11a & 11b) have always been lower than sorghum after wheat.

We planted grain sorghum every year from 1986-1992. By 1992 the shatter cane weed problem was so severe that we chose to plant corn in 1993 to allow use of herbicides that could control the shatter cane. Two additional plots were added to the experiment in that same year so that we could test a rotation effect within the continuous row-crop system. This year the continuous row crop sorghum yielded 51, 58, and 50 bu/A (3200, 3640, and 3135 kg/ha) for the summit, sideslope and toeslope respectively. Continuous row crop corn yielded 44, 54, and 50 bu/A (2760, 3385, and 3135 kg/ha) for the summit, sideslope and toeslope respectively (Table 11a).

Phosphorus fertilizer did not affect grain sorghum yield on any soil or in any cropping system. The carryover of P applied to the previous wheat crop may be responsible for this observation, where sorghum follows wheat, but in the continuous row crop system a sorghum and corn yield response was expected on the summit and sideslope soils based on soil tests.

Sorghum yields at Lamar averaged 29 bu/A (1820 kg/ha) and did not differ for ungrazed and grazed treatments, respectively (Table 10).

Proso Millet

Proso millet yields at Akron averaged 2300 lbs/A (2575 kg/ha) (Table 10). This excellent yield was attainable because of the favorable August rainfall, 4 in. (102 mm) above the normal amount.

Sunflower

Sunflower was produced at both the Briggsdale and Akron sites (Table 10). Yields at Briggsdale averaged 1290 lbs/A (1445 kg/ha), which was excellent for the area. At Akron the crop failed because of herbicide damage. The Spartan herbicide rate that was applied was not compatible with the soil characteristics and thus killed the sunflower.

Soybean

Soybean was grown at Briggsdale, Sterling, Stratton and Walsh for the first time in 1999. Soybean is planted after corn in two systems, WCSb and WWCSb. We had limited soybean production experience from which to choose a variety, but settled on Asgrow 2301 based on two1998 variety trials we conducted at Sterling and Stratton.

Combine yields averaged 13 bu/A (875 kg/ha) at Briggsdale, 10 bu/A (670 kg/ha) at Sterling,15 bu/A (1000 kg/ha) at Stratton, and 11 bu/A (740 kg/ha) at Walsh (Tables 10, 16a, 16b, 17, 18, & 19). At $5.00/bu it requires about 11 bu/A to pay the out of pocket costs, and thus it is obvious that we had less than break even yields. On the positive side the Round Up Ready soybean allowed us to have excellent weed control; especially for sandbur which has been an increasing problem at Sterling and Walsh.

Using plant samples taken prior to the combining operation we determined that a 40% field loss occurred because of shattering and combine header loss. Thus average total yield produced was approximately 20 bu/A (1340 kg/ha), which if harvestable, would make the soybean profitable.

Opportunity Cropping

Opportunity cropping is an attempt to crop continuously without resorting to monoculture. It has no planned summer fallow periods, and is cropped as intensively as possible. In 1999 we grew corn in the opportunity system at Sterling and Stratton and sorghum at Walsh (Tables 11a, & 11b). Opportunity corn at Sterling and Stratton followed a 1998 wheat crop and thus yielded the same as corn in the WCF and WWCSb systems because it had equivalent soil water storage. Sorghum at Walsh followed a 1998 sorghum crop and yields were similar to the continuous row crop sorghum where sorghum follows a corn crop. However, opportunity sorghum yields averaged 12 bu/A (800 kg/ha) less than sorghum following wheat because of less opportunity to store soil water between seasons.

From the initiation of our project in fall 1985 we have grown 12, 12, and 10 crops in 14 years at Sterling, Stratton and Walsh, respectively in the opportunity system (Tables 17, 18 & 19). Productivity in opportunity cropping has been excellent. Note that in 14 years at the two northern sites the system has produced a total of 118 to 164 bushels of wheat, 368 to 427 bushels of corn or sorghum, and 4.7 tons of forage per acre. Crop productivity at Walsh over 14 years has been 93 bushels of wheat, 323 bushels of corn or sorghum, and 0.5 tons of forage. Two fallow years were included at Walsh and crops failed in two years, 1987 and 1990.

Using 1983-1999 average crop prices, the average total gross value of the 14 year production averaged over soils was $1456, $1724, and $1038 at Sterling, Stratton and Walsh, respectively (Tables 17, 18 & 19). Average total value (gross income) was $104, $123, and $74/A/year at Sterling, Stratton and Walsh, respectively. Suppose, for comparison purposes, you produced 40 bu/A wheat yields in a wheat-fallow system. Using the same wheat price per bushel, the average gross value would have been $63/A/year, since you only produce wheat on one-half of your acres each year. Obviously the opportunity cropping has an advantage in gross income compared to wheat-fallow at the two northern locations. If you had a wheat-corn-fallow system with 40 bu/A wheat and 70 bu/A corn yields, annual gross income would be $99/A/year, which is somewhat less than the $104 and $123/A/year produced in the opportunity system at Sterling and Stratton, respectively.

Above average annual precipitation has been a major factor contributing to the excellent productivity; annual precipitation has been 2 to 3 inches above the long-term averages for all sites during the 14 year study period. Therefore, growers should use extreme caution in extrapolating these results to their own operations. On the other hand, the systems could have been even more productive had we managed them more carefully. The missed crop at Sterling and Stratton in 1989 was a management mistake and not related to weather. The stored water was used by weeds that summer and thus functioned like crop removal in terms of the water budget.

Failure to produce a millet crop at Walsh in 1987 occurred because we chose proso millet, which is not a well adapted crop for that climate. A forage like sudex, for example, would have done well that year. Sunflowers at Walsh in 1990 failed because of jack rabbit damage, and not because of climatic factors. The fallows in 1993 and 1996, however, were necessary.

Our goal has been to produce wheat and corn or sorghum, the highest value crops, as frequently as possible in our systems. We have used forages to transition from row crops back to fall planted wheat. We harvest the forage and plant winter wheat that fall. Another good possibility is planting proso the year after corn or sorghum, harvesting it as early as possible, and then planting wheat immediately into the proso stubble. We are now planting soybean in our new systems and planting wheat right after soybean harvest.

Opportunity cropping has had about the same net income as the 3-year systems, but it has some properties that can be advantageous. For example it has the best residue cover of all systems, and weed control has been less of a problem in the opportunity system. The combination of crop competition and no fallow has reduced weed pressures compared to other systems. One major difference in weed pressure has been in regard to the invasion of the perennials, Tumblegrass (*Schedonnardis paniculata*) and Red Threeawn (*Aristada longiseta*), in our no-till systems.

All systems with fallows, especially WF and WC(S)F, have had devastating invasions of these grassy weeds and have required shallow sweep tillage to control these grasses. The opportunity system has remained free of these weeds. These particular perennial grasses are shallow rooted and cannot get established if surface soil water is low and if a crop is competing for the light. Fallow, where we are saving water and keeping the surface weed free, provides an excellent environment for their establishment. In contrast, opportunity cropping has no long fallows. Crop plants keep the soil surface dry much of the time and the two grassy invaders have not established.

Crop Residue Base

Maintenance of crop residue cover during non-crop periods and during seedling growth stages is vital to maximizing water storage in the soil. Crop residues provide protection from raindrop impact, slow runoff, and decrease water evaporation rates from the soil. Cover also greatly reduces erosion, both by wind and water.

Residue amount is being monitored by soil and crop within each system (Tables 22, 23 & 24). Residues present at planting are needed to protect the soil during the early plant growth stages when there is little canopy present. Residue levels are subject to annual variations in climate, both in terms of production and decomposition rates. Obviously, drier years decrease production but also may decrease decomposition rates. The net effect is difficult to assess because the particular portion of the year that is extra dry or wet will change the direction of the impact. Residue quantities always are largest on toeslopes at each site, which is a function of productivity level. Walsh, the most stressed site, usually has had the lowest residue levels over all years.

Cropping systems that involve a fallow period, like WCF or WSF, have minimum residue levels just prior to wheat planting because this time marks the end of the summer fallow period where decomposition has been occurring with no new additions of crop biomass. Therefore, cover is at its minimum, and erosion potential is at its maximum point. One of the advantages of our new continuous cropping systems is the avoidance of a year with no crop residue input. Residues present at wheat planting are given in Table 22. There were no obvious differences related to cropping system at any site in 1999. One might expect that the system with fallow, WC(S)F, may in the long-term have less residue than the continuously cropped systems. At corn planting, Table 23, the residue amounts did not appear to be affected by cropping system except for the opportunity system at all sites and the continuous cropped systems at Walsh. These had higher residue levels than all other systems. One would expect this because of the longer history of annual residue return in these systems. Residues at soybean planting, Table 24, did show any obvious relationship to cropping system.

Over the life of the experiment the opportunity cropping has resulted in more residue than all other systems. Two factors are responsible: (1) There is more addition of residue from the high intensity cropping; and (2) there is no summer fallow period with warm, moist soil conditions to encourage decomposition at the expense of addition. Over the past 14 years there have been crops produced in 12 of the 14 at Sterling and Stratton and in 10 of the 14 at Walsh. At Sterling and Stratton there was a large input of weed residues to the soil in one of the failed crop years, and thus residue inputs at these sites are even higher than indicated by harvested crop data.

Soil Water

Soil water supplies plant demand between rainfall events, but soils of eastern Colorado cannot store sufficient water to sustain a crop for the whole season, even if at field capacity at planting time. We monitor soil water in our systems to determine how efficiently various rotations and crops within rotations are using water. Our concern is how well precipitation is captured in non-crop periods, and subsequently how efficiently water is used for plant growth. Soil water at planting and harvest of each crop is shown by soil depth increment for each crop (Tables 25 to 35).

Wheat:

Soil profile available water was measured at all soil positions in all systems at wheat planting in the fall of 1998 (Tables 25-28). Our new systems represent different opportunities for water storage prior to wheat planting. The continuous cropping systems like WCSb and WWC(S)Sb should have the least amount of stored soil water at planting compared to the most in the WCF or WSF systems. Wheat after fallow in the WCF or WSF systems has had 12 months of time to store soil water. Second year wheat in the WWC(S)Sb system has had approximately 2 months (July and August) to store water prior to planting. Wheat in the WCSb and first year wheat in the WWC(S)Sb systems are planted immediately after soybean harvest and essentially have no time between crops to store soil water. In the latter cases, only rainfall received after soybean senescence and before wheat planting can be stored.

Wheat planted in fall 1998 in the continuously cropped systems followed proso millet or safflower, not soybean, because the new systems as originally planned included proso at Sterling and Stratton and safflower at Walsh. Soybean replaced proso and safflower in spring 1999. Data in Tables 25 - 28 reflect that in fall 1998 proso and safflower were the crops previous to the fall planted wheat. Also for the second year wheat in the WWCSb system was destroyed and only planting time water was measured. No water data for the WWSSb system at Walsh was measured at Walsh in the 1998-99 crop year.

As expected available water at planting was generally highest following fallow (Table 25) compared to the other systems (Tables 26-28). Water use by the wheat crop at Sterling averaged 145 mm in WCF, 42 mm in WCP, and 74 mm in (W)WCP. The main reason for the differences was directly related to the amount of available soil water at planting. Water use at Stratton followed the same pattern. At Walsh the wheat exhausted all available water from the soil profile with total crop water use again being directly related to amount present at wheat planting.

Note that the winter wheat plant can easily extract soil water from depths as great as 6 feet (150-180 cm). Note that some water was used from the deepest depth in all systems.

Corn and Sorghum:

Soil water contents at corn and sorghum planting ranged from average at Sterling to above average at the other sites in 1999 (Tables 29- 33). Higher than normal July and August precipitation at Stratton and Walsh allowed for above average soil water storage. Even the planting time soil water content in the continuous row crop system at Walsh was excellent (Table 33) because of the high rainfall in October 1998 and the above spring rainfall in 1999 prior to planting.

Soil depth distribution of the available soil water at corn and sorghum planting and harvest also is shown in these tables. Both corn and sorghum were extracting soil water from depths as deep as 155 cm (5-6 ft.), which has often been the case in previous years.

Opportunity:

Soil water data for the opportunity system, which was cropped to corn in 1999 at all sites, are shown in Table 32. All sites had excellent soil water contents at planting. At Sterling and Stratton the corn followed wheat and so one would expect a soil water profile like WCF. However, at Walsh the previous crop was sorghum and we would not expect much stored water to be present the next spring. From 1 October 1998 until planting in May the Walsh site received 14.7 in. (370 mm) of precipitation, which is 8 in. (200 mm) above the long-term average for that time period. All sites had some available water remaining at harvest, especially at Stratton where August rain was abundant in 1999.

Soybean:

Soil water contents at soybean planting were lower than at corn planting as would be expected, since soybean follows corn in both the WCSb and WWCSb systems and the corn usually depletes the available soil water (Tables 34-35). The long-term average precipitation from September, when corn water use is usually complete, until soybean planting near the end of May the following spring is 9.0, 8.5, and 8.7 in. at Sterling, Stratton, and Walsh, respectively. From September 1998 until May 31 1999 precipitation was 1.5, 2.3, and 6.0 in. above the average at Sterling, Stratton, and Walsh respectively. Thus in the 1999 crop year water storage possibilities before soybean were better than average, but even in average years the potential water storage is favorable. From corn harvest in fall 1998 until soybean planting in 1999 we stored 24, 44, and 33% of the precipitation at Sterling, Stratton, and Walsh respectively. We anticipated that the percentage of the precipitation that could be stored would be higher than this because climatic conditions during this storage period have low evaporation potential and the precipitation is of low intensity.

The soybean crop used soil water to depths as great as 155 cm at Walsh, but only to depths of 135 cm at Sterling and Stratton. Stored water profiles at Walsh were essentially exhausted by soybean harvest. These data indicate that wheat planted after the soybean will have little stored water for the fall and winter, and final yield will be highly dependent on spring rainfall.

Nitrogen Content of Grain and Stover

Nitrogen content was determined for both grain and stover for each crop on each soil at each original site (Tables 36-38) and N content of wheat grain was measured at each of the new sites (Tables 39a,b,c). The reader can calculate crude protein content of grain by multiplying wheat grain N content by 5.7; corn or sorghum grain N content by 6.3; and hay millet or triticale forage N by 6.3. All nutrient concentrations are on a dry weight basis, consequently crude protein levels will appear high compared to market levels. Therefore, a grain moisture correction must be applied to obtain market levels.

On a dry matter basis, wheat proteins averaged 12.8% at Sterling, 11.8% at Stratton, 11.6 % at Walsh, and 13.0% at Lamar (Tables 36a and 39a,b,). To correct these values for grain moisture content, multiply by 0.88, which results in an average of about 10.8% protein averaged over all sites at market moisture levels. Goos, et al. (1984) established that if grain protein levels were above 11.1%, yield was not likely to be limited by N deficiency. A comparison of 1999 wheat protein to this standard indicates that N fertilization was adequate for the wheat crop at Sterling, but short for the wheat crop at Stratton and Walsh.

Wheat straw N concentrations ranged from 0.21 to 0.83% and averaged 0.36 % at the original sites; thus each ton of straw contained about 7 lbs of N (Table 36b). There was no obvious relationship of straw N concentration and crop rotation at any site.

Nitrogen levels in corn and sorghum grain varied from 1.04 to 1.81 %, which is equivalent to 5.6 to 9.6% protein on a market moisture basis (Table 37a). Corn and sorghum stover N contents varied from 0.41 to 1.21% and averaged 0.69% (Table 37b). Each ton of corn or sorghum stalks thus contained an average of 14 lbs of N.

Nitrogen levels in soybean grain (Table 38a) ranged from 5.15 to 6.39%, which is equivalent to 28 to 35% crude protein at market moisture content of the grain. Stover ranged from 0.55 to

1.21%, which is only slightly higher than the N concentration in corn stover or wheat straw (Table 38b). Since soybean stover yields are about 70% less than those of corn or wheat, the N carryover after soybean is smallest of all crops in our systems.

Soil Nitrate-Nitrogen

Residual soil NO_3-N analyses are routinely conducted on soil profile samples (0-6 ft or 0-180 cm) taken prior to planting for each crop, except for soybean, on each soil at each site (Table 40). These analyses are used to make fertilizer N applications for a particular crop on each soil at each site. Accumulation of residual nitrate allows reduction in the fertilizer rate. By using residual soil nitrate analyses of the root zone we also can determine if nitrate is leaching beneath the root zone. With improved precipitation-use efficiency in the more intensive crop rotations, the amount of nitrate escaping the root zone should be minimized. In the first 12 years of experimentation we found that the wheat-fallow system generally had higher residual nitrates than the 3- or 4-year rotations at the end of fallow prior to wheat planting.

At fall wheat planting in 1998 the amount of nitrate-nitrogen present varied from site to site, but rotation effects were not consistent at a given site or over soils. We would expect soil nitrate levels at wheat planting to be highest after fallow in systems like WCF and WSF, but since the WCSb and WWCSb systems have only been in place two years it is not possible to draw definite conclusions from the data.

Soil nitrates at corn and sorghum planting of were similar to those observed in most years. It is apparent that NO_3-N is not accumulating in the soil profile of any cropping system, which indicates that no system is over-fertilized. If fertilizer N is not used by wheat for example, it is used by the subsequent corn or sorghum crop. The carry-over N is accounted for in the soil test used and reduces the amount of fertilizer N applied to the crop. In the long-term, the systems with soybean should be the most N efficient because the soybean removes nitrate-nitrogen in addition to the amount fixed symbiotically during its growth period.

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Table 4. Nitrogen fertilizer application by soil and crop for 1999.

SITE	SOIL	CROP	WCF	WCSb	WWCSb	OPP	
			ROTATION				
			--------------------------Lbs/A--------------------------				
Sterling	Summit	Wheat	72	72	72		
	Sideslope	"	72	72	72		
	Toeslope	"	72	72	72		
	Summit	Corn	101	101	101	101	
	Sideslope	"	101	101	101	101	
	Toeslope	"	101	101	101	101	
	Summit	Soybean	-	6	6		
	Sideslope	"	-	6	6		
	Toeslope	"	-	6	6		
			WCF	WCSb	WWCSb	OPP	
Stratton	Summit	Wheat	65	65	65		
	Sideslope	"	65	65	65		
	Toeslope	"	65	65	65		
	Summit	Corn	101	101	101	101	
	Sideslope	"	101	101	101	101	
	Toeslope	"	101	101	101	101	
	Summit	Soybean	-	6	6		
	Sideslope	"	-	6	6		
	Toeslope	"	-	6	6		
			WSF	WCSb	WWSSb	OPP	CONT. CROP
Walsh	Summit	Wheat	45	45	45	-	-
	Sideslope	"	45	45	45	-	-
	Toeslope	"	45	45	45	-	-
	Summit	Sorghum	51	-	51	-	51
	Sideslope	"	51	-	51	-	51
	Toeslope	"	51	-	51	-	51
	Summit	Corn	-	106	-	101	101
	Sideslope	"	-	106	-	101	101
	Toeslope	"	-	106	-	101	101
	Summit	Soybean	-	6	6	-	-
	Sideslope	“	-	6	6	-	-
	Toeslope	“	-	6	6	-	-

Table 5a. Monthly precipitation for the original sites for the 1998-99 growing season.

MONTH	LOCATION					
	STERLING		STRATTON		WALSH	
	Inches					
1998	1998	Normals[1]	1998	Normals[1]	1998	Normals[1]
JULY	4.37	3.23	5.14	2.80	3.43	2.62
AUGUST	1.07	1.90	2.86	2.60	4.86	1.96
SEPTEMBER	1.87	1.04	0.30	1.45	0.25	1.74
OCTOBER	1.87	0.76	1.03	0.85	2.71	0.89
NOVEMBER	0.91	0.50	1.01	0.62	0.95	0.53
DECEMBER	0.40	0.40	0.90	0.28	0.03	0.31
SUBTOTAL	10.49	7.83	11.24	8.60	12.23	8.05
1999	1999	Normals	1999	Normals	1999	Normals
JANUARY	0.30	0.33	0.29	0.28	1.12	0.27
FEBRUARY	0.22	0.33	0.21	0.30	0.11	0.28
MARCH	0.21	1.07	0.70	0.76	2.79	0.81
APRIL	2.27	1.60	4.08	1.23	2.88	1.15
MAY	2.73	3.27	2.23	2.70	3.79	2.69
JUNE	2.74	3.00	2.22	2.45	0.77	2.29
SUBTOTAL	8.47	9.60	9.73	7.72	11.46	7.49
1999	1999	Normals	1999	Normals	1999	Normals
JULY	0.95	3.23	1.00	2.80	3.05	2.62
AUGUST	4.51	1.90	5.50	2.60	3.75	1.96
SEPTEMBER	1.58	1.04	1.05	1.45	2.25	1.74
OCTOBER	0.24	0.76	0.29	0.85	0.89	0.89
NOVEMBER	0.21	0.50	0.29	0.62	0.53	0.53
DECEMBER	0.55	0.40	0.37	0.28	0.31	0.31
SUBTOTAL	8.04	7.83	8.50	8.60	10.78	8.05
YEAR TOTAL	16.51	17.43	18.23	16.32	22.24	15.54
18 MONTH TOTAL	27.00	25.26	29.47	24.92	34.47	23.59

[1]Normal = 1961-1990 data base

Table 5b. Monthly precipitation for the three new sites for the 1998-99 growing season.

MONTH	BRIGGSDALE		AKRON		LAMAR	
	Inches					
1998	1998	Normals[1]	1998	Normals[1]	1998	Normals[1]
JULY	4.52	2.63	3.84	2.73	7.88	2.23
AUGUST	1.28	1.77	2.44	2.04	4.07	1.85
SEPTEMBER	1.03	1.29	0.35	0.98	0.72	1.33
OCTOBER	1.81	0.70	0.95	0.60	1.44	0.71
NOVEMBER	0.42	0.36	0.81	0.56	1.63	0.56
DECEMBER	0.64	0.27	0.21	0.32	0.22	0.40
SUBTOTAL	9.70	7.02	8.60	7.23	15.96	7.08
1999	1999	Normals	1999	Normals	1999	Normals
JANUARY	0.17	0.26	0.07	0.33	1.12	0.42
FEBRUARY	0.00	0.18	0.15	0.30	0.12	0.42
MARCH	0.50	0.75	0.28	0.91	2.25	0.90
APRIL	4.92	1.27	2.26	1.32	3.06	1.15
MAY	1.29	2.08	2.16	3.25	3.76	2.50
JUNE	2.14	2.10	3.44	2.62	2.42	2.19
SUBTOTAL	9.02	6.64	8.36	8.73	12.73	7.58
1999	1999	Normals	1999	Normals	1999	Normals
JULY	1.65	2.63	2.70	2.73	1.43	2.23
AUGUST	4.33	1.77	6.45	2.04	2.62	1.85
SEPTEMBER	2.63	1.29	1.59	0.98	0.66	1.33
OCTOBER	0.39	0.70	0.72	0.60	0.13	0.71
NOVEMBER	0.18	0.36	0.53	0.56	0.12	0.56
DECEMBER	0.00	0.27	0.37	0.32	0.05	0.40
SUBTOTAL	9.18	7.02	12.36	7.23	5.01	7.08
YEAR TOTAL	18.20	13.66	20.72	15.96	17.74	14.66
18 MONTH TOTAL	27.90	20.68	29.32	23.19	33.70	21.74

[1]Normal = 1961-1990 data base

Table 5c. Precipitation by growing season segments for Sterling from 1987-1999.

	Growing Season Segments			
	Wheat		Corn	
	Vegetat. Sep - Mar	Reprod. Apr - Jun	Preplant Jul - Apr	Growing Season May - Oct
Year	Inches			
1987-88	5.2	9.9	11.1	15.8
1988-89	3.1	6.5	10.5	14.3
1989-90	5.1	4.7	11.8	13.0
1990-91	3.8	7.2	12.3	11.7
1991-92	4.5	4.8	9.1	14.8
1992-93	4.5	6.2	15.5	10.6
1993-94	6.4	3.0	10.2	6.1
1994-95	7.3	14.4	9.6	17.2
1995-96	4.2	9.2	7.5	18.0
1996-97	4.7	7.0	10.6	21.4
1997-98	5.5	4.9	16.7	13.8
1998-99	5.8	7.7	13.5	12.8
Long Term Average	4.4	7.9	11.2	13.2

Table 5d. Precipitation by growing season segment for Stratton from 1987 -1999.

	Growing Season Segments			
	Wheat		Corn	
	Vegetat. Sep - Mar	Reprod. Apr - Jun	Preplant Jul - Apr	Growing Season May - Oct
Year	Inches			
1987-88	4.3	7.2	8.8	12.6
1988-89	3.0	9.4	5.3	15.5
1989-90	5.3	6.1	11.0	13.4
1990-91	4.4	4.1	10.7	14.7
1991-92	3.3	6.1	14.2	13.6
1992-93	3.3	3.8	11.8	14.7
1993-94	4.3	7.8	16.7	13.5
1994-95	7.0	10.0	14.8	13.7
1995-96	3.5	6.0	8.1	14.5
1996-97	2.9	6.2	12.2	23.2
1997-98	8.0	5.9	22.6	13.9
1998-99	4.4	8.5	15.6	12.3

Long Term Average	4.5	6.4	11.2	12.9

Table 5e. Precipitation by growing season segment for Walsh from 1987-1999.

	Growing Season Segments			
	Wheat		Sorghum	
	Vegetat.	Reprod.	Preplant	Growing Season
	Sep - Mar	Apr - Jun	Jul - Apr	May - Oct
Year	Inches			
1987-88	4.3	7.6	7.4	11.1
1988-89	4.1	11.5	8.1	20.2
1989-90	5.7	7.4	14.1	12.5
1990-91	5.0	7.7	11.7	12.2
1991-92	2.7	5.8	7.1	13.2
1992-93	6.1	9.2	13.8	14.5
1993-94	3.2	5.3	8.7	16.3
1994-95	4.6	7.2	16.6	7.2
1995-96	1.7	3.5	1.9	17.1
1996-97	5.8	5.3	17.2	11.3
1997-98	6.9	2.3	12.3	13.3
1998-99	8.2	7.4	19.4	14.5
Long Term Average	4.8	6.1	10.6	12.2

Table 5f. Precipitation by growing season segment for Briggsdale from 1997-1999.

	Wheat		Sorghum	
	Vegetat. Sep - Mar	Reprod. Apr - Jun	Preplant Jul - Apr	Growing Season May - Oct
Year	Inches			
1997-98	3.9	3.9	11.6	11.9
1998-99	4.6	8.4	15.3	12.4
Long Term Average	3.8	5.5	9.5	10.6

Table 5g. Precipitation by growing season segment for Akron from 1997-1999.

	Wheat		Sorghum	
	Vegetat. Sep - Mar	Reprod. Apr - Jun	Preplant Jul - Apr	Growing Season May - Oct
Year	Inches			
1997-98	5.6	2.1	11.1	6.5
1998-99	2.8	7.9	11.4	17.1
Long Term Average	4.0	7.2	10.1	12.2

Table 5h. Precipitation by growing season segment for Lamar from 1997-1999.

	Wheat		Sorghum	
	Vegetat. Sep - Mar	Reprod. Apr - Jun	Preplant Jul - Apr	Growing Season May - Oct
Year	Inches			
1997-98	10.5	2.6	19.4	15.9
1998-99	7.5	9.2	22.5	11.0
Long Term Average	4.7	5.8	10.0	10.8

Table 6a. Grain and stover yields for WHEAT in English units in 1999.

SITE & ROTATION	SUMMIT GRAIN NP*	SUMMIT GRAIN NP	SUMMIT STOVER NP*	SUMMIT STOVER NP	SIDESLOPE GRAIN NP*	SIDESLOPE GRAIN NP	SIDESLOPE STOVER NP*	SIDESLOPE STOVER NP	TOESLOPE GRAIN NP*	TOESLOPE GRAIN NP	TOESLOPE STOVER NP*	TOESLOPE STOVER NP
STERLING:	Bu./A.		lbs./A.		Bu./A.		lbs./A.		Bu./A.		lbs./A.	
WCF	35	37	3108	3297	37	43	3037	3423	46	45	4016	4470
WCSb	33	33	2730	2858	25	24	2142	2098	29	33	2601	2911
(W)WCSb	27	31	2225	2583	29	28	2807	2518	28	31	2668	2792
W(W)CSb	No Harvest				No Harvest				No Harvest			
STRATTON:	Bu./A.		lbs./A.		Bu./A.		lbs./A.		Bu./A.		lbs./A.	
WCF	53	57	5212	5462	37	39	3694	3941	49	51	5382	9001
WCP	32	40	2829	3727	23	31	2053	2227	34	34	3994	4273
(W)WCSb	35	34	3054	2847	30	31	2660	2820	45	43	5008	4280
W(W)CSb	No Harvest				No Harvest				No Harvest			
WALSH:	Bu./A.		lbs./A.		Bu./A.		lbs./A.		Bu./A.		lbs./A.	
WSF	55	48	6885	5521	53	52	5512	5415	53	55	6296	6186
WCSb	37	42	3642	4015	41	50	4046	4697	50	53	5187	5880
(W)WSSa	34	40	3194	3847	34	38	3102	3353	36	38	3206	3509
W(W)SSa	51	56	5446	6369	48	53	4586	5132	53	52	5234	4938

1. Wheat grain yield expressed at 12% moisture.
* Only receives phosphorus in wheat phase of each rotation.

Table 6b. Grain, stover and total biomass yields for WHEAT in 1999.

SITE & ROTATION	SLOPE POSITION																	
	SUMMIT						SIDE						TOE					
	GRAIN		*STOVER*		*TOTAL*		*GRAIN*		*STOVER*		*TOTAL*		*GRAIN*		*STOVER*		*TOTAL*	
	NP*	NP	NP*	NP	NP*	NP	NP*	NP	NP*	NP	NP*	NP	NP*	NP	NP*	NP	NP*	NP
STERLING:	------------------kg/ha--------------------						---------------------kg/ha--------------------						-------------------kg/ha--------------------					
WCF	2324	2458	3481	3692	5526	5855	2494	2873	3401	3833	5596	6361	3106	3030	4498	5007	7232	7673
WCSb	2195	2248	3058	3201	4990	5179	1653	1643	2399	2350	3854	3795	1940	2218	2913	3261	4621	5212
(W)WCSb	1800	2078	2276	2893	4076	4722	1917	1904	3144	2820	4831	4495	1901	2052	2988	3128	4660	4933
W(W)CSb	No Harvest						No Harvest						No Harvest					
STRATTON:	------------------kg/ha--------------------						---------------------kg/ha--------------------						-------------------kg/ha-------------------					
WCF	3586	3820	5837	6118	8993	9480	2474	2648	4137	4414	6315	6744	3316	3426	6028	10081	8946	13096
WCSb	2131	2693	3169	4174	5044	6544	1536	2115	2299	2494	3651	4356	2312	2290	4473	4786	6508	6801
(W)WCSb	2365	2303	3420	3189	5501	5216	2027	2075	2979	3158	4762	4984	3015	2883	5609	4794	8263	7331
W(W)CSb	No Harvest						No Harvest						No Harvest					
WALSH:	------------------kg/ha--------------------						---------------------kg/ha--------------------						-------------------kg/ha-------------------					
WSF	3674	3205	7711	6184	10944	9004	3539	3520	6174	6065	9288	9163	3586	3701	7051	6929	10206	10186
WCSb	2477	2828	4079	4497	6259	6985	2788	3339	4532	5261	6985	8200	3390	3542	5810	6586	8793	9703
(W)WSSb	2315	2706	3577	4308	5614	6690	2306	2553	3475	3755	5504	6001	2408	2539	3591	3930	5710	6164
W(W)SSb	3424	3741	6099	7133	9112	10425	3224	3563	5136	5748	7973	8883	3566	3479	5862	5531	9000	8592

* Only receives phosphorus in wheat phase of each rotation.

Table 7. Wheat yields by rotation at optimum fertility by year year and soil position at STERLING from 1998-1999.

	ROTATION	SUMMIT	SIDE	TOE	MEAN
			SLOPE POSITION		
		---------------------------------Bu/A----------------------------			
1998	WCF	28	16	40	28
	WCP	32	33	30	32
	(W)WCP	----------------No yield-------------			
	W(W)CP	32	36	46	38
1999	WCF	36	40	46	41
	WCSb	33	24	31	29
	(W)WCSb	29	28	29	29
	W(W)CSb	----------------No yield-------------			
MEAN	WCF	32	28	43	34
	WCSb	32	28	30	30
	(W)WCSb	29	28	29	29
	W(W)CSb	32	36	46	38

Table 8. Wheat yields by rotation at optimum fertility by year and year and soil position at STRATTON from 1998-1999.

	ROTATION	SUMMIT	SIDE	TOE	MEAN
			SLOPE POSITION		
		---------------------------------Bu/A----------------------------			
1998	WCF	37	29	51	39
	WCP	34	34	48	39
	(W)WCP	35	31	40	35
	W(W)CP	37	39	51	42
1999	WCF	55	38	50	48
	WCSb	36	27	34	32
	(W)WCSb	34	30	44	36
	W(W)CSb	----------------No yield-------------			
MEAN	WCF	46	34	50	43
	WCSb	35	30	41	35
	(W)WCSb	34	30	42	35
	W(W)CSb	37	39	51	42

Table 9. Wheat yields by rotation at optimum fertility by year and year and soil position at WALSH from 1998-1999.

	ROTATION	SLOPE POSITION SUMMIT	SIDE	TOE	MEAN
		--------------------------------- Bu/A----------------------------			
1998	WSF	31	31	38	33
	WCSf	25	31	40	32
	(W)WSSf	8	12	20	13
	W(W)SSf	27	29	32	29
1999	WSF	52	52	54	53
	WCSb	40	46	52	46
	(W)WSSb	37	36	37	37
	W(W)SSb	54	50	52	52
MEAN	WSF	42	42	46	43
	WCSb	32	38	46	39
	(W)WSSb	37	36	37	37
	W(W)SSb	40	40	42	41

Table 10. Grain yields for the Briggsdale-Nunn, Akron and Lamar sites for 1999.

Site & Crop	**Previous Crop**			
Briggsdale-Nunn	**Wheat**	**Millet**	**Fallow**	
	--Bu/A or lbs/A--			
Wheat - HALT variety (At Nunn)			65	
Wheat - AKRON variety (At Nunn)			72	
Corn (At Briggsdale)	56	52		
Soybean (At Briggsdale)	16	10		
Hay Millet (At Briggsdale)	4380	3810		
Sunflower (At Briggsdale)	1410	1170		
Akron	**Previous Crop**			
	Wheat	**Corn**	**Millet**	**Fallow**
	--Bu/A or lbs/A--			
Wheat - HALT variety				39
Wheat - TAM 107 variety				43
Corn	78			
Sunflower			No Yield	
Proso Millet		2300		
Lamar	**Wheat-Fallow**		**Wheat-Sorghum-Fallow**	
	Grazed	**Ungrazed**	**Grazed**	**Ungrazed**
	--Bu/A--			
Wheat - PROWERS variety	32	35	36	39
Wheat - LAMAR variety	40	41	39	42
Grain Sorghum			29	

Table 11a. Grain and stover yields for CORN AND SORGHUM in English units in 1999.

SITE & ROTATION	SLOPE POSITION											
	SUMMIT				SIDESLOPE				TOESLOPE			
	GRAIN		STOVER		GRAIN		STOVER		GRAIN		STOVER	
	N	NP	N	NP	N	NP	N	NP	N	NP	N	NP
STERLING:	---- Bu./A. ----		---- lbs./A. ----		---- Bu./A. ----		---- lbs./A. ---		---- Bu./A. ----		---- lbs./A. ----	
WCF	64	47	3949	1893	61	64	2993	2645	87	75	3768	2733
WCSb	53	46	2398	2063	61	51	2532	2464	75	66	3951	2782
WWCSb	38	40	3130	2469	65	54	2749	2789	86	76	3577	3322
OPP	55	55	3289	4153	69	65	2623	2854	72	61	2650	2187
	N	NP	N	NP	N	NP	N	NP	N	NP	N	NP
STRATTON:	---- Bu./A. ----		---- lbs./A.----		---- Bu./A. ----		---- lbs./A. ---		---- Bu./A. ----		---- lbs./A. ---	
WCF	88	87	3203	2787	79	82	2220	2412	100	101	3984	3959
WCSb	64	82	2292	2433	69	71	2519	2215	94	98	3246	3741
WWCSb	79	84	2495	2582	79	92	2156	3043	116	101	4348	3813
OPP	83	103	3202	3335	75	84	2197	2237	98	113	3312	3953
	N	NP	N	NP	N	NP	N	NP	N	NP	N	NP
WALSH:	----- Bu./A. ----		--- lbs./A. ----		---- Bu./A. ----		--- lbs./A. ----		---- Bu./A. ---		---- lbs./A. ---	
WSF	62	65	1778	1986	64	73	1815	2421	59	61	2039	2622
WCSb	30	46	1531	1898	44	65	1936	2618	52	56	2837	2715
WWSSb	56	59	1780	2272	71	67	2131	1990	51	57	1235	1609
OPP(Sorghum)	51	47	2394	2443	54	53	2684	4070	41	38	2728	2997
CS (Corn)	44	45	1245	1676	49	58	1677	2321	54	46	1384	1227
CS (Sorghum)	49	54	2233	3994	65	52	2816	2668	47	43	2408	2913

1. Corn grain yield expressed at 15.5% moisture.
2. Sorghum grain yield expressed at 14% moisture.

Table 11b. Grain, stover and total biomass yields for CORN and SORGHUM in 1999.

SITE & ROTATION	SLOPE POSITION																	
	SUMMIT						SIDE						TOE					
	GRAIN		STOVER		TOTAL		GRAIN		STOVER		TOTAL		GRAIN		STOVER		TOTAL	
	N	NP	N	NP	N	NP	N	NP	N	NP	N	NP	N	NP	N	NP	N	NP
STERLING:	kg/ha						kg/ha						kg/ha					
WCF	4043	2950	4128	1979	7545	4472	3843	3985	3129	2765	6376	6133	5449	4709	3938	2857	8543	6836
WCSb	3355	2900	2506	2157	5342	4607	3854	3202	2647	2575	5904	5281	4681	4132	4131	2908	8086	6400
WWCSb	2410	2485	3272	2581	5308	4681	4074	3397	2874	2915	6316	5786	5379	4775	3739	3473	8285	7508
OPP	3441	3444	3438	4341	6346	7251	4308	4103	2742	2984	6383	6451	4520	3801	2770	2286	6590	5498
	N	NP	N	NP	N	NP	N	NP	N	NP	N	NP	N	NP	N	NP	N	NP
STRATTON:	kg/ha						kg/ha						kg/ha					
WCF	5519	5484	3349	2914	8012	7547	4958	5158	2320	2521	6510	6879	6302	6312	4164	4139	9490	9472
WCSb	3993	5140	2396	2543	5770	6887	4307	4439	2633	2316	6272	6067	5887	6165	3393	3911	8367	9120
WWCSb	4943	5296	2608	2699	6785	7174	4953	5751	2254	3181	6439	8040	7271	6344	4545	3986	10689	9346
OPP	5179	6491	3348	3487	7724	8971	4678	5239	2296	2339	6249	6765	6135	7099	3462	4132	8645	10131
	N	NP	N	NP	N	NP	N	NP	N	NP	N	NP	N	NP	N	NP	N	NP
WALSH:	kg/ha						kg/ha						kg/ha					
WSF	3867	4049	1859	2076	5126	5498	4017	4568	1897	2531	5291	6391	3702	3824	2132	2741	5260	5973
WSSb	1904	2876	1600	1984	3210	4414	2790	4079	2024	2737	4382	6184	3239	3485	2965	2838	5703	5783
WWSSb	3518	3715	1860	2375	4833	5514	4446	4213	2227	2081	5984	5641	3187	3563	1291	1681	3984	4692
OPP	3199	2974	2502	2554	5205	5067	3394	3325	2806	4255	5674	7065	2592	2399	2851	3132	5042	5160
CS (Corn)	2777	2841	1301	1752	3648	4153	3093	3626	1753	2426	4366	5490	3418	2873	1447	1283	4335	3711
CS(Sorghum	3071	3382	2334	4175	4929	7033	4064	3276	2943	2789	6377	5557	2947	2713	2517	3045	5008	5337

Table 12. Corn yields by rotation at optimum fertility by year and soil position at STERLING from 1998-1999.

YEAR	ROTATION	SUMMIT	SIDE	TOE	MEAN
		SLOPE POSITION			
		--------------------------------Bu/A----------------------------			
1998	WCF	50	44	54	49
	WCSb	56	71	96	74
	WWCSb	44	55	84	61
1999	WCF	56	62	81	66
	WCSb	50	56	70	59
	WWCSb	39	67	66	57
MEAN	WCF	53	53	68	58
	WCSb	53	64	83	67
	WWCSb	42	61	75	59

Table 13. Corn yields by rotation at optimum fertility by year and soil position at STRATTON from 1998-1999.

YEAR	ROTATION	SUMMIT	SIDE	TOE	MEAN
		SLOPE POSITION			
		--------------------------------Bu/A----------------------------			
1998	WCF	122	94	117	111
	WCSb	110	94	124	109
	WWCSb	122	100	117	113
1999	WCF	88	80	100	89
	WCSb	73	70	96	80
	WWCSb	82	86	108	92
MEAN	WCF	105	87	108	100
	WCSb	92	82	110	95
	WWCSb	102	91	112	102

Table 14. Sorghum and corn yields by rotation at optimum fertility by and soil position at WALSH from 1998-1999.

YEAR	ROTATION	SLOPE POSITION SUMMIT	SIDE	TOE	MEAN
		---------------------------------Bu/A----------------------------			
1998	WSF	60	76	76	71
	WCSb	38	56	100	65
	WWCSb	61	74	80	72
	Cont. Row C	54	62	80	65
	Cont. Row S	60	64	60	61
1999	WCF	64	68	60	64
	WCSb	46	65	54	55
	WWCSb	59	70	54	61
	Cont. Row C	45	58	50	51
	Cont. Row S	52	58	45	52
MEAN	WCF	62	72	68	67
	WCSb	42	60	77	60
	WWCSb	60	72	67	66
	Cont. Row C	50	60	65	58
	Cont. Row S	56	61	52	56

Table 15a. Grain and stover yields for Soybean at Sterling, Stratton and Walsh in English units in 1999.

SITE & ROTATION	SLOPE POSITION: SUMMIT GRAIN		SUMMIT STOVER		SIDESLOPE GRAIN		SIDESLOPE STOVER		TOESLOPE GRAIN		TOESLOPE STOVER	
	N	NP	N	NP	N	NP	N	NP	N	NP	N	NP
STERLING:	------ Bu./A. ------		------ lbs./A. ------		------ Bu./A. ------		------ lbs./A. ------		------ Bu./A. ------		------ lbs./A. ------	
WCSb	6	14	477	1175	9	9	535	481	13	9	1086	586
WWCSb	10	11	791	923	12	12	836	721	8	10	835	753
	N	NP	N	NP	N	NP	N	NP	N	NP	N	NP
STRATTON:	------ Bu./A. ------		------ lbs./A. ------		------ Bu./A. ------		------ lbs./A. ------		------ Bu./A. ------		------ lbs./A. ------	
WCSb	14	15	639	706	8	9	517	396	18	19	1399	1571
WWSb	12	18	659	940	8	12	365	609	21	24	3136	1895
	N	NP	N	NP	N	NP	N	NP	N	NP	N	NP
WALSH:	--------Bu/A------		--------lbs./A------		--------Bu/A------		------ lbs./A. ------		--------Bu/A------		------ lbs./A. ------	
WSSb	8	8	475	630	11	11	664	655	17	14	1446	1361
WWSSb	7	10	419	567	8	12	451	706	14	13	1331	1046

1. Soybean yield expressed at 13.0% moisture.

Table 15b. Grain and stover yields for Soybean at Sterling, Stratton and Walsh in 1999.

SITE & ROTATION	SUMMIT						SIDESLOPE						TOESLOPE					
	GRAIN		STOVER		TOTAL		*GRAIN*		STOVER		*TOTAL*		*GRAIN*		*STOVER*		TOTAL	
	N	NP	N	NP	N	NP	N	NP	N	NP	N	NP	N	NP	N	NP	N	NP
STERLING:	kg/ha						kg/ha						kg/ha					
WCSb	383	973	535	1316	868	2162	619	618	600	539	1138	1076	890	595	1216	657	1990	1175
WWCSb	676	750	886	1034	1474	1686	829	804	937	807	1658	1506	561	671	935	843	1423	1427
	N	NP	N	NP	N	NP	N	NP	N	NP	N	NP	N	NP	N	NP	N	NP
STRATTON:	kg/ha						kg/ha						kg/ha					
WCSb	956	992	715	790	1547	1653	542	578	579	444	1051	947	1210	1289	1566	1759	2620	2881
WWSb	794	1181	738	1053	1429	2080	527	787	409	682	868	1367	1390	1633	3513	2123	4722	3544
	N	NP	N	NP	N	NP	N	NP	N	NP	N	NP	N	NP	N	NP	N	NP
WALSH:	kg/ha						kg/ha						kg/ha					
WSSb	562	529	533	706	1022	1166	752	736	744	734	1398	1374	1163	959	1619	1524	2631	2430
WWSSb	471	648	469	635	879	1198	548	796	505	791	982	1483	937	898	1491	1172	2306	1953

SLOPE POSITION

1. Soybean yield expressed at 13.0% moisture.

Table 16. Soybean yields by rotation at optimum fertility by year and soil postion at STERLING from 1998-1999.

YEAR	ROTATION	SUMMIT	SIDE	TOE	MEAN
		---------------------------------Bu/A----------------------------			
1999	WCSb	10	9	11	10
	WWCSb	10	12	9	10
MEAN	WCSb	10	9	11	10
	WWCSb	10	12	9	10

Table 17. Soybean yields by rotation at optimum fertility by year and soil postion at STRATTON from 1998-1999.

YEAR	ROTATION	SUMMIT	SIDE	TOE	MEAN
		---------------------------------Bu/A----------------------------			
1999	WCSb	14	8	18	13
	WWCSb	15	10	22	16
MEAN	WCSb	14	8	18	13
	WWCSb	15	10	22	16

Table 18. Soybean yields by rotation at optimum fertility by year and soil postion at WALSH from 1998-1999.

YEAR	ROTATION	SUMMIT	SIDE	TOE	MEAN
		--------------------------------Bu/A---------------------------			
1999	WCSb	8	11	16	12
	WWSSb	8	10	14	11
MEAN	WCSb	8	11	16	12
	WWSSb	8	10	14	11

Table 19. Grain and forage yields in the opportunity cropping system at STERLING.

YEAR	CROP	SLOPE POSITION			
		SUMMIT	SIDE	TOE	MEAN
		----------------------Bu/A or T/A----------------------			
1986	Wheat	27	25	28	27
1987	Corn	46	59	70	58
1988	Corn	52	60	63	58
1989	Attempted Hay Millet	0	0	0	0
1990	Wheat	29	40	42	37
1991	Corn	57	69	105	77
1992	Hay Millet	2.35	2.45	3.17	2.66
1993	Corn	30	37	44	37
1994	Sunflower	0	0	0	0
1995	Wheat	25	31	32	29
1996	Corn	68	72	84	75
1997	Hay Millet	2.22	1.97	1.98	2
1998	Wheat	24	24	26	25
1999	Corn	55	67	66	63
Total Yields	Wheat (4)	105	120	128	118
	Corn (6)	308	364	432	368
	Forage (3)	4.57	4.42	5.15	4.71
	Sunflower (1)	0	0	0	0
		------------------------------$------------------------------			
Value*	Wheat (4)	331.80	379.20	404.48	372.88
	Corn (6)	748.44	884.52	1049.76	894.24
	Forage (3)	182.80	176.80	206.00	188.53
	Sunflower (1)	0.00	0.00	0.00	0.00
Total Value for 14 Years		1263.04	1440.52	1660.24	1455.65

*Wheat @ $3.16/Bu; Corn @ $2.43/bu; Sorghum @ $2.14/Bu;
Hay Millet & Forage @ $40.00/T (1989-1997 average prices)

Table 20. Grain and forage yields in the opportunity cropping system at STRATTON.

YEAR	CROP	SLOPE POSITION			
		SUMMIT	SIDE	TOE	MEAN
		---------------------Bu/A or T/A---------------------			
1986	Wheat	32	29	23	28
1987	Sorghum	31	34	51	39
1988	Sorghum	30	28	52	37
1989	Attempted Hay Millet	0	0	0	0
1990	Wheat	45	32	78	52
1991	Corn	89	75	114	93
1992	Hay Millet	2.75	2.52	2.55	2.61
1993	Corn	47	54	44	48
1994	Sunflower	0	0	0	0
1995	Wheat	55	47	50	51
1996	Corn	110	118	124	117
1997	Hay Millet	2.37	2.34	1.55	2.09
1998	Wheat	30	32	40	34
1999	Corn	93	80	106	93
Total	Wheat (4)	162	140	191	164
Yields	Corn & Sorghum (6)	400	389	491	427
	Forage (3)	5.12	4.86	4.10	4.69
	Sunflower (1)	0	0	0	0
		-----------------------------$----------------------------			
Value*	Wheat (4)	511.92	442.40	603.56	518.24
	Corn (5)	954.31	927.29	1163.26	1014.95
	Forage (3)	204.80	194.40	164.00	187.73
	Sunflower (1)	0.00	0.00	0.00	0.00
Total Value for 14 Years		1671.03	1564.09	1930.82	1720.93

*Wheat @ $3.16/Bu; Corn @ $2.43/bu; Sorghum @ $2.14/Bu;
Hay Millet & Forage @ $40.00/T (1989-1997 average prices)

Table 21. Grain and forage yields in the opportunity cropping system at WALSH.

YEAR	CROP	SLOPE POSITION			
		SUMMIT	SIDE	TOE	MEAN
		---Bu/A or T/A---			
1986	Sorghum	34	25	42	34
1987	Millet	0	0	0	0
1988	Forage	0.39	0.32	0.71	0.47
1989	Sorghum	18	38	82	46
1990	Sunflower	0	0	0	0
1991	Wheat	40	38	44	41
1992	Corn	45	46	56	49
1993	Fallow	0	0	0	0
1994	Wheat	32	37	46	38
1995	Wheat	13	12	18	14
1996	Fallow	0	0	0	0
1997	Corn	54	63	83	67
1998	Sorghum	72	80	84	79
1999	Corn	49	54	40	48
Total	Wheat (3)	85	87	108	93
Yields	Sorghum & Corn (6)	272	306	387	322
	Forage (1)	0.39	0.32	0.71	0.47
	Sunflower (1)	0	0	0	0
	Millet (1)	0	0	0	0
		---$---			
Value*	Wheat (4)	294.95	301.89	374.76	322.71
	Sorghum & Corn (5)	625.00	702.11	880.09	737.26
	Forage (2)	15.60	12.80	28.40	18.93
	Sunflower (1)	0.00	0.00	0.00	0.00
	Millet (1)	0.00	0.00	0.00	0.00
	Fallow (1)	0.00	0.00	0.00	0.00
Total Value for 14 Years		935.55	1016.80	1283.25	1078.90

*Wheat @ $3.16/Bu; Corn @ $2.43/bu; Sorghum @ $2.14 /Bu; Hay Millet & Forage @ $40.00/T (1989-1997 average prices)

Table 22. Crop residue weights on all plots in WHEAT during the 1998-1999 crop year.

SITE & ROTATION	SLOPE POSITION					
	SUMMIT		SIDESLOPE		TOESLOPE	
	Pre-Plant		*Pre-Plant*		*Pre-Plant*	
	NP*	NP	NP*	NP	NP*	NP
STERLING:	----------kg/ha-----------		----------kg/ha-----------		----------kg/ha-----------	
WCF	3730	4590	2760	2550	7270	6850
WCSb	3870	4130	3070	2890	5480	5560
(W)WCSb	6570	4880	1920	2250	3050	4560
W(W)CSb	3080	3400	1890	2250	3580	3890
	NP*	NP	NP*	NP	NP*	NP
STRATTON:	----------kg/ha-----------		----------kg/ha--------		----------kg/ha--------	
WCF	2520	1880	1510	1680	2420	2250
WCSb	3700	4340	4690	3450	4350	3860
(W)WCSb	2850	3460	3560	3760	3560	3860
W(W)CSb	4560	6620	3450	3250	4290	4050
	NP*	NP	NP*	NP	NP*	NP
WALSH:	----------kg/ha--------		----------kg/ha--------		----------kg/ha--------	
WSF	2050	2360	1700	1850	1630	1850
WCSb	2490	2650	2350	2450	3110	2850
(W)WSSb	1900	1450	3640	3290	3190	2640
W(W)SSb	1600	2020	3100	2850	3680	3900

1. For conversion to lbs/Acre multiply kg/ha by 0.893.
* Only receives phosphorus in wheat phase of each rotation.

Table 23. Crop residue weights on all plots in Corn or Sorghum during the 1999 crop year.

	SLOPE POSITION					
	SUMMIT		SIDESLOPE		TOESLOPE	
SITE & ROTATION	*Pre-Plant*		*Pre-Plant*		*Pre-Plant*	
	NP*	NP	NP*	NP	NP*	NP
STERLING:	-------kg ha^{-1}--------		-------kg ha^{-1}--------		-------kg ha^{-1}--------	
WCF	2480	2050	1870	3000	2750	3010
WCSb	510	1200	1220	1060	2400	920
WWSb	1030	1890	1860	1360	2440	1620
OPP	930	29309	1720	3000	2020	1510
	NP*	NP	NP*	NP	NP*	NP
STRATTON:	------kg ha^{-1}--------		-------kg ha^{-1}--------		-------kg ha^{-1}--------	
WCF	4490	3930	4120	2670	8340	4430
WCSb	2200	2000	4040	2050	2080	1250
WWCSb	3850	2060	3200	3370	2430	2340
OPP	4960	4840	4760	5400	4900	4470
	NP*	NP	NP*	NP	NP*	NP
WALSH:	-------kg ha^{-1}--------		-------kg ha^{-1}--------		-------kg ha^{-1}--------	
WSF	1530	1720	890	2310	1850	1760
WCSb	990	1360	1960	1880	2120	1790
WWSSb	1560	1820	1790	2010	2590	1980
OPP (S)	2270	1940	3920	3120	3660	2460
CC (C)	2640	2760	3360	5210	3460	3340
CC (S)	4700	4622	3730	4710	5110	5840

1. For conversion to lbs/Acre multiply kg/ha by 0.893.
* Only receives phosphorus in wheat phase of each rotation.

Table 24. Crop residue weights on all plots in Soybean during the 1999 crop year.

SITE & ROTATION	SLOPE POSITION					
	SUMMIT		SIDESLOPE		TOESLOPE	
	Pre-Plant		*Pre-Plant*		*Pre-Plant*	
	NP*	NP	NP*	NP	NP*	NP
STERLING:	-------kg ha^{-1}--------		-------kg ha^{-1}--------		-------kg ha^{-1}--------	
WCSb	2020	3060	2260	2540	5790	2670
WWCSb	4620	3750	3780	4760	4540	4620
	NP*	NP	NP*	NP	NP*	NP
STRATTON:	------kg ha^{-1}--------		-------kg ha^{-1}--------		-------kg ha^{-1}--------	
WCSb	2990	3640	3630	4030	5440	7150
WWCSb	4410	6150	5750	6610	6400	5930
	NP*	NP	NP*	NP	NP*	NP
WALSH:	-------kg ha^{-1}--------		-------kg ha^{-1}--------		-------kg ha^{-1}--------	
WCSb	2260	2500	2200	2740	4570	4500
WWSSb	2060	2580	1920	4220	3210	3550

1. For conversion to lbs/Acre multiply kg/ha by 0.893.
* Only receives phosphorus in wheat phase of each rotation.

Table 25 . Available soil water by soil depth in the WHEAT phase of the WCF rotation at Sterling, Stratton, and WSF at Walsh in 1999.

SITE & DEPTH (cm)	SLOPE POSITION								
	SUMMIT			SIDESLOPE			TOESLOPE		
	Planting	Harvest	Change	Planting	Harvest	Change	Planting	Harvest	Change
	-------------mm/30cm-------------			-------------mm/30cm-------------			------------mm/30cm-------------		
STERLING:									
15	44	25	19	38	10	28	48	15	33
45	50	7	43	53	6	47	47	8	39
75	35	9	26	45	4	41	51	8	43
105	27	18	9	12	3	9	61	8	53
135	-	-	-	-	-	-	29	6	23
155	-	-	-	-	-	-	31	10	21
TOTAL	156	59	97	148	23	125	267	54	213
STRATTON:									
15	13	2	11	18	20	(+2)	38	15	23
45	42	8	34	36	12	24	56	6	50
75	42	5	37	55	25	30	65	17	48
105	41	8	33	50	19	31	71	18	53
135	44	15	29	51	24	27	42	5	37
155	44	21	23	39	18	21	37	11	26
TOTAL	226	58	168	249	119	130	309	72	237
WALSH:									
15	0	0	0	0	0	0	0	0	0
45	19	0	19	16	0	16	27	1	26
75	20	0	20	37	0	37	35	9	26
105	22	0	22	40	3	37	42	30	12
135	40	0	40	27	0	27	44	20	24
155	31	0	31	47	16	31	54	26	29
TOTAL	132	0	132	167	19	148	202	86	116

1. To convert from millimeters of H_2O/30 centimeters of soil to inches of H_2O/foot of soil multiply by 0.04.
2. ( ) Indicates a positive change in available soil water.

Table 26 . Available soil water by soil depth in the WHEAT phase of the WCSb rotation at Sterling, Stratton, and Walsh in 1999.

SITE & DEPTH (cm)	SLOPE POSITION								
	SUMMIT			SIDESLOPE			TOESLOPE		
	Planting	Harvest	Change	Planting	Harvest	Change	Planting	Harvest	Change
	-------------mm/30cm-------------			-------------mm/30cm-------------			-----------mm/30cm-------------		
STERLING:									
15	19	19	0	26	3	23	29	9	20
45	21	8	13	13	1	12	11	0	11
75	8	10	(+2)	13	9	4	32	10	22
105	16	23	(+7)	5	3	2	35	14	21
135							8	7	1
155							13	9	4
TOTAL	64	60	4	57	16	41	128	48	80
STRATTON:									
15	0	4	(+4)	0	19	(+19)	10	14	(+4)
45	42	20	22	29	8	21	49	10	39
75	35	16	19	36	15	21	48	14	34
105	33	22	11	41	24	17	45	25	20
135	36	31	5	54	42	13	34	31	3
155	36	24	12	50	38	12	40	39	1
TOTAL	182	117	65	210	144	66	226	134	92
WALSH:									
15	8	0	8	0	0	0	0	0	0
45	55	0	55	19	0	19	0	1	(+1)
75	56	0	56	15	0	15	0	9	(+9)
105	51	0	51	6	1	5	18	26	(+8)
135	52	0	52	0	0	0	50	5	45
155	40	0	40	51	25	26	68	26	42
TOTAL	262	0	262	91	26	65	136	67	69

1. To convert from millimeters of H_2O/30 centimeters of soil to inches of H_2O/foot of soil multiply by 0.04.
2. ( ) Indicates a positive change in available soil water.

Table 27 . Available soil water by soil depth in the WHEAT phase of the (W)WCSb rotation at Sterling, Stratton, and (W)WSSb at Walsh in 1999.

SITE & DEPTH (cm)	SLOPE POSITION								
	SUMMIT			SIDESLOPE			TOESLOPE		
	Planting	Harvest	Change	Planting	Harvest	Change	Planting	Harvest	Change
	-------------mm/30cm-------------			-------------mm/30cm-------------			------------mm/30cm-------------		
STERLING:									
15	29	17	12	22	12	10	32	14	18
45	21	2	19	22	6	16	34	14	20
75	30	21	9	36	17	19	50	11	39
105	38	37	1	31	10	21	42	11	31
135							11	6	5
155							13	10	3
TOTAL	118	77	41	111	45	66	182	66	116
STRATTON:									
15	16	0	16	10	23	(+13)	35	20	15
45	29	7	22	40	12	28	57	6	51
75	25	7	18	42	27	15	68	25	43
105	30	14	16	30	30	0	59	16	43
135	30	23	7	27	44	(+17)	43	16	27
155	34	27	7	12	51	(+39)	56	52	4
TOTAL	164	79	85	161	186	(+25)	318	134	184
WALSH:									
15	2	0	2	0	0	0	0	0	0
45	11	0	11	17	0	17	6	1	5
75	15	3	13	24	1	23	18	12	6
105	20	4	16	31	19	12	40	42	(+2)
135	29	10	19	11	16	(+5)	32	23	9
155	31	5	26	25	32	(+17)	57	27	30
TOTAL	108	21	87	108	67	41	153	105	48

1. To convert from millimeters of H_2 O/30 centimeters of soil to inches of H_2 O/foot of soil multiply by 0.04.
2. ( ) Indicates a positive change in available soil water.

Table 28 . Available soil water by soil depth in the WHEAT phase of the W(W)CSb rotation at Sterling, Stratton in 1999. (No crop harvested, only planting data available)

SITE & DEPTH (cm)	SLOPE POSITION								
	SUMMIT			SIDESLOPE			TOESLOPE		
	Planting	Harvest	Change	Planting	Harvest	Change	Planting	Harvest	Change
	-------------mm/30cm-------------			-------------mm/30cm-------------			------------mm/30cm-------------		
STERLING:									
15	32			15			25		
45	36			40			42		
75	13			23			26		
105	9			16			20		
135							17		
155							16		
TOTAL	90			94			146		
STRATTON:									
15	0			2			19		
45	47			37			63		
75	31			44			60		
105	30			33			59		
135	32			32			48		
155	33			34			47		
TOTAL	173			182			296		

1. To convert from millimeters of H_2O/30 centimeters of soil to inches of H_2O/foot of soil multiply by 0.04.
2. ( ) Indicates a positive change in available soil water.

Table 29 . Available soil water by soil depth in the CORN phase of the WCF rotation at Sterling, Stratton, and WCSa rotation at Walsh in 1999.

SITE & DEPTH (cm)	SLOPE POSITION								
	SUMMIT			SIDESLOPE			TOESLOPE		
	Planting	Harvest	Change	Planting	Harvest	Change	Planting	Harvest	Change
	-------------mm/30cm-------------			-------------mm/30cm-------------			------------mm/30cm-------------		
STERLING:									
15	44	20	24	29	16	13	47	29	18
45	57	11	46	52	9	44	56	20	35
75	38	12	26	30	5	25	54	15	38
105	22	12	9	34	9	25	41	14	27
135							11	8	3
155							8	7	1
TOTAL	161	55	106	146	39	108	216	93	123
STRATTON:									
15	13	3	10	24	17	7	43	53	(+10)
45	54	10	44	46	14	32	66	56	11
75	46	9	37	53	22	31	84	71	143
105	49	13	37	43	15	28	73	69	5
135	47	18	29	50	23	27	50	46	4
155	43	18	25	47	18	28	61	59	2
TOTAL	252	69	183	263	110	154	379	354	25
WALSH:									
15	0	2	(+2)	0	0	0	0	0	0
45	20	3	17	33	0	33	23	0	23
75	19	0	19	41	13	28	24	0	24
105	36	0	36	46	0	46	46	12	34
135	40	0	40	29	0	29	53	14	39
155	47	0	47	45	0	45	17	30	(+13)
TOTAL	161	5	156	193	13	181	162	56	106

1. To convert from millimeters of H_2O/30 centimeters of soil to inches of H_2O/foot of soil multiply by 0.04.
2. ( ) Indicates a positive change in available soil water.

Table 30 . Available soil water by soil depth in the CORN phase of the WCSb rotation at Sterling, Stratton, and Walsh in 1999.

SITE & DEPTH (cm)	SLOPE POSITION								
	SUMMIT			SIDESLOPE			TOESLOPE		
	Planting	Harvest	Change	Planting	Harvest	Change	Planting	Harvest	Change
	------------mm/30cm------------			------------mm/30cm------------			-----------mm/30cm------------		
STERLING:									
15	50	23	27	18	19	(+1)	39	27	12
45	61	7	53	42	2	40	43	13	30
75	34	12	22	44	14	30	50	13	37
105	36	19	17	31	17	14	49	17	32
135							28	13	15
155							30	19	11
TOTAL	181	62	119	136	52	83	240	102	137
STRATTON:									
15	26	22	5	34	37	(+4)	47	46	1
45	51	25	26	41	22	19	69	52	16
75	41	18	23	59	27	32	81	58	22
105	41	24	17	56	35	21	55	45	10
135	36	30	6	51	39	12	45	42	3
155	27	28	(+1)	45	41	3	29	23	7
TOTAL	222	146	76	286	202	84	325	266	59
WALSH:									
15	0	2	(+2)	0	0	0	0	0	0
45	20	3	17	33	0	33	23	0	23
75	19	0	19	41	13	28	24	0	24
105	36	0	36	46	0	46	46	12	34
135	40	0	40	29	0	29	53	14	39
155	47	0	47	45	0	45	17	30	(+13)
TOTAL	161	5	156	193	13	181	162	56	106

1. To convert from millimeters of H_2O/30 centimeters of soil to inches of H_2O/foot of soil multiply by 0.04.
2. ( ) Indicates a positive change in available soil water.

Table 31 . Available soil water by soil depth in the CORN phase of the WWCSb rotation at Sterling, Stratton, and the SORGHUM phase of the WWSSb rotation at Walsh in 1999.

SITE & DEPTH (cm)	SLOPE POSITION								
	SUMMIT			SIDESLOPE			TOESLOPE		
	Planting	Harvest	Change	Planting	Harvest	Change	Planting	Harvest	Change
	------------mm/30cm------------			------------mm/30cm------------			-----------mm/30cm------------		
STERLING:									
15	46	32	15	36	19	17	47	23	24
45	46	12	34	53	5	48	50	10	40
75	43	24	20	37	6	31	35	8	27
105	38	38	0	22	9	13	13	11	2
135							12	19	(+7)
155							12	19	(+7)
TOTAL	174	105	69	149	39	109	169	89	80
STRATTON:									
15	26	10	16	41	22	19	43	57	(+14)
45	47	7	40	47	8	39	70	46	24
75	40	6	35	52	15	37	63	43	20
105	40	10	30	52	22	30	63	46	17
135	54	18	36	47	33	14	46	40	6
155	38	18	20	44	26	17	39	37	2
TOTAL	246	68	178	282	126	156	324	268	56
WALSH:									
15	19	14	4	20	19	2	44	10	34
45	29	15	13	39	5	34	31	0	31
75	24	0	23	40	0	40	33	0	33
105	15	10	4	42	0	42	51	0	51
135	32	16	15	23	0	23	38	0	37
155	28	8	20	26	0	26	45	15	30
TOTAL	146	65	81	191	24	167	242	25	216

1. To convert from millimeters of H_2O/30 centimeters of soil to inches of H_2O/foot of soil multiply by 0.04.
2. ( ) Indicates a positive change in available soil water.

Table 32 . Available soil water by soil depth for CORN in the Opportunity rotation at Sterling, Stratton, and Walsh in 1999.

SITE & DEPTH (cm)	SLOPE POSITION								
	SUMMIT			SIDESLOPE			TOESLOPE		
	Planting	Harvest	Change	Planting	Harvest	Change	Planting	Harvest	Change
	------------mm/30cm------------			------------mm/30cm------------			-----------mm/30cm------------		
STERLING:									
15	52	24	28	41	21	20	38	28	10
45	58	5	53	49	20	29	25	20	5
75	42	13	29	59	28	31	35	11	24
105	92	24	69	63	24	40	33	11	22
135							19	16	3
155							13	17	(+4)
TOTAL	244	66	178	213	94	119	162	103	60
STRATTON:									
15	26	23	3	38	29	10	49	43	6
45	58	26	32	41	11	30	66	44	22
75	46	20	26	50	17	33	85	65	20
105	44	24	20	58	23	35	72	48	24
135	34	24	10	49	25	24	48	39	9
155	35	28	7	48	27	21	44	42	2
TOTAL	243	145	98	284	131	153	364	281	83
WALSH:									
15	4	0	4	0	0	0	1	0	1
45	28	0	28	36	0	36	27	0	27
75	39	6	34	36	7	29	34	0	34
105	41	18	23	29	2	27	45	11	34
135	54	25	29	27	0	27	29	14	15
155	50	30	19	38	10	28	49	38	11
TOTAL	216	78	137	166	20	146	184	63	121

1. To convert from millimeters of H_2O/30 centimeters of soil to inches of H_2O/foot of soil multiply by 0.04.
2. ( ) Indicates a positive change in available soil water.

Table 33 . Available soil water by soil depth for CORN and SORGHUM in the Continuous Crop rotation at Walsh in 1999.

SITE & DEPTH (cm)	SLOPE POSITION								
	SUMMIT			SIDESLOPE			TOESLOPE		
	Planting	Harvest	Change	Planting	Harvest	Change	Planting	Harvest	Change
	-------------mm/30cm-------------			-------------mm/30cm-------------			------------mm/30cm-------------		
CORN:									
15	13	6	7	0	0	0	9	0	9
45	28	5	23	28	3	24	22	0	22
75	44	17	27	29	0	29	37	0	37
105	53	20	33	31	0	31	42	8	34
135	48	16	32	15	0	15	45	14	31
155	40	10	30	33	2	32	60	33	27
TOTAL	226	75	150	137	5	132	215	55	160
SORGHUM:									
15	23	13	9	20	16	4	22	11	10
45	29	13	16	40	9	30	30	0	30
75	26	0	26	33	0	33	28	0	28
105	30	18	12	36	2	34	52	6	46
135	46	25	21	22	0	22	35	16	20
155	21	19	2	30	2	28	44	38	6
TOTAL	174	88	86	181	30	152	211	71	140

1. To convert from millimeters of H_2 O/30 centimeters of soil to inches of H_2 O/foot of soil multiply by 0.04.
2. ( ) Indicates a positive change in available soil water.

Table 34 . Available soil water by soil depth in the SOYBEAN phase of the WCSb rotation at Sterling, and Stratton, and WSSb rotation at Walsh in 1999.

SITE & DEPTH (cm)	SLOPE POSITION								
	SUMMIT			SIDESLOPE			TOESLOPE		
	Planting	Harvest	Change	Planting	Harvest	Change	Planting	Harvest	Change
	-------------mm/30cm-------------			-------------mm/30cm-------------			-------------mm/30cm-------------		
STERLING:									
15	53	30	23	46	28	19	39	24	15
45	42	13	29	43	10	32	33	15	18
75	19	12	7	36	33	2	16	15	0
105	34	26	8	40	26	13	11	13	(+1)
135							11	8	3
155							13	15	(+2)
TOTAL	147	80	67	164	97	67	123	90	33
STRATTON:									
15	28	17	11	36	41	(+5)	50	58	(+8)
45	46	17	29	45	24	21	64	48	16
75	30	17	13	45	32	13	66	65	1
105	25	20	5	28	27	1	70	77	(+8)
135	26	31	(+5)	36	40	(+4)	55	63	(+8)
155	23	26	(+3)	37	52	(+15)	44	56	(+12)
TOTAL	178	128	50	227	216	11	348	367	(+19)
WALSH:									
15	20	0	20	25	0	25	27	0	27
45	21	0	21	30	0	30	27	0	27
75	18	0	18	34	0	34	27	0	27
105	30	4	26	35	0	35	34	13	21
135	51	8	43	33	17	16	31	21	10
155	48	6	42	49	23	26	44	37	7
TOTAL	188	18	170	206	40	166	190	71	119

1. To convert from millimeters of H_2O/30 centimeters of soil to inches of H_2O/foot of soil multiply by 0.04.
2. ( ) Indicates a positive change in available soil water.

Table 35. Available soil water by soil depth in the Soybean phase of the WWCSb rotation at Sterling, and Stratton, and WWSSb rotation at Walsh in 1999.

SITE & DEPTH (cm)	SLOPE POSITION								
	SUMMIT			SIDESLOPE			TOESLOPE		
	Planting	Harvest	Change	Planting	Harvest	Change	Planting	Harvest	Change
	-------------mm/30cm-------------			-------------mm/30cm-------------			------------mm/30cm-------------		
STERLING:									
15	40	25	14	42	31	10	45	22	23
45	46	12	34	46	14	33	44	13	31
75	22	4	18	34	21	13	25	17	8
105	4	0	4	10	28	(+18)	17	12	6
135							9	4	5
155							7	8	(+1)
TOTAL	112	41	71	132	94	38	147	76	72
STRATTON:									
15	27	9	18	34	23	11	73	72	1
45	50	8	43	43	20	23	70	57	13
75	36	7	28	50	31	19	72	68	4
105	32	16	16	39	29	10	72	74	(+2)
135	26	25	1	30	25	5	45	58	(+13)
155	22	23	(+1)	25	25	0	57	60	(+3)
TOTAL	194	88	106	221	153	68	388	389	0
WALSH:									
15	18	0	18	25	0	25	26	0	26
45	21	1	20	41	0	41	27	0	27
75	19	0	19	43	0	43	33	3	30
105	22	0	22	42	9	33	39	9	30
135	43	6	37	16	15	1	20	23	(+3)
155	36	0	36	50	18	32	35	31	4
TOTAL	159	7	152	217	43	174	180	66	114

1. To convert from millimeters of H_2 O/30 centimeters of soil to inches of H_2 O/foot of soil multiply by 0.04.
2. ( ) Indicates a positive change in available soil water.

Table 36a. Total Nitrogen content of WHEAT GRAIN in the 1998-1999 crop.

SITE & ROTATION	SLOPE POSITION					
	SUMMIT		SIDESLOPE		TOESLOPE	
	*N Side**	*NP Side*	*N Side**	*NP Side*	*N Side**	*NP Side*
	N	N	N	N	N	N
STERLING:	------------- % -------------		------------- % -------------		------------- % -------------	
WCF	2.55	2.38	2.31	2.18	2.11	2.04
WCSb	2.50	2.50	2.53	2.60	2.42	2.50
(W)WCSb	2.44	2.21	2.17	2.09	2.02	2.13
W(W)CSb	-	-	-	-	-	-
	N	N	N	N	N	N
STRATTON:	------------- % -------------		------------- % -------------		------------- % -------------	
WCF	1.91	1.97	2.07	1.79	1.86	2.04
WCP	2.10	1.95	2.31	2.12	2.40	2.33
(W)WCP	2.22	2.01	2.15	1.99	1.90	2.14
W(W)CP	-	-	-	-	-	-
	N	N	N	N	N	N
WALSH:	------------- % -------------		------------- % -----------		------------- % -------------	
WSF	2.34	2.15	2.12	2.16	1.75	1.84
WSSa	1.98	2.05	2.20	2.22	1.87	1.86
(W)SSF	2.31	2.21	2.06	1.97	1.70	1.70
W(W)SSF	2.17	2.03	2.08	2.08	2.03	2.00

* Only receives phosphorus in wheat phase of each rotation.

Table 36b. Total Nitrogen content of WHEAT STRAW in the 1998-1999 crop.

SITE & ROTATION	SLOPE POSITION					
	SUMMIT		SIDESLOPE		TOESLOPE	
	*N Side**	*NP Side*	*N Side**	*NP Side*	*N Side**	*NP Side*
	N	N	N	N	N	N
STERLING:	--- % ---		--- % ---		--- % ---	
WCF	0.50	0.34	0.28	0.36	0.28	0.40
WCSb	0.53	0.48	0.61	0.45	0.49	0.54
(W)WCSb	0.31	0.32	0.32	0.31	0.38	0.43
W(W)CSb						
	N	N	N	N	N	N
STRATTON:	--- % ---		--- % ---		--- % ---	
WCF	0.29	0.21	0.31	0.29	0.31	0.59
WCSb	0.31	0.27	0.37	0.31	0.64	0.83
(W)WCSb	0.26	0.27	0.29	0.28	0.38	0.29
W(W)CSb						
	N	N	N	N	N	N
WALSH:	--- % ---		--- % ---		--- % ---	
WSF	0.41	0.52	0.24	0.27	0.22	0.24
WSSb	0.29	0.29	0.36	0.34	0.25	0.27
(W)WSSb	0.29	0.33	0.27	0.27	0.21	0.24
W(W)SSb	0.31	0.32	0.30	0.31	0.27	0.26

* Only receives phosphorus in wheat phase of each rotation.

Table 37a. Total Nitrogen content of CORN GRAIN or SORGHUM GRAIN in the 1999 crop.

SITE & ROTATION	SLOPE POSITION					
	SUMMIT		SIDESLOPE		TOESLOPE	
	*N Side**	*NP Side*	*N Side**	*NP Side*	*N Side**	*NP Side*
	N	N	N	N	N	N
STERLING:	------------- % -------------		------------- % -------------		------------- % -------------	
WCF	1.79	1.80	1.76	1.70	1.72	1.63
WCSb	1.85	1.77	1.65	1.75	1.59	1.49
WWCSb	1.78	1.81	1.58	1.82	1.65	1.81
OPP	1.66	1.76	1.68	1.77	1.54	1.70
	N	N	N	N	N	N
STRATTON:	------------- % -------------		------------- % -------------		------------- % -------------	
WCF	1.53	1.61	1.65	1.57	1.90	1.85
WCSb	1.59	1.61	1.51	1.56	1.78	1.70
WWCSb	1.68	1.53	1.62		1.69	1.68
OPP	1.64	1.66	1.61	1.60	1.72	1.79
	N	N	N	N	N	N
WALSH:	------------- % -------------		------------- % -----------		------------- % -------------	
WSF	1.22	1.39	1.23	1.23	1.63	1.60
W(C)b	1.33	1.24	1.35	1.33	1.43	1.50
WW(S)Sb	1.16	1.20	1.23	1.28	1.62	1.58
Cont. Crop (C)	1.39	1.43	1.47	1.51	1.77	1.75
Cont. Crop (S)	1.04	1.23	1.09	1.23	1.22	1.21
OPP	1.40	1.40	1.40	1.45	1.50	1.62

* Only receives phosphorus in wheat phase of each rotation.

Table 37b. Total Nitrogen content of CORN STOVER or SORGHUM STOVER in the 1999 crop.

	SLOPE POSITION					
	SUMMIT		SIDESLOPE		TOESLOPE	
SITE & ROTATION	*N Side**	*NP Side*	*N Side**	*NP Side*	*N Side**	*NP Side*
	N	N	N	N	N	N
STERLING:	------------- % -------------		------------- % -------------		------------- % -------------	
WCF	0.93	0.77	0.93	0.73	0.72	0.76
WCSb	0.69	0.77	0.60	0.93	0.70	0.76
WWCSb	1.11	1.09	0.75	0.82	0.66	0.70
OPP	0.98	0.83	0.73	0.62	0.91	1.21
	N	N	N	N	N	N
STRATTON:	------------- % -------------		------------- % -------------		------------- % -------------	
WCF	0.61	0.84	0.57	0.51	0.78	0.36
WCSb	0.69	0.47	0.45	0.51	0.73	0.67
WWCSb	0.41	0.48	0.56	0.71	0.89	0.99
OPP	0.76	0.48	0.50	0.51		0.57
	N	N	N	N	N	N
WALSH:	------------- % -------------		------------- % -----------		------------- % -------------	
WSF	No sample		No sample		No sample	
W(S)Sb	0.67	0.66	0.56	0.57	0.55	0.60
WW(S)Sb	No sample		No sample		No sample	
Cont. Crop (C)	0.60	0.64	0.71	0.69	0.73	0.66
Cont. Crop (S)	No sample		No sample		No sample	
OPP	0.57	0.59	0.60	0.53	0.70	0.b0

* Only receives phosphorus in wheat phase of each rotation.

Table 38a. Total Nitrogen content of SOYBEAN GRAIN in the 1999 crop.

SITE & ROTATION	SLOPE POSITION					
	SUMMIT		SIDESLOPE		TOESLOPE	
	*N Side**	*NP Side*	*N Side**	*NP Side*	*N Side**	*NP Side*
	N	N	N	N	N	N
STERLING:	%		%		%	
WCSb	5.64	5.42	5.54	5.51	5.39	5.15
WWCSb	5.62	5.54	5.51	5.05	5.39	5.21
	N	N	N	N	N	N
STRATTON:	%		%		%	
WCSb	5.96	5.91	5.83	5.96	5.50	5.45
WWCSb	5.70	5.82	5.63	5.79	5.28	5.20
	N	N	N	N	N	N
WALSH:	%		%		%	
WSSb	5.99	6.19	6.03	6.07	6.36	6.36
WWSSb	5.87	5.94	5.90	6.21	6.39	6.37

* Only receives phosphorus in wheat phase of each rotation.

Table 38b. Total Nitrogen content of SOYBEAN STOVER in the 1999 crop.

SITE & ROTATION	SLOPE POSITION					
	SUMMIT		SIDESLOPE		TOESLOPE	
	*N Side**	*NP Side*	*N Side**	*NP Side*	*N Side**	*NP Side*
	N	N	N	N	N	N
STERLING:	-------------- % -------------		-------------- % -------------		-------------- % -------------	
WCSb	0.68	0.55	0.66	0.66	0.85	0.76
WWCSb	0.54	0.60	0.57	0.72	0.69	0.69
	N	N	N	N	N	N
STRATTON:	-------------- % -------------		-------------- % -------------		-------------- % -------------	
WCSb	0.69	0.82	0.70	0.88	0.73	0.78
WWCSb	0.72	0.61	0.91	0.61	0.68	0.87
	N	N	N	N	N	N
WALSH:	-------------- % -------------		-------------- % -----------		-------------- % -------------	
WSSb	0.82	0.61	0.57	0.66	1.05	1.08
WWSSb	0.61	0.59	0.66	0.79	1.21	0.99

* Only receives phosphorus in wheat phase of each rotation.

Table 39a. Total Nitrogen content of CORN,, SOYBEAN, and SUNFLOWER GRAIN and HAY MILLET forage in the 1998-1999 crop at the Briggsdale site.

CROP	
	--------% N ---------
Corn	1.80
Soybean	6.83
Sunfower	3.81
Hay Millet forage	1.08

Table 39b. Total Nitrogen content of WHEAT GRAIN in the 1997-1998 crop at the Lamar site.

	Not grazed		Grazed	
	Variety		Variety	
ROTATION	Lamar	Prowers	Lamar	Prowers
	--------% N ---------	----------% N --------	-------% N -------	-------% N -------
WF	2.15	2.17	2.60	2.22
WSF	2.16	2.13	2.67	2.19

Table 40. Nitrate-N content of the soil profile at Planting for each crop during 1998-1999 crop year.

Site & Rotation	SLOPE POSITION								
	SUMMIT			SIDESLOPE			TOESLOPE		
	Crop and Time			Crop and Time			Crop and Time		
	Wheat Fall 98	Corn S 99	Sorghum S 99	Wheat Fall 98	Corn S 99	Sorghum S 99	Wheat S 98	Corn S 99	Sorghum S 99
	------------kg NO3-N ha $^{-1}$------------			----------kg NO3-N ha $^{-1}$------------			-------------kg NO3-N ha $^{-1}$-----------		
STERLING									
WCF	75	31		42	18		60	41	
WCSb	116	65		59	48		75	41	
(W)WCSb	28	102		30	46		18	43	
W(W)CSb	10			10			1		
OPP		84			46			1	
STRATTON:									
WCF	44	65		63	76		55	63	
WCSb	47	55		73	60		79	75	
(W)WCSb	37	53		31	70		34	69	
W(W)CSb	33			46			66		
OPP		24			26			78	
WALSH									
WSF	162		56	127		84	117		58
WCSb	97	100		112	138		95	117	
(W)WSSb	65		53	75		80	78		105
W(W)SSb	109			117			99		
CC (C)		38			97			61	
CC (S)			39			29			53
OPP		52			98			57	

APPENDIX I

ANNUAL HERBICIDE PROGRAMS
FOR EACH SITE

Table 1. Weed control methods including herbicide rate, cost and date applied at STERLING in 1999 season.

Crop	Herbicide/Tillage	Rate (English)	Rate (Metric)	Weed Pressure	Cost	Date Applied
Rotation: Wheat-Corn-Fallow						
Wheat:	Ally 2,4-D Ester 6# Atrazine 4L Fallowmaster *	1/10 oz/A 5.3 oz/A 32 oz/A 32 oz/A	7.0 g/ha 0.39 l/ha 2.34 l/ha 2.34 l/ha	II II I I	$2.27 $0.89 $3.57 $4.54	4-19-99 4-19-99 8-16-99 8-16-99
Corn:	Round-up Ultra* Round-up Ultra* Round-up Ultra*	16 oz/A 16 oz/A 16 oz/A	1.17 l/ha 1.17 l/ha 1.17 l/ha	I I I	$4.93 $4.93 $4.93	4-19-99 6-8-99 7-8-99
Fallow:	Fallowmaster* Round-up Ultra* Fallowmaster* Round-up Ultra*	32 oz/A 16 oz/A 32 oz/A 48 oz/A	2.34 l/ha 1.17 l/ha 2.34 l/ha 3.50 l/ha	I I I III	$4.54 $4.93 $4.54 $14.79	5-10-99 6-21-99 8-16-99 9-22-99
Rotation: Wheat-Corn-Soybean						
Wheat:	Ally 2,4-D Ester 6# Atrazine 4L Fallowmaster *	1/10 oz/A 5.3 oz/A 32 oz/A 32 oz/A	7.0 g/ha 0.39 l/ha 2.34 l/ha 2.34 l/ha	II II I I	$2.27 $0.89 $3.57 $4.54	4-19-99 4-19-99 8-16-99 8-16-99
Corn:	Round-up Ultra* Round-up Ultra* Round-up Ultra*	16 oz/A 16 oz/A 16 oz/A	1.17 l/ha 1.17 l/ha 1.17 l/ha	I I I	$4.93 $4.93 $4.93	4-19-99 6-8-99 7-8-99
Soybean:	Landmaster* Round-up Ultra* Round-up Ultra*	40 oz/A 16 oz/A 48 oz/A	2.92 l/ha 1.17 l/ha 3.50 l/ha	I I III	$6.83 $6.83 $14.79	5-10-99 6-21-99 9-22-99
Rotation:Wheat-Wheat-Corn-Soybean						
Wheat:	Ally 2,4-D Ester 6# Fallowmaster * Round-up Ultra* Maverick	1/10 oz/A 5.3 oz/A 32 oz/A 12 oz/A 2/3 oz/A	7.0 g/ha 0.39 l/ha 2.34 l/ha 0.87 l/ha 46.8 g/ha	II II I I I	$2.27 $0.89 $4.54 $3.69 $8.89	4-19-99 4-19-99 8-16-99 9-22-99 11-10-99
Wheat:	Ally 2,4-D Ester 6# Fallowmaster* Round-up Ultra* Atrazine 4L	1/10 oz/A 5.3 oz/A 44 oz/A 16 oz/A 32 oz/A	7.0 g/ha 0.39 l/ha 3.21 l/ha 1.17 l/ha 2.34 l/ha	II II II I I	$2.27 $0.89 $3.57 $4.54 $3.57	4-19-99 5-10-99 6-21-99 8-16-99 8-16-99
Corn:	Round-up Ultra* Round-up Ultra* Round-up Ultra*	16 oz/A 16 oz/A 16 oz/A	1.17 l/ha 1.17 l/ha 1.17 l/ha	I I I	$4.93 $4.93 $4.93	4-19-99 6-8-99 7-8-99
Soybean:	Landmaster* Round-up Ultra* Round-up Ultra*	40 oz/A 16 oz/A 48 oz/A	2.92 l/ha 1.17 l/ha 3.50 l/ha	I I III	$6.83 $6.83 $14.79	5-10-99 6-21-99 9-22-99
Rotation: Opportunity						
Corn:	Round-up Ultra* Round-up Ultra* Round-up Ultra*	16 oz/A 16 oz/A 16 oz/A	1.17 l/ha 1.17 l/ha 1.17 l/ha	I I I	$4.93 $4.93 $4.93	4-19-99 6-8-99 7-8-99
*Applied 1qt. Quest/100 gallons water with Round-up products.						
Weed Preesure Ratings: I =Farmer would need to spray. II = Farmer would delay application. III =Farmer would not plan a spray application.						
Note: Atrazine is applied at 75 % of the rate on sideslope soils.						

Table 2. Weed control methods including herbicide rate, cost and date applied at STRATTON in 1999 season.

Crop	Herbicide/Tillage	Rate (English)	Rate (Metric)	Weed Pressure	Cost	Date Applied
Rotation: Wheat-Corn-Fallow						
Wheat:	Fallowmaster* Fallowmaster* Atrazine 4L	44 oz/A 32 oz/A 32 oz/A	3.21 l/ha 2.34 l/ha 2.34 l/ha	I I I	$6.24 $4.54 $3.57	7-29-99 8-19-99 8-19-99
Corn:	Round-up Ultra* Prowl Atrazine 4L Fallowmaster*	12 oz/A 32 oz/A 32 oz/A 32 oz/A	0.87 l/ha 2.34 l/ha 2.34 l/ha 2.34 l/ha	II I I	$3.69 $7.33 $3.57 $4.54	4-13-99 5-18-99 5-18-99 5-18-99
Fallow:	Fallowmaster* Fallowmaster* Fallowmaster* Round-up Ultra*	32 oz/A 44 oz/A 32 oz/A 48 oz/A	2.34 l/ha 3.21 l/ha 2.34 l/ha 3.50 l/ha	I I I III	$4.54 $6.24 $4.54 $14.78	5-18-99 7-8-99 8-19-99 9-23-99
Rotation: Wheat-Corn-Soybean						
Wheat:	Fallowmaster Fallowmaster* Atrazine 4L	44 oz/A 32 oz/A 32 oz/A	3.21 l/ha 2.34 l/ha 2.34 l/ha	I I I	$6.24 $4.54 $3.57	7-29-99 8-19-99 8-19-99
Corn:	Round-up Ultra* Prowl Atrazine 4L Fallowmaster*	12 oz/A 32 oz/A 32 oz/A 32 oz/A	0.87 l/ha 2.34 l/ha 2.34 l/ha 2.34 l/ha	II I I	$3.69 $7.33 $3.57 $4.54	4-13-99 5-18-99 5-18-99 5-18-99
Soybean:	Round-up Ultra* Round-up Ultra* Round-up Ultra* Round-up Ultra*	16 oz/A 24 oz/A 16 oz/A 48 oz/A	1.17 l/ha 1.75 l/ha 1.17 l/ha 3.50 l/ha	I I I III	$4.93 $7.39 $4.93 $14.78	5-18-99 6-15-99 7-29-99 9-23-99
Rotation: Wheat-Wheat-Corn-Soybean						
Wheat:	Fallowmaster* Fallowmaster*	44 oz/A 32 oz/A	3.21 l/ha 2.34 l/ha	I I	$6.24 $4.54	7-29-99 8-19-99
Wheat:	Fallowmaster* Fallowmaster* Atrazine 4L Round-up Ultra* Maverick	44 oz/A 32 oz/A 32 oz/A 48 oz/A 2/3 oz/A	3.21 l/ha 2.34 l/ha 2.34 l/ha 3.50 l/ha 46.8 g/ha	I I I III I	$6.24 $4.54 $3.57 $14.78 $8.89	7-29-99 8-19-99 8-19-99 9-23-99 11-9-99
Corn:	Round-up Ultra* Prowl Atrazine 4L Fallowmaster*	12 oz/A 32 oz/A 32 oz/A 32 oz/A	0.87 l/ha 2.34 l/ha 2.34 l/ha 2.34 l/ha	II I I	$3.69 $7.33 $3.57 $4.54	4-13-99 5-18-99 5-18-99 5-18-99
Soybean:	Round-up Ultra* Round-up Ultra* Round-up Ultra* Round-up Ultra*	16 oz/A 24 oz/A 16 oz/A 48 oz/A	1.17 l/ha 1.75 l/ha 1.17 l/ha 3.50 l/ha	I I I III	$4.93 $7.39 $4.93 $14.78	5-18-99 6-15-99 7-29-99 9-23-99
Rotation: Opportunity						
Corn:	Round-up Ultra* Prowl Atrazine 4L Fallowmaster*	12 oz/A 32 oz/A 32 oz/A 32 oz/A	0.87 l/ha 2.34 l/ha 2.34 l/ha 2.34 l/ha	II I I	$3.69 $7.33 $3.57 $4.54	4-13-99 5-18-99 5-18-99 5-18-99
*Applied 1qt. Quest/100 gallons water						
Weed Pressure Ratings: I =Farmer would need to spray. II = Farmer would delay application. III = Farmer would not plan a spray application.						
Note: Atrazine is applied at 75 % of the rate on the sideslope soils.						

Table 3. Weed control methods including herbicide rate, cost and date applied at WALSH in 1998 season.

Crop	Herbicide/Tillage	Rate (English)	Rate (Metric)	Weed Pressure	Cost	Date Applied
Rotation: Wheat-Sorghum-Fallow						
Wheat:	Ally	0.10 oz/A	7.02 g/ha	I	$2.27	3-31-99
	Landmaster BW	48 oz/A	3.50 l/ha	I	$7.05	8-9-99
	Round-up Ultra	2 oz/A	0.15 l/ha	I	$0.62	8-9-99
Sorghum:	Landmaster BW	40 oz/A	2.92 l/ha	I	$5.88	3-31-99
	Round-up	4 oz/A	0.29 l/ha	I	$1.23	3-31-99
	Round-up	16 oz/A	1.17 l/ha	I	$4.93	6-5-99
	Atrazine	0.75 lb ai/A	842 g/ha	I	$2.29	7-6-99
	Crop Oil	32 oz/A	2.33 l/ha	I	$1.06	7-6-99
	Banvel	2.5 oz/A	0.18 l/ha	I	$1.75	7-6-99
	Cultivated					7-26-99
Fallow:	Landmaster BW	48 oz/A	3.50 l/ha	I	$7.05	4-27-99
	Round-up	3 oz/A	0.22 l/ha	I	$0.92	4-27-99
	Round-up Ultra	16 oz/A	1.17 l/ha	I	$4.93	6-5-99
	Round-up Ultra	16 oz/A	1.17 l/ha	I	$4.93	7-6-99
	Landmaster BW	54 oz/A	3.94 l/ha	I	$7.93	8-9-99
Rotation: Wheat-Corn-Soybean						
Wheat:	Ally	0.10 oz/A	7.02 g/ha	I	$2.27	3-31-99
	Landmaster BW	48 oz/A	3.50 l/ha	I	$7.05	8-9-99
	Round-up Ultra	2 oz/A	0.15 l/ha	I	$0.62	8-9-99
Corn:	Landmaster BW	40 oz/A	2.92 l/ha	I	$5.88	3-31-99
	Round-up Ultra	4 oz/A	0.29 l/ha	I	$1.23	3-31-99
	Round-up Ultra	16 oz/A	1.17 l/ha	I	$4.93	6-5-99
	Round-up Ultra	16 oz/A	1.17 l/ha	I	$4.93	7-6-99
Soybean:	Round-up Ultra	16 oz/A	1.17 l/ha	I	$4.93	4-27-99
	Round-up Ultra	16 oz/A	1.17 l/ha	I	$4.93	6-5-99
	Round-up Ultra	16 oz/A	1.17 l/ha	I	$4.93	7-6-99
	Cultivated					7-26-99
	Round-up Ultra	16 oz/A	1.17 l/ha	I	$4.93	8-23-99
Rotation: Wheat-Wheat-Sorghum-Soybean						
Wheat:	Ally	0.10 oz/A	7.02 g/ha	I	$2.27	3-31-99
	Landmaster BW	48 oz/A	3.50 l/ha	I	$7.05	8-9-99
	Round-up Ultra	2 oz/A	0.15 l/ha	I	$0.62	8-9-99
Wheat:	Ally	0.10 oz/A	7.02 g/ha	I	$2.27	3-31-99
	Landmaster BW	48 oz/A	3.50 l/ha	I	$7.05	8-9-99
	Round-up Ultra	2 oz/A	0.15 l/ha	I	$0.62	8-9-99
Sorghum:	Landmaster BW	40 oz/A	2.92 l/ha	I	$5.88	3-31-99
	Round-up	4 oz/A	0.29 l/ha	I	$1.23	3-31-99
	Round-up	16 oz/A	1.17 l/ha	I	$4.93	6-5-99
	Atrazine	0.75 lb ai/A	842 g/ha	I	$2.29	7-6-99
	Crop Oil	32 oz/A	2.33 l/ha	I	$1.06	7-6-99
	Banvel	2.5 oz/A	0.18 l/ha	I	$1.75	7-6-99
	Cultivated					7-26-99
	Banvel					
Soybean:	Round-up Ultra	16 oz/A	1.17 l/ha	I	$4.93	4-27-99
	Round-up Ultra	16 oz/A	1.17 l/ha	I	$4.93	6-5-99
	Round-up Ultra	16 oz/A	1.17 l/ha	I	$4.93	7-6-99
	Cultivated					7-26-99
	Round-up Ultra	16 oz/A	1.17 l/ha	I	$4.93	8-23-99
	Round-up	4 oz/A	0.29 l/ha	I	$1.33	
Opportunity						
Corn:	Landmaster BW	48 oz/A	3.50 l/ha	I	$7.05	4-27-99
	Round-up Ultra	3 oz.A	0.22 l/ha	I	$0.92	4-27-99
	Round-up Ultra	16 oz/A	1.17 l/ha	I	$4.93	6-5-99
	Round-up Ultra	16 oz/A	1.17 l/ha	I	$4.93	7-6-99
Continuous Cropping:						
Corn:	Landmaster BW	48 oz/A	3.50 l/ha	I	$7.05	4-27-99
	Round-up	3 oz/A	0.22 l/ha	I	$0.92	4-27-99
	Round-up Ultra	16 oz/A	1.17 l/ha	I	$4.93	6-5-99
	Round-up Ultra	16 oz/A	1.17 l/ha	I	$4.93	7-6-99

Sorghum:	Landmaster BW Round-up Round-up Utlra Atrazine Crop Oil Banvel Cultivated	48 oz/A 3 oz/A 16 oz/A 0.75 lb ai/A 32 oz/A 2.5 oz/A	3.50 l/ha 0.22 l/ha 1.17 l/ha 842 g/ha 2.33 l/ha 0.18 l/ha	I I I I I I	$7.05 $0.92 $4.93 $2.29 $1.06 $1.75	4-27-99 4-27-99 6-5-99 7-6-99 7-6-99 7-6-99 7-26-99
Weed Preesure Ratings: I =Farmer would need to spray. II = Farmer would delay application. III =Farmer would not plan a spray application.						

Table 4. Weed control methods including herbicide rate, cost and date applied at BRIGGSDALE in 1999 season.

Crop	Herbicide/Tillage	Rate (English)	Rate (Metric)	Weed Pressure	Cost	Date Applied
Rotation: Wheat-Fallow						
Wheat:	Ally 2,4-D 4# Fallowmaster* Fallowmaster* Atrazine 4L	0.1 oz/A 8 oz/A 32 oz/A 32 oz/A 19 oz/A(0.67#)	7.0 g/ha 0.58 l/ha 2.33 l/ha 2.33 l/ha 1.39l/ha(302g)	II II I I III	$2.27 $0.89 $4.40 $4.40 $3.57	4 May 1999 4 May 1999 5 July 1999 17 Aug. 1999 17 Aug. 1999
Fallow:	Tillage - 18" sweeps Tillage - Disc Fallowmaster*	32 oz/A	2.33 l/ha	I I I	$3.57	27 May 1999 6 July 1999 17 Aug. 1999
Rotation: Wheat-Millet-Fallow						
Wheat:	Ally 2,4-D 4# Fallowmaster* Fallowmaster* Atrazine 4L	0.1 oz/A 8 oz/A 32 oz/A 32 oz/A 19 oz/A(0.67#)	7.0 g/ha 0.58 l/ha 2.33 l/ha 2.33 l/ha 1.39l/ha(302g)	II II I I III	$2.27 $0.89 $4.40 $4.40 $3.57	4 May 1999 4 May 1999 5 July 1999 17 Aug. 1999 17 Aug. 1999
Millet:	Round-up Ultra* 2,4-D 4# Round-up Ultra*	16 oz/A 8 oz/A 16 oz/A	1.17 l/ha 0.58 l/ha 1.17 l/ha	I I I	$4.88 $0.89 $4.88	14 May 1999 14 May 1999 27 June 1999
Fallow:	Tillage - 18" sweeps Tillage - Disc Fallowmaster*	32 oz/A	2.33 l/ha	I I I	$3.57	27 May 1999 6 July 1999 17 Aug. 1999
Rotation:Wheat-Wheat-Corn-Soybeans-Sunflowers-Peas:						
Wheat:	Ally 2,4-D 4# Fallowmaster* Fallowmaster* Maverick	0.1 oz/A 8 oz/A 32 oz/A 32 oz/A 0.66 oz/A	7.0 g/ha 0.58 l/ha 2.33 l/ha 2.33 l/ha 46.3 g/ha	II II I I I	$2.27 $0.89 $4.40 $4.40 ?	4 May 1999 4 May 1999 5 July 1999 17 Aug. 1999 2 Nov. 1999
Wheat:	Ally 2,4-D 4# Fallowmaster* Fallowmaster* Atrazine 4L	0.1 oz/A 8 oz/A 32 oz/A 32 oz/A 19 oz/A(0.67#)	7.0 g/ha 0.58 l/ha 2.33 l/ha 2.33 l/ha 1.39 l/ha(302g)	II II I I II	$2.27 $0.89 $4.40 $4.40 $3.57	4 May 1999 4 May 1999 5 July 1999 17 Aug. 1999 17 Aug. 1999
Corn:	Prowl Atrazine 4L Fallowmaster*	32 oz/A 32 oz/A(1#) 32 oz/A	2.33 l/ha 2.33 l/ha(454g) 2.33 l/ha	I I I	$6.56 $3.57 $4.40	14 May 1999 14 May 1999 14 May 1999
Soybeans:	Landmaster BW* Round-up Ultra* Round-up Ultra*	40 oz/A 24oz/A 20 oz/A	2.92 l/ha 1.75 l/ha 1.46 l/ha	I I I	$5.88 $7.31 $6.09	14 May 1999 27 June 1999 17 Aug. 1999
Sunflowers:	Prowl Landmaster*	48 oz/A 40 oz/A	3.50 l/ha 2.92 l/ha	I I	$9.84 $5.88	14 May 1999 14 May 1999
Peas(Millet)	Round-up Ultra* 2,4-D 4# Round-up Ultra*	16 oz/A 8 oz/A 16 oz/A	1.17 l/ha 0.58 l/ha 1.17 l/ha	I I I	$4.88 $0.89 $4.88	14 May 1999 14 May 1999 27 June 1999
Rotation: Opportunity						
Millet:	Round-up Ultra* 2,4-D 4# Round-up Ultra*	16 oz/A 8 oz/A 16 oz/A	1.17 l/ha 0.58 l/ha 1.17 l/ha	I I I	$4.88 $0.89 $4.88	14 May 1999 14 May 1999 27 June 1999

*Applied 17 lbs. Ammonium Sulfate/100 gallons water with Round-up products

Weed Preesure Ratings: I =Farmer would need to spray. II = Farmer would delay application. III =Farmer would not plan a spray application.

APPENDIX II
PROJECT PUBLICATIONS

Papers in Scientific Journals:

Kitchen, N. R., L. A. Sherrod, C. W. Wood, G. A. Peterson and D. G. Westfall. 1990. Nitrogen contamination of soils from sampling bags. Agron. J. 82:354-356.

Kitchen, N. R., J. L. Havlin and D. G. Westfall. 1990. Soil sampling under no-till banded phosphorus. Soil Sci. Soc. Am. J. 54:1661-1665.

Wood, C. W., D. G. Westfall, G. A. Peterson and I. C. Burke. 1990. Impacts of cropping intensity on carbon and nitrogen mineralization under no-till agroecosystems. Agron. J. 82: 1115-1120.

Wood, C. W., D. G. Westfall and G. A. Peterson. 1991. Soil carbon and nitrogen changes upon initiation of no-till cropping systems in the West Central Great Plains. Soil Sci. Soc. Am. J. 55:470-476.

Wood, C. W., G. A. Peterson, D. G. Westfall, C. V. Cole and W. F. Willis. 1991. Nitrogen balance and biomass production of newly established no-till dryland agroecosystems. Agron. J. 83:519-526.

Moore, I.D., P.E. Gessler, G.A. Nielsen, and G.A. Peterson. 1993. Soil attribute prediction using terrain analysis. Soil Sci. Soc. Am. J. 57:443-452.

Peterson, G.A., D.G. Westfall, and C.V. Cole. 1993. Agroecosystem approach to soil and crop management research. Soil Sci. Soc. Am. J. 57:1354-1360.

Evans, S.D., G.A. Peterson, D.G. Westfall and E. McGee. 1994. Nitrate leaching in dryland agroecosystems as influenced by soil and climate gradients. J. Environ. Qual. 23:999-1005.

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Westfall, D.G., J.L. Havlin, G.W. Hergert, and W.R. Raun. 1996. Nitrogen management in dryland cropping systems. J. of Prod. Agric. 9:192-199.

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Kolberg, R.L., N.R. Kitchen, D.G. Westfall, and G.A. Peterson. 1996. Cropping intensity and nitrogen management impact on dryland no-till rotations in the semi-arid western Great Plains. J. Prod. Agric. 9:517-522.

Follett, R.F., E.A. Paul, S.W. Leavitt, A.D. Halvorson, D. Lyon, and G.A. Peterson. 1997. Carbon isotope ratios of Great Plains soils in wheat-fallow systems. Soil Sci. Soc. Am. J. 61:1068-1077.

Paul, E.A., R.F. Follett, S.W. Leavitt, A.D. Halvorson, G.A. Peterson, and D. Lyon. 1997. Carbon isotope ratios of Great Plains soils in wheat-fallow systems. Soil Sci. Soc. Am. J. 61:1058-1067.

Kolberg R.L., B. Roupett, D.G. Westfall, and G.A. Peterson. 1997. Evaluation of an *in situ* net nitrogen mineralization method in dryland agroecosystems. Soil Sci. Soc. Am. J. 61:504-508.

McGee, E.A., G.A. Peterson, and D.G. Westfall. 1997. Water storage efficiency in no-till dryland cropping systems. J. Soil and Water Cons. 52:131-136.

Peterson, G.A., A.D Halvorson, J.L. Havlin, O.R. Jones, D.J. Lyon, and D.L. Tanaka. 1998. Reduced tillage and increasing cropping intensity in the Great Plains conserves soil carbon. Soil and Tillage Res. 47:207-218.

Farahani, H.J., G.A. Peterson, D.G. Westfall, and L.R. Ahuja. 1998. Soil water storage in dryland cropping systems: The significance of cropping intensification. Soil Sci. Soc. Am. J. 62:984-991.

Power, J.F. and G.A. Peterson. 1998. Nitrogen transformations, utilization, and conservation as affected by fallow tillage method. Soil and Tillage Res. 49:37-47.

Farahani, H.J., G.W. Buchleiter, L.R. Ahuja, G.A. Peterson, and L. Sherrod. 1999. Season evaluation of the root zone water quality model in Colorado. Agron. J. 91:212-219.

Ma, L., G.A. Peterson, L.R. Ahuja, L. Sherrod, M.J. Shafer, and K.W. Rojas. 1999. Decomposition of surface crop residues in long-term studies of dryland agroecosystems. Agron. J. 91:401-409.

Rodriguez, J.B., J.R. Self, G.A. Peterson, and D.G. Westfall. 1999. Sodium bicarbonate-DTPA test for macro- and micro-nutrient elements in soils. Comm. Soil Sci. Plant Anal. 30:957-970.

Chapters in Books or Monographs:

Peterson, G.A. 1994. Interactions of surface residues with soil and climate. p. 9-12. IN: W.C. Moldenhauer and A.L. Black (eds.) Crop residue management to reduce erosion and improve soil quality: Northern Great Plains. USDA/ARS Cons. Res. Report No. 38. Washington, D.C.

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