Contents

Subject	Pages
Research Application Summary	1-3
Concurrent Research Projects	4-7
Introduction	8
Materials and Methods	9-16
Results and Discussion	17-26
Climate	17
Wheat	17
Corn and Sorghum	18
Proso Millet	19
Safflower	20
Sunflower	20
Opportunity Cropping	20
Crop Residue	22
Soil Water	22
Nitrogen and Phosphorus in Grain and Stover	23
Soil Nitrate-Nitrogen	24
Soil Organic Carbon	24
Available Phosphorus and pH	25
References	26
Data Tables	28-70
Herbicide Information - Appendix I	71-78
Project Publications	79-86

List of Tables

Table Title	**Page**
Table 1 - Elevation, annual precipitation and evaporation characteristics for each site.	9
Table 2a - Cropping systems for each of the original sites in 1998.	15
Table 2b - Cropping systems for the new sites in 1998.	16
Table 3 - Crop variety, seeding rate, and planting date for each site in 1998.	16
Table 4 - Nitrogen fertilizer application by soil and crop in 1998.	28
Table 5a & 5b - Monthly precipitation for each site for the 1997-1998 growing season.	29-30
Table 5c - 5h - Precipitation summaries by growing season segments.	31-33
Table 6a & 6b - Grain and stover yields for wheat.	34-35
Table 7 - Wheat yields at optimum fertility by year and by soil position at Sterling 1986-1998.	36
Table 8 - Wheat yields at optimum fertility by year and by soil position at Stratton 1986-1998.	36
Table 9 - Wheat yields at optimum fertility by year and by soil position at Walsh 1986-1998.	37
Table 10 - Grain yields at Nunn, Akron, and Lamar sites in 1998.	38
Table 11a & 11b - Grain and stover yields for corn and sorghum.	39-40
Table 12 - Corn yields at optimum fertility by year and soil at Sterling 1986-1998.	41
Table 13 - Corn (sorghum) yields at optimum fertility by year and soil at Stratton 1986-1998.	41
Table 14 - Rotation sorghum yields at optimum fertility by year and soil at Walsh 1986-1998.	42
Table 15 - Continuous row crop yields at optimum fertility by year and soil at Walsh 1986-1998.	42
Table 16a & 16b - Grain and stover yields for proso millet and sunflower.	43-44
Table 17 - Grain and forage yields in the opportunity cropping system at Sterling.	45
Table 18 - Grain and forage yields in the opportunity cropping system at Stratton.	46
Table 19 - Grain and forage yields in the opportunity cropping system at Walsh.	47
Table 20 - Crop residue weights on all plots in wheat during the 1997-1998 crop year.	48
Table 21 - Crop residue weights on all plots in corn and sorghum during the 1997-1998 crop year.	49
Table 22 - Crop residue weights on all plots in proso millet and safflower during the 1997-1998 crop year.	50
Table 23 - 30 - Available soil water in various crops during the 1997-1998 growing season.	51-58
Table 31a - Total nitrogen and phosphorus of wheat grain in 1998.	59
Table 31b - Total nitrogen and phosphorus of wheat straw in 1998.	60
Table 32a - Total nitrogen and phosphorus of corn and sorghumt grain in 1998.	61
Table 32b - Total nitrogen and phosphorus of corn and sorghum stover in 1998.	62
Table 33a - Total nitrogen and phosphorus of proso millet and safflower grain in 1998.	63

Table 33b - Total nitrogen and phosphorus of proso millet and safflower stover in 1998.	64
Table 34a - Total nitrogen content of wheat grain in 1998 at the Nunn site.	65
Table 34b - Total nitrogen content of wheat grain in 1998 at the Akron site.	65
Table 34c - Total nitrogen content of wheat grain in 1998 at the Lamar site.	66
Table 35 - Nitrate-N content of the soil profile at planting for each crop in 1997-1998.	67
Table 36 - Soil organic C at Sterling, Stratton, and Walsh Colorado in 1998.	68
Table 37 - Extractable sodium bicarbonate phosphorus at Sterling, Stratton, and Walsh Colorado in 1998.	69
Table 38 - Soil pH in water (1:2) at Sterling, Stratton, and Walsh Colorado in 1998.	70

1999

SUSTAINABLE DRYLAND AGROECOSYSTEM MANAGEMENT[1]

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A Cooperative Project

of the

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Department of Bioagricultural Sciences and Pest Management
Colorado State University
Fort Collins, Colorado

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USDA - Agriculture Research Service
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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 13-year period.

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 12 years' average yield history for wheat, corn, sorghum, and proso millet at our three study locations. Wheat has been grown all 13 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).

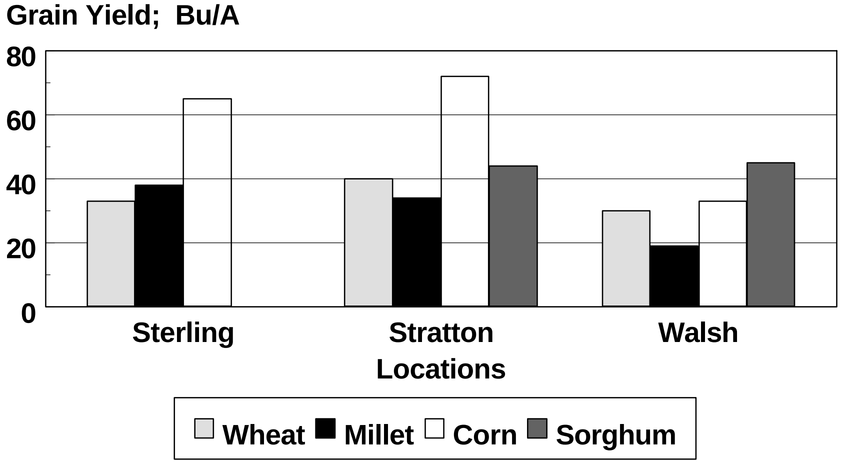


Figure 1. Grain yields averaged over soil positions and 13 years of production for each location.

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. Fluctuations in corn and sorghum yields are of most interest because they represent the highest input crops. Corn yields have averaged 65 bu/A (Ranging from 14 to 107 bu/A) at Sterling and 76 bu/A (Ranging from 37 to 112 bu/A) at Stratton. These averages include the disastrous yields recorded in 1994, which were caused by drought, and the low yields caused by early frost in 1995. Grain sorghum was produced at Stratton for 4 years and yielded an average of 44 bu/A (ranging from 20 to 63 bu/A), but corn has averaged 76 bu/A for the past 9 years, making it a better choice for this environment. At Walsh grain sorghum yields have averaged 48 bu/A (ranging from 27 to 75 bu/A), including the results from the very dry 1995 season and severe hail in 1996. Dryland corn yields at Walsh, using Bt varieties, have averaged 60 bu/A in 1997 and 1998.

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.

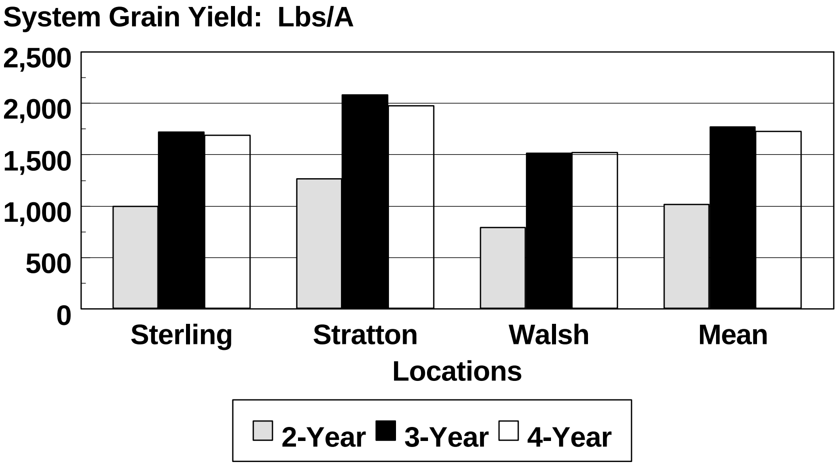


Figure 2 . System grain yield for each location.

Our data have shown 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 in all three study environments when compared over years. 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. New, more intensive 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.

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. Compared to the original three experiments, 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.

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 over 191,000 acres in 1998. Total dryland corn acreage in Colorado increased from 23,700 historically to 240,000 in 1998. One-third of the additional 90,000 acres in 1998 occurred because of new growers in Cheyenne, Lincoln, and Weld counties. 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 145,000 in 1998.

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).

Dryland Corn Acreage in Eight Northeastern Colorado Counties and total for state 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

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

CONCURRENT RESEARCH PROJECTS

Triticale-Corn-Hay Millet 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.

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, Atrazine, and Command applied after harvest.

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

iv) Corn is harvested in late September.

v) Hay millet is planted into corn stalks the following May and is harvested in July, leaving a 4-6 inch stubble. 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 Roundup Ready, Dekalb, DK493 RR, was grown to aid in sandbur control

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

iii) 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 well below average in 1998.

Triticale and corn grain yields by soil for 1998.

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

[1] Harvested leaving 10" stubble;

Expectations:

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 thirteen year period. Beginning in summer 1999 Roundup Ready soybean for forage will be substituted for hay millet. This should allow excellent sandbur control and production of a higher protein forage compared to hay millet.

Experiment Managers:

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

Wheat-Corn-Pea Rotation at Sterling and Stratton: {Experiment established in fall 1994}

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 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. Soil water content is measured monthly in the peas. After harvest remaining 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:

i)

Sterling						
Pea Type	Planting Date	1995	1996	1997	1998	Mean (97 & 98)
		----------------------------------Lbs/A---------------------------------------				
AWP*	Fall	--	3110	3480	2250	2865
AWP	Spring	--	--	3390	1360	2375
Trapper	Spring	--	--	2610	1590	2100

* = Austrian Winter Pea

Notes: In 1995 the peas were hailed out approximately 1 week prior to harvest. The Trapper spring peas were infested with weeds in 1996 and no yield was measured. Spring planted AWP was not tested prior to 1997.

ii)

Stratton						
Pea Type	Planting Date	1995	1996	1997	1998	Mean (97 & 98)
		----------------------------------Lbs/A--				
AWP*	Fall	3520	--	1920	2870	2395
AWP	Spring	--	--	2220	1260	1740
Trapper	Spring	--	--	1970	1640	1805

* = Austrian Winter Pea

Notes: The AWP desiccated in 1996 resulting in poor stands. This problem was corrected by planting the seed deeper (2 to 3" below the surface). The Trapper spring pea was infested with weeds in 1995 and 1996 and no yield as measured. Spring planted AWP was not tested prior to 1997.

Expectations:

Soil water measurements are made to determine how much water is used by the peas and how that might affect subsequent winter wheat yields. Data from the literature would indicate there should be little effect on wheat yield because water use by peas is minimal, and water storage from pea harvest to wheat planting should be adequate to establish good winter wheat stands in the fall.

Economic evaluations of peas for forage will be completed in 1999. To date it appears that the high quality of the pea forage makes it equal to alfalfa hay in value and that our yields, even including failed years, may be economically feasible.

Experiment Managers: David Poss, G.A. Peterson 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 soybeans in eastern
2) To observe growth characteristics and potential harvest dates.

Procedure:

Varieties:

Asgrow	1901, 2101, 2301	(Groups 1.9, 2.1, 2.3)
Pioneer	92B01, 92B21	(Groups 2.0, 2.2)

Population:

180,000 to 185,000 seeds/A
(3000 seeds/pound)

Planting Date:

Stratton = 28 May 1998
Sterling = 27 May 1998

Seed cost: Roundup Ready = $24 per 50 lbs; Planted @ 60#/A = $28.80/A

Results:

Sterling - Hail in September destroyed the crop completely. Over 80% of the pods were split open and the seed on the ground.

Stratton - Harvested on 8 October 1998

Variety	Grain Yield	Grain moisture
	----Bu/A—	-------%-------
Asgrow 2301	35	9.6
Pioneer 92B21	33	11.4
Asgrow 1901	33	10.9
Pioneer 92B01	32	12.2
Asgrow 2101	27	11.4
MEAN	32	11.1
L.S.D.	6	1.4

The yields at Stratton obviously were excellent, but July and August rainfall was 2.6" above average in 1998, and thus we probably cannot expect to consistently produce these yield levels. Using our experience in 1998, 12-15 bu/A yields would be the breakeven point. In 1999 we are experimenting with lower seeding rates to decrease production cost, which would allow us to profit at even lower soybean yield levels.

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, and 1998). 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, Stratton and Walsh, 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 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 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 these findings from 1985 to the present, we have now altered the systems being studied to reflect the new knowledge.

New more intensive 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.

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. Compared to 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. 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.

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, 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, Sratton, 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.

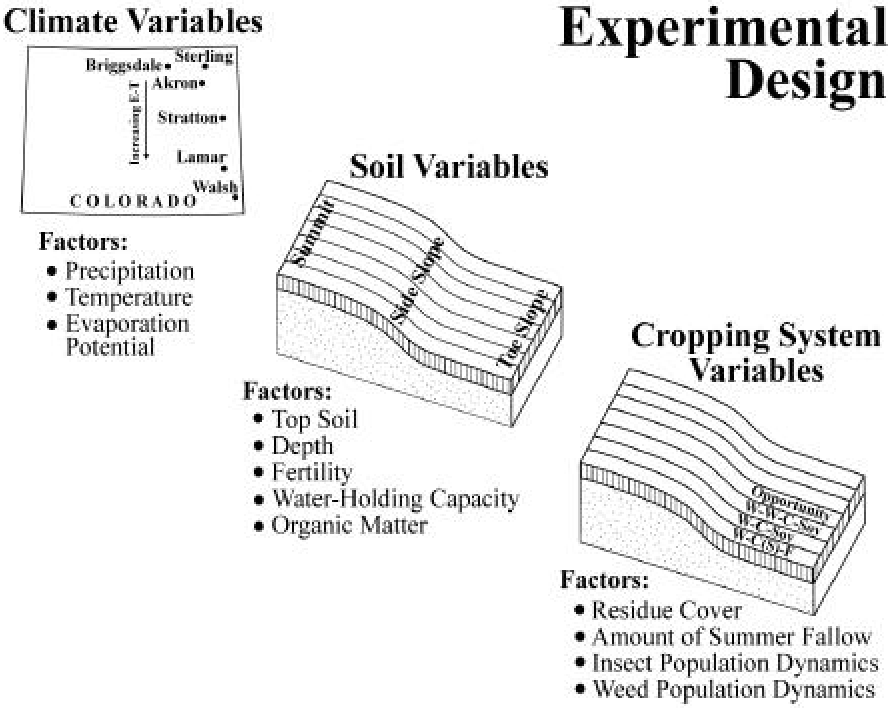
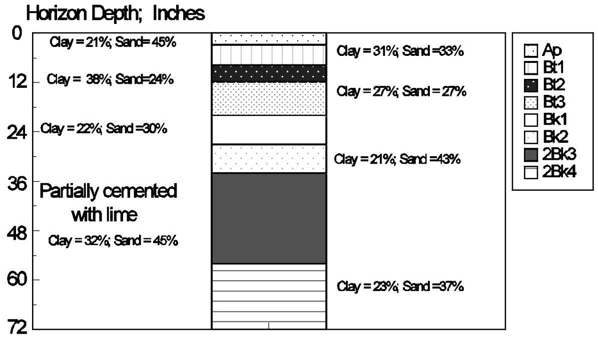


Figure 3. Experimental design with climate, soil, and cropping system variables.

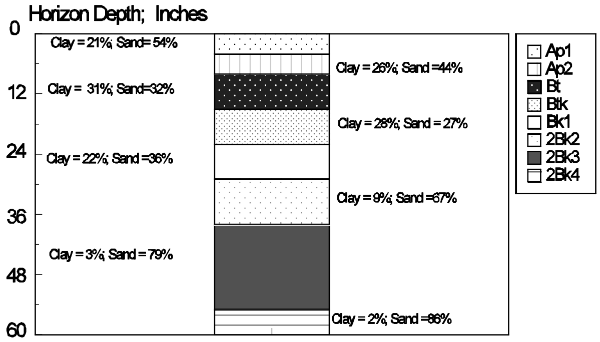
The summit soil profile at Sterling (Figure 4a) changes from a clay content of 21% at the surface(Ap) to 31% in the 3-8" depth (Bt1) to a clay content of 38% in the layer between the 8-12" depth (Bt2). At the 12" depth the clay content drops abruptly to 27%. The water infiltration in this soil is greatly 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

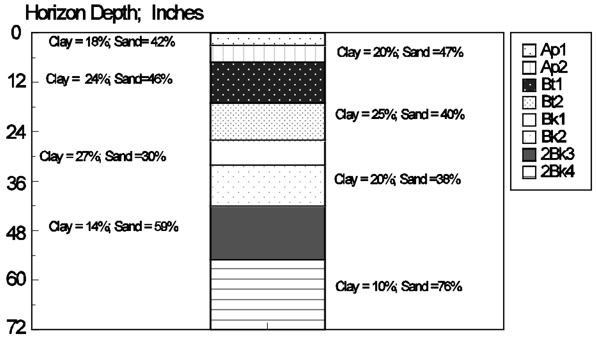
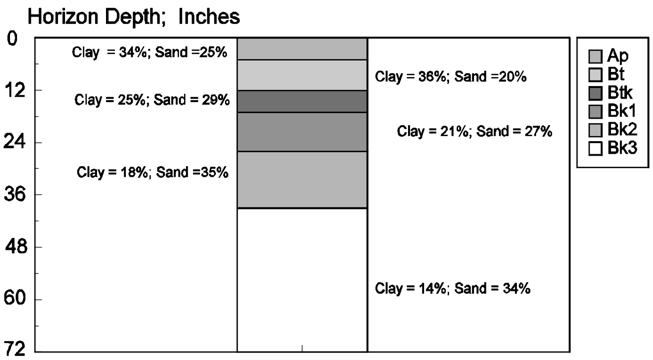
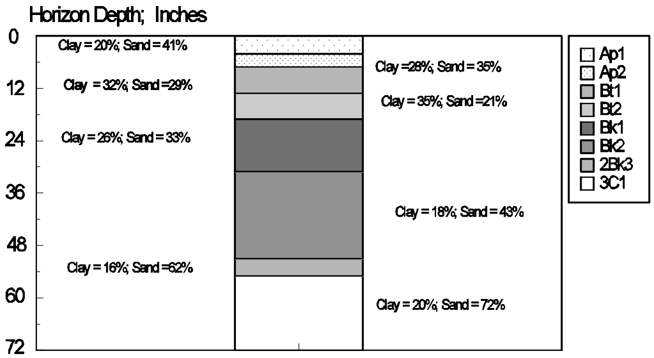


Figure 4a. Soil profile textural characteristics for soils at the Sterling site.

Stratton Summit Soil Profile



Stratton Sideslope Soil Profile



Stratton Toeslope Soil Profile

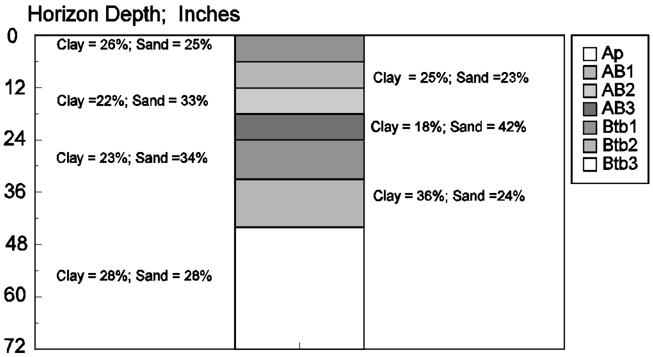
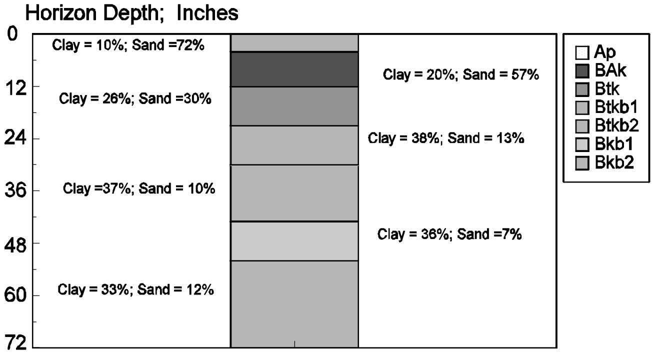


Figure 4b. Soil profile textural characteristics for soils at the Stratton site.

Walsh Summit Soil Profile

Walsh Sideslope Soil Profile



Walsh Toeslope Soil Profile

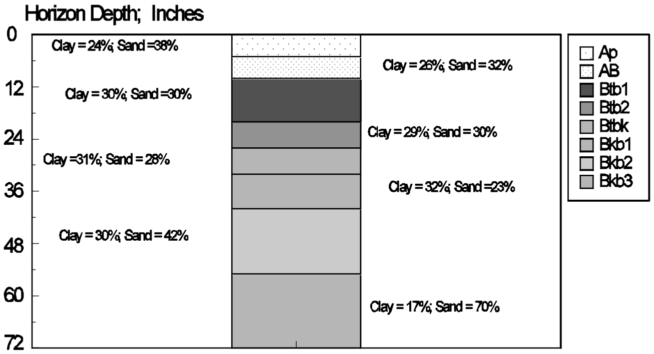


Figure 4c. Soil profile textural characteristics for soils at the Walsh site.

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 water 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 at this time. 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 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 8.5 lbs/A (20 lbs P_2O_5/A) or (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 and Stratton to correct a soil Zn deficiency.

Table 2a. Cropping systems for each of the original sites in 1998.

Site	Rotations
Sterling	1) Wheat-Corn-Fallow (WCF)
	2) Wheat-Corn-Proso (WCP)
	3) Wheat-Wheat-Corn-Proso (WWCP)
	4) Opportunity Cropping*
	5) Perennial Grass
Stratton	1) Wheat-Corn-Fallow (WCF)
	2) Wheat-Corn-Proso (WCP)
	3) Wheat-Wheat-Corn-Proso (WWCP)
	4) Opportunity Cropping*
	5) Perennial Grass
Walsh	1) Wheat-Sorghum-Fallow (WSF)
	2) Wheat-Corn-Safflower (WCSa)
	3) Wheat-Wheat-Sorghum-Safflower (WWSSa)
	4) Continuous Row Crop (Alternate corn & sorghum)
	5) Opportunity Cropping*
	6) Perennial Grass

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[*] 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

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 1998.

Site	Rotations
Nunn (Briggsdale)	1) Wheat-Proso-Fallow (WPF) 2) Wheat-Sunflower-Fallow (WSnF)
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 1998.

Site	Crop	Variety	Seeding Rate	Planting Date
Nunn	Wheat	Halt & Akron	60 lbs/A	9/16/97
	Proso	Cope	10 lbs/A	6/5/98
	Sunflower	Triumph 565	15,000 seeds/A	5/20/98
Sterling	Wheat	Halt	60 lbs/A	9/25/97
	Corn	Pioneer 3752	18,000 seeds/A	5/4/98
	Proso	Sunup	15 lbs/A	5/27/98
Akron	Wheat	Halt & TAM 107	56 lbs/A	8/26/97
	Corn	Pioneer 4835	16,100 seeds/A	5/11/98
	Proso	Sunup	12 lbs/A	6/12/98
	Sunflower	Triumph 565	19,000 seeds/A	5/27/98
Stratton	Wheat	Halt	60 lbs/A	9/30/97
	Corn	Pioneer 3752	18,000 seeds/A	5/18/98
	Proso	Sunup	15 lbs/A	5/28/98
Lamar	Wheat	Halt and TAM 107	40 lbs/A	9/10/97
	Sorghum	NK 310	26,400 seeds/A	5/28/98
Walsh	Wheat	Halt	50 lbs/A	9/29/97
	Sorghum	Cargill 627	43,000 seeds/A	6/9/98
	Safflower	SF 797	20 lbs/A	3/13/98

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 1997, the period prior to wheat planting and the fall growth period, was above the normals by 7.7 in. (195 mm) at Sterling, by 11.5 in. (293 mm) at Stratton, and by 2.1 in. (54 mm) at Walsh (Table 5a). However, the first half of 1998 was substantially below normal at Sterling (-3.8 in. or -96 mm) , about normal at Stratton, and 3.4 in. (86 mm) below normal at Walsh. Precipitation was well above normal during the second half of 1998 at all sites; 2.7 in. (68mm) at Sterling, 1.7 in. (44 mm) at Stratton, and 4.5 in. (113 mm) at Walsh (Table 5a).

The exceptionally high July and August rainfall at Stratton, 8.0 in., compared to a normal of 5.4 in., and at Walsh, 8.3 in., compared to a normal of 4.6 in., greatly increased yields of the summer crops. Summer rainfall also was favorable at the new locations (Table 5b). Tables 5c-5h show the precipitation distribution as related to crop growing season at each of the six sites.

Wheat

Our wheat yields in 1998 were near the 12 year average at the three original sites (Tables 7, 8 & 9), despite below average winter and spring precipitation as noted above. The excellent precipitation before wheat seeding obviously provided the reserve soil water to maintain yields. As in previous years soil position altered wheat grain yield (Tables 6a & 6b), with toeslopes always having the highest yields due to their greater opportunity for additional water and soils with no root restrictions (Figures 4a, 4b, & 4c).

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. Thus it is obvious that the 1998 wheat data, except for WCF and WSF, do not represent yields that are necessarily indicative of that system. Within two years, by 2000, we should be getting results that reflect cropping system effects.

Downy brome (*Bromus tectorum L.)* infestations were a continuing problem in WF and have decreased yields relative to the other rotations. Over the long term, 3-year systems have yielded the same as WF when no downy brome is present. It will be interesting to see how the new continuous systems alter downy brome populations. Historically, the 4-year systems, that had the 4th year in fallow have yielded about 5 bu/A more than either WF or WCF at Sterling and Stratton. We do not know why. At Walsh all systems yielded essentially the same. It is important to note that the shorter fallows in the more intensive systems never decreased wheat yield at any site from 1986 to 1997.

Wheat yields at the three new sites, Nunn, Akron, and Lamar are reported in Table 10 and tended to be average for the area at Nunn and Lamar, but below average at Akron. Since the sites are new, the wheat yields should not be regarded as indicative of a specific cropping system. For example at Nunn wheat followed fallow in two reps and averaged over 50 bu/A, while in the other two reps where it followed wheat, it averaged only 29 bu/A. At Akron the wheat following fallow yielded 32 bu/A, while following millet it yielded 12 bu/A. There was little precipitation after millet harvest and the soil profile was dry. In addition the winter and spring were dry, which further stressed the wheat. Lamar yields were excellent, averaging 41 bu/A. Cattle grazing decreased grain yields over 5 bu/A. This may be attributable to allowing the animals to be on the wheat too long.

Cultivar effects at the new sites were small. Varieties susceptible to Russian wheat aphid had yields equal to the aphid resistant ones because aphid pressure was low at all sites.

Corn and Sorghum

Corn yields at Sterling were near the 13-year average, 62 bu/A 3890 kg/ha), but were 35 bu/A (2200 kg/ha) above the average at Stratton (Tables 12 & 13). We attributed the high yields at Stratton to the above average rainfall during July and August, which totaled 8.0 in.; 3.7 in. above the normal. The rainfall from 15 July to 25 August, the critical period for corn production (Nielsen, et al., 1996), was 5.4 in. at Sterling, which is very near the average and thus we produced average corn yields.

As in all years the toeslope soil position produced the highest corn yields at both sites (Tables 11a & 11b). However, at Stratton the summit and sideslope soil positions produced proportionately more grain than usual. For example the summit and sideslope produced 99 and 81% of the yield of the toeslope, respectively. The long-term means are 74 and 69% of the toeslope yield for the summit and sideslope positions, respectively. Obviously in years with favorable precipitation during the critical period, soil water storage capacity and slope position have less influence on yield.

Phosphorus fertilization had no effect on corn grain yield on any soil at either Sterling or Stratton (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 does not result in an increase in grain yields.

Sorghum yields at Walsh ranged from 37 to 84 bu/A (2320 to 5270 kg/ha) (Tables 11a & 11b), which is above the long-term average (Table 14). The August rainfall, 4.9 in. (124 mm), which was 2.9 in. above normal, gave us excellent yield potential (Table 5a).

Long-term sorghum yields (Tables 14 & 15) are 48 bu/A for the WSF and 37 bu/A for the continuous row crop system. Our sorghum yields the first year after wheat are 18 bu/A (1130 kg/ha) higher than the Baca County average sorghum yield [30 Bu/A = 1880 kg/ha (1986-1996)].

One of our new systems at Walsh, WCSa, had corn for the first time in 1998 and yielded between 37 and 101 bu/A (2320 to 6330 kg/ha) with an average of 65 bu/A (4070 kg/ha). This yield is excellent even compared to the lower E-T environments, and obviously is related to the excellent summer precipitation. The use of Bt corn varieties has allowed us to plant later which is vital to growing successful dryland corn in Southeastern Colorado. We now plant in mid May as compared to mid April prior to the use of Bt corn, and this allows us to take advantage of the late season precipitation distribution. Our success with later planted corn was made possible by using a Bt corn, which prevented damage from the southwestern corn borer. In previous years we did not treat our corn with an insecticide for corn borer control because we considered treatment to be too expensive for a dryland system.

A continuous row-crop system (Tables 11a, 11b & 15) has always been included at the Walsh site. 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 corn yielded 54, 62, and 80 bu/A for the summit, sideslope and toeslope respectively (Table 11a). These yields are 2.5 times greater than our corn yield average prior to the use of Bt corn. Sorghum in the continuous row crop system averaged 62 Bu/A (3860 kg/ha) over all soils.

Phosphorus fertilizer tended to increase grain sorghum yields about 10 bu/A (630 kg/ha) on both summit and sideslope soils at Walsh, but had no effect on toeslope yields. This was true even though we have been adding P fertilizer to the previous wheat crop every year it is planted. The carryover to the sorghum crop from the wheat is not yet measurable at this site. Corn did not appear to respond to P fertilization except on the sideslope soil. Sometimes response to P fertilization relates to effects on maturity in terms of either timely rainfall events or earlier than expected frost dates. In 1998 neither of these maturity related issues was a factor.

Our corn crop at Akron only yielded 43 bu/A (Table 10) which was probably the result of using a very short season variety, Pioneer 4835. Sorghum yields at Lamar were 19 and 9 bu/A for ungrazed an grazed treatments, respectively. When the grazed treatments were tilled prior to sorghum planting clods were formed that prevented a good seedbed. A chiseling operation was used to remove compaction caused by animal grazing and this created the cloddy surface. Therefore, sorghum stands were poorer in the grazed plots and yields lower.

Proso Millet

Our newest cropping systems at Sterling and Stratton, WCP and WWCP, both had proso millet just ahead of the wheat crop. The millet was swathed down in early September, the windrows combined after drying, and then winter wheat was planted directly into the millet residue. Unless there is late weed growth in the millet no herbicides are needed before wheat planting. In 1998 the proso millet was planted into corn stalks in both systems as it will be in the future. Since the crop sequence in both of the new systems is the same as it will be in the future the 1998 yields should be representative of the system.

Proso millet yields at Sterling were not measured because of severe sandbur infestation. Millet yields at Stratton averaged over 35 bu/A (1960 kg/ha) (Tables 16a & 16b). Kochia was a problem in WWCP relative to the WCP system. The WWCP system was the former WCMF rotation and had a seedbank of kochia compared to the WCP system plots that previously had been in WF. Because of the weed problems encountered with proso millet at both sites we plan to substitute Roundup Ready soybean for proso in each of the new systems in 1999.

Our proso millet yields at Nunn averaged 24 bu/A (Table 10), but varied from 18 bu/A, when planted into wheat stubble, to 29 bu/A planted into fallow. We hypothesize that the difference was due to more available N in the fallowed soil. At Akron the proso treatments were destroyed because of heavy weed infestations, primarily sandbur and green foxtail.

Safflower

At Walsh the new continuous cropping systems were WCSa and WWSSa in 1998, where safflower occupies the position that proso millet occupies at Sterling and Stratton. Historically proso millet has yielded poorly in southeastern CO, consequently we chose a crop that might be more profitable than proso for the high E-T environment of Walsh. Safflower also is harvested early enough to permit winter wheat planting at a reasonable date in the fall.

Safflower yields averaged 570 lbs/A (640 kg/ha), over all fertility levels and soils (Table 16a & 16b). There was, however, a strong response to P fertilizer, which averaged 190 lbs/A (210 kg/ha). The safflower was harvested early enough to allow wheat planting at the usual September date, which met one of our requirements for the new systems. However, weed control problems in the safflower were large and this kept yield levels to low to be profitable. We plan to discontinue safflower and plant Roundup Ready soybean in its place in 1999.

Sunflower

Sunflower was produced at both the Nunn and Akron sites (Table 10). Yields at Nunn were low, averaging 452 lbs/A, and varied only slightly whether grown after wheat or after fallow. Grasshoppers destroyed a significant number of plants just after emergence, which reduced stands and subsequently reduced seed yields. In open spaces where populations were low, weed densities were high, further decreasing seed yields. In addition to these problems, there was an infestation of seed weevil at Nunn. At Akron seed yields were only 682 lbs/A, which was caused by poor weed control in our no-till situation.

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 1998 we grew wheat in the opportunity system at Sterling and Stratton and sorghum at Walsh (Tables 6a, & 6b and 11a, & 11b). Opportunity wheat at Sterling yielded 7 to 13 bu/A (470-870 kg/ha) less than the wheat in all other systems. The plants did not tiller as much as wheat in the other systems, and in addition the wheat had a chlorotic appearance throughout the season. Stratton opportunity wheat yields were about 4 bu/A (270 kg/ha) less than the yields in other systems and had the same symptoms as the wheat at Sterling. We are quite sure neither site was N deficient because we applied 60 and 74 lbs/A of N at planting at Sterling and Stratton, respectively.

Grain sorghum yields in the opportunity system at Walsh were excellent and similar to yields in other systems. The sorghum responded to P fertilizer on summit and sideslope soils as in other systems. Sorghum at Walsh followed corn, which should have depleted soil water substantially and thus we would hypothesize that 1998 sorghum yields would be depressed. Obviously the excellent summer rainfall compensated for the lower soil water potential.

From the initiation of our project in fall 1985 we have grown 11, 11, and 9 crops in 13 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 13 years at the two northern sites the system has produced a total of 118 to 164 bushels of wheat, 305 to 334 bushels of corn or sorghum, and 4.7 tons of forage per acre. Crop productivity at Walsh over 13 years has been 93 bushels of wheat, 274 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 1989-1997 average crop prices, the average total gross value of the 13 year production averaged over soils was $1381, $1615, and $1007 at Sterling, Stratton and Walsh, respectively (Tables 17, 18 & 19). Average total value (gross income) was $106, $124, and $77/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 $70/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 $106/A, which is similar to the $106 and $124/A/year produced in the opportunity system at Sterling and Stratton, respectively. Obviously opportunity cropping, although more productive than the 3-year system, is not as profitable as the 3-year system.

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 13 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 again 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 experimenting with soybean in our new systems.

Opportunity cropping has not been as profitable 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. 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 20, 21 & 22). 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 19. These values do not reflect the outcome of the specific rotations because conversion to the new systems just occurred at wheat planting in fall 1997. In several of the cases fallow preceded wheat planting. In fall 1998 we will begin to get an estimate of the effect of our new systems. It is impossible to draw conclusions regarding system residue levels based on this first year of observation.

Opportunity cropping has no planned summer fallow periods, but is cropped as intensively as possible. In general opportunity cropping has had 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 13 years there have been crops produced in 11 of the 13 at Sterling and Stratton and in 9 of the 13 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 23 to 30).

Wheat:

Soil profile available water was near field capacity at all soil positions in all systems at wheat planting in the fall of 1997 (Tables 23-27). Note that at all sites the amount of available water at planting was essentially equal in all systems. Because of the conversion to the new systems in fall

1997 most of the wheat was planted following a fallow period, and thus one would expect soil water contents to be similar. Soil water contents tended to be lower in the first year wheat of the (W)WCP system, because it was preceded by sunflower at Sterling and Stratton and by grain sorghum at Walsh. The soil water content at Walsh was near field capacity because the site received two times normal rainfall from August through October of 1997.

Water use by the wheat crop was similar for all systems at all sites, except for first year wheat in the (W)WCP system at Sterling where low soil water at planting severely limited water use (Table 25).

Wheat can 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 were excellent in 1998 (Tables 28- 30). Favorable summer rainfall in 1997 after wheat harvest recharged the soil despite below average spring rainfall.

Distribution of soil water at corn and sorghum planting and harvest also is shown in these tables. A relatively large amount of available water remained in the soil at corn and sorghum harvests at all sites compared to what we observe in most years. At Walsh corn and sorghum in the WCSf and WWSSf systems actually accumulated soil water compared to the amount at planting. High rainfall in July and August, 8.3 inches (210 mm) compared to a normal of 4.6 inches (115 mm), allowed the accumulation (Table 5a). Both corn and sorghum used water from depths greater than 5 feet (150 cm) as is often the case.

Opportunity:

Soil water data for the opportunity system at Sterling and Stratton are shown in Table 27, but no data were collected at Walsh in opportunity sorghum. Note that at both sites following wheat there was adequate water remaining in the profile at harvest to favor cropping again next year. Wheat was planted into the hay millet residue at Sterling and Stratton in fall 1997. At Walsh the opportunity cropping was planted to corn in 1997 and sorghum was planted directly into the corn stalks in 1998.

Nitrogen and Phosphorus Contents of Grain and Stover

Nitrogen and P contents were determined for both grain and stover for each crop on each soil at each original site (Tables 31-33) and N content of wheat grain was measured at each of the new sites (Tables 34a,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 14.7% at Sterling, 13.9% at Stratton, 14.70 % at Walsh, 10.5% at Nunn, 12.5% at Akron and 12.0% at Lamar (Tables 31a and 34a,b,c). To correct these values for grain moisture content, multiply by 0.88, which results in an average of about 11.5% 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 1998 wheat protein to this standard indicates that N fertilization was adequate for the wheat crop at Sterling, Stratton and Walsh, barely adequate at Akron, and deficient at Nunn and Lamar.

Wheat straw N concentrations ranged from 0.37 to 1.03% and averaged 0.55 % at the original sites; thus each ton of straw contained about 11 lbs of N (Table 31b). In cases where grain yields were low, like at Walsh in the first year wheat of the (W)WSSa system, the straw N contents tended to be higher, which is what one would expect.

Nitrogen levels in corn and sorghum grain varied from 1.10 to 1.63 %, which is equivalent to 5.9 to 8.7% protein on a market moisture basis (Table 32a). Corn and sorghum stover N contents varied from 0.40 to 1.08% and averaged 0.69% (Table 32b). Each ton of corn or sorghum stalks thus contained an average of 14 lbs of N.

Nitrogen levels in proso millet grain (Table 33a) ranged from 1.48 to 1.74% at Stratton, while levels in the stover ranged from 0.55 to 1.00% (Table 33b). Safflower seed N levels at Walsh ranged from 2.7 to 3.2% (Table 33a). No safflower stover samples were available for analysis.

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 on each soil at each site (Table 35). 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 generally the wheat-fallow system had higher residual nitrates than the 3- or 4-year rotations at the end of fallow prior to wheat planting. In fall 1997 the wheat in the WCP system at Sterling, Stratton, and the WCSa system at Walsh were planted on plots that were originally in the WF system. These cropping systems had the highest soil nitrate at planting on all soil positions at Sterling and Stratton and on the sideslope and toeslope positions at Walsh.

Soil nitrates at planting of corn and sorghum were about the same as 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.

Soil Organic Carbon

Soil organic carbon (C) can be used as an indicator of changes in soil quality. If C is increasing it generally indicates that erosion has been diminished and that C additions to the soil exceed C losses. Organic C is important for both nutrient and physical reasons in soils. Nutrient wise, higher soil C would indicate increased nutrient availability, particularly for N. Physically, increased soil C should stabilize surface soil structure, which in turn should improve soil water infiltration rates. Thus if soil organic C increases over time, soil productivity should increase. We have been tracking soil organic C since the project was initiated in fall 1985. Increased cropping intensity, made possible by no-till practices, has increased soil organic C as reported in Peterson, et al. (1998). A new sampling regime using soil depths of 0-5, 5-10, 10-15, and 15-20 cm(0-2, 2-4, 4-6, and 6-8 inches) was instituted in 1998 and data for four systems are shown in Table 36. Note that in most instances the perennial grass treatment has the highest soil organic C concentrations, followed by opportunity cropping. The WCF, our new standard of comparison has the lowest C contents. Although the WCP system was just started in 1998, it has higher C concentrations than WCF. This is the case because the additional plots that were added at each site had been cropped more intensively than the WCF. For example at Sterling there had been no summer fallow on these additional plots for over 10 years. The other plots that represent the WCP system were previously in WF and they have C concentrations lower than WCF.

Interestingly increased cropping intensity has significantly increased soil C even in the 10-15 cm depth. In addition there is a strong tendency that increased cropping intensity has started to increase C levels even in the 15-20 cm depth.

Available Phosphorus and Soil pH

Plant available soil phosphorus (P) levels in the Great Plains are often too low for maximum crop production, especially for small grains like winter wheat. The sodium bicarbonate ($NaHCO_3$)-extractable P is a widely used index of plant available P. In our experiments the grass system has had no P fertilizer added since we started the experiment, and thus soil test levels in this system reflect the general P status of each soil position at each site (Table 37). Small grains like winter wheat usually need fertilizer P if the $NaHCO_3$ - P is below 12 mg/kg, which is the case on summit and sideslope soils at all three of the original sites (Table 37). Toeslope soils exeed that value and rarely respond positively to applied P fertilizer.

Corn and sorghum, on the other hand, do not respond to P application unless the $NaHCO_3$ - P test level is below 8 mg/kg. Note in Table 36 that the average level in the 0-5 and 5-10 cm layers (top 4 inches of soil) is near that value on summit and sideslope soils. Over the years we have occasionally observed responses to P fertilizer on corn and sorghum on summit soils, almost always on sideslope soils, and rarely on toeslope soils. The soil test levels reflect why this has been the case. Increased cropping intensity has tended to increase $NaHCO_3$ - P levels in the 0-5 cm soil layer because we are fertilizing more frequently as intensity increases.

Soil pH is an indicator of acidity and basicity in soils. In soils of the Great Plains it is common to find soil pH near 7 (neutral point) to highly basic, pH = 8. Soils that form in low rainfall areas are not as chemically weathered as the soils in wetter areas, and therefore have not had their bases replaced with hydrogen ion. Note in Table 38 that below the 0-5 cm depth almost every combination of soil position and site has a pH above 7. If a soil contains free $CaCO_3$ (lime), then its pH is buffered near 8. At the Walsh site there is $CaCO_3$ right at the surface and the high pH reflects that fact. At Sterling where the $CaCO_3$ is found below 20 cm on the summit and toeslope positions, the pH at the soil surface is slightly acid in some cases. No-till systems tend to acidify the soil surface because CO_2 is released during residue decomposition, which in turn creates a weak acid, carbonic acid. Since, in no-till most residue decomposition is occurring in the surface 0-5 cm, the soil pH of that layer is most greatly impacted and tends to go down faster than under conventional tillage. At sites like Walsh, where $CaCO_3$ is present in the 0-5 cm layer, the acidity is neutralized and the pH remains unchanged.

Increased cropping intensity with no-till can be expected to lower soil pH for the reasons given above, plus the fact that more N fertilizer is used as cropping intensity increases. Most N fertilizers used in the Great Plains are ammonia based and as the ammonia is microbially oxidized to nitrate, hydrogen ion is released. This means soil pH will decrease if the acid is not neutralized by $CaCO_3$. In another study Iremonger, et al.(1997) reported that the pH in the surface 1" of soil (2.5 cm) decreased from 6.5 to 5.2 at Sterling and from 6.7 to 6.2 at Stratton as a result of N fertilization.

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Table 4. Nitrogen fertilizer application by soil and crop for 1998.

					ROTATION		
SITE	SOIL	CROP	WCF	WCM	WWCM	OPP	
				---------------------------Lbs/A---------------------------			
Sterling	Summit	Wheat	48	48	48	60	
	Sideslope	"	48	48	48	60	
	Toeslope	"	48	48	48	60	
	Summit	Corn	101	101	101		
	Sideslope	"	101	101	101		
	Toeslope	"	101	101	101		
	Summit	Proso Millet	-	41	41		
	Sideslope	"	-	41	41		
	Toeslope	"	-	41	41		
	Summit	Hay Millet					
	Sideslope	"					
	Toeslope	"					
			WCF	WCM	WWCM	OPP	
Stratton	Summit	Wheat	74	48	74	74	
	Sideslope	"	74	48	74	74	
	Toeslope	"	74	48	74	74	
	Summit	Corn	101	101	101		
	Sideslope	"	101	101	101		
	Toeslope	"	101	101	101		
	Summit	Proso Millet	-	41	41		
	Sideslope	"	-	41	41		
	Toeslope	"	-	41	41		
	Summit	Hay Millet					
	Sideslope	"					
	Toeslope	"					
			WSF	WCSa	WWSSa	OPP	CONT. CROP
Walsh	Summit	Wheat	61	61	61		
	Sideslope	"	62	61	61		
	Toeslope	"	61	61	61		
	Summit	Sorghum	36	-	36	36	
	Sideslope	"	36	-	36	36	
	Toeslope	"	36	-	36	36	
	Summit	Corn	70	-	-		
	Sideslope	"	70	-	-		
	Toeslope	"	70	-	-		
	Summit	Safflower	-	61	61		
	Sideslope	“	-	61	61		
	Toeslope	“	-	61	61		

Table 5a. Monthly precipitation for the original sites for the 1997-98 growing season.

MONTH	LOCATION					
	STERLING		STRATTON		WALSH	
	Inches					
1997	1997	Normals[1]	1997	Normals[1]	1997	Normals[1]
JULY	7.86	3.23	9.11	2.80	0.53	2.62
AUGUST	3.05	1.90	4.24	2.60	4.63	1.96
SEPTEMBER	1.69	1.04	0.45	1.45	0.60	1.74
OCTOBER	2.31	0.76	4.21	0.85	2.47	0.89
NOVEMBER	0.18	0.50	0.96	0.62	0.00	0.53
DECEMBER	0.41	0.40	1.16	0.28	1.94	0.31
SUBTOTAL	15.50	7.83	20.13	8.60	10.17	8.05
1998	1998	Normals	1998	Normals	1998	Normals
JANUARY	0.00	0.33	0.17	0.28	0.00	0.27
FEBRUARY	0.83	0.33	0.96	0.30	0.56	0.28
MARCH	0.04	1.07	0.10	0.76	1.31	0.81
APRIL	0.36	1.60	1.27	1.23	0.25	1.15
MAY	2.34	3.27	3.20	2.70	2.00	2.69
JUNE	2.23	3.00	1.39	2.45	0.00	2.29
SUBTOTAL	5.80	9.60	7.09	7.72	4.12	7.49
1998	1998	Normals	1998	Normals	1998	Normals
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	0.31	0.31
SUBTOTAL	10.49	7.83	10.34	8.60	12.51	8.05
YEAR TOTAL	23.20	17.43	28.12	16.32	16.50	15.54
18 MONTH TOTAL	32.49	25.26	37.62	25.70	30.52	23.59

[1] Normal = 1961-1990 data base

Table 5b. Monthly precipitation for the three new sites for the 1997-98 growing season.

MONTH	LOCATION					
	BRIGGSDALE*		AKRON		LAMAR	
	Inches					
1997	1997	Normals[1]	1997	Normals[1]	1997	Normals[1]
JULY	2.80	2.63	1.19	2.73	0.65	2.23
AUGUST	4.34	1.77	3.47	2.04	7.51	1.85
SEPTEMBER	1.32	1.29	1.06	0.98	2.03	1.33
OCTOBER	1.38	0.70	2.40	0.60	4.77	0.71
NOVEMBER	0.19	0.36	0.26	0.56	0.24	0.56
DECEMBER	0.23	0.27	0.44	0.32	1.10	0.40
SUBTOTAL	10.26	7.02	8.82	7.23	16.30	7.08
1998	1998	Normals	1998	Normals	1998	Normals
JANUARY	0.06	0.26	0.05	0.33	0.00	0.42
FEBRUARY	0.15	0.18	1.26	0.30	0.30	0.42
MARCH	0.53	0.75	0.15	0.91	2.01	0.90
APRIL	0.64	1.27	0.77	1.32	0.81	1.15
MAY	1.78	2.08	0.99	3.25	0.88	2.50
JUNE	1.52	2.10	0.36	2.62	0.87	2.19
SUBTOTAL	4.68	6.64	3.58	8.73	4.87	7.58
1998	1998	Normals	1998	Normals	1998	Normals
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
YEAR TOTAL	14.38	13.66	12.18	15.96	20.83	14.66
18 MONTH TOTAL	24.64	20.68	21.00	23.19	37.13	21.74

*Briggsdale weather substituted for missing Nunn data; Briggsdale site will replace Nunn in 1999.

[1] Normal = 1961-1990 data base

Table 5c. Precipitation by growing season segments for Sterling from 1987-1998.

	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
Long Term Average	4.4	7.9	11.2	13.2

Table 5d. Precipitation by growing season segment for Stratton from 1986 -1998.

	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
1997-1998	8.0	5.9	22.6	13.9
Long Term Average	4.5	6.4	11.2	12.9

Table 5e. Precipitation by growing season segment for Walsh from 1986-1998.

	Growing Season Segments			
	Wheat		Sorghum	
	Vegetat. Sep - Mar	Reprod. Apr - Jun	Preplant Jul - Apr	Growing Season 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
Long Term Average	4.8	6.1	10.6	12.2

Table 5f. Precipitation by growing season segment for Briggsdale from 1997-1998.

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

Table 5g. Precipitation by growing season segment for Akron from 1997-1998.

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

Table 5h. Precipitation by growing season segment for Lamar from 1997-1998.

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

Table 6a. Grain and stover yields for WHEAT in English units in 1998.

SITE & ROTATION	SLOPE POSITION											
	SUMMIT				SIDESLOPE				TOESLOPE			
	GRAIN		*STOVER*		*GRAIN*		*STOVER*		*GRAIN*		*STOVER*	
	NP*	NP	NP*	NP	NP*	NP	NP*	NP	NP*	NP	NP*	NP
STERLING:	------ Bu./A. ------		------ lbs./A. ------		------ Bu./A. ------		------ lbs./A. ------		------ Bu./A. ------		------ lbs./A. ------	
WCF	31	26	2200	2100	16	17	2300	2700	41	39	3600	3900
WCP	32	33	2500	2700	25	33	2800	2800	33	27	3300	2900
(W)WCP												
W(W)CP	31	34	2700	3000	35	37	2800	3300	44	48	4000	3800
OPP	23	25	1800	1900	21	24	1600	1800	29	25	2400	2300
	NP*	NP	NP*	NP	NP*	NP	NP*	NP	NP*	NP	NP*	NP
STRATTON:	------ Bu./A. ------		------ lbs./A. ------		------ Bu./A. ------		------ lbs./A. ------		------ Bu./A. ------		------ lbs./A. ------	
WCF	32	37	2800	3400	32	29	2500	2500	49	53	5600	5900
WCP	28	34	2300	3200	36	34	3100	3200	47	50	5400	5700
(W)WCP	32	35	2400	2600	35	31	2700	2400	42	37	4100	5100
W(W)CP	28	37	2300	3300	36	39	2900	3000	51	51	6700	6000
OPP	27	34	2300	3200	34	31	2400		37	43	3700	4500
	NP*	NP	NP*	NP	NP*	NP	NP*	NP	NP*	NP	NP*	NP
WALSH:	------ Bu./A. ------		------ lbs./A. ------		------ Bu./A. ------		------ lbs./A. ------		------ Bu./A. ------		------ lbs./A. ------	
WSF	30	31	3200	2800	31	31	3400	3300	36	39	5100	5200
WCSa	26	24	3600	2600	31	31	2700	4400	40	39	4400	6900
(W)WSSa	6	10	1600	200	11	12	1100	900	21	18	2200	2000
W(W)SSa	29	25	2800	3900	29	29	3000	3500	32	33	4400	4900

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 1998.

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	18004	15603	2470	23100	42704	3870	19302	20404	31403	31908	50604	52303	24403	23303	40302	43302	6470	6660
WCP	2050	19403	27901	30102	48401	49504	14902	19706	25605	30100	40504	49703	19504	15807	3700	32807	5650	4860
(W)WCP																		
W(W)CP	18504	20203	30100	33504	48605	53702	20706	21902	31706	36605	52403	58504	26003	28403	44908	42702	7090	7110
OPP	13703	14605	19801	21302	33504	35908	1210	14403	18302	20202	30403	34601	17201	14504	27302	26005	4450	4050
STRATTON:	-----------------kg/ha--------------------						---------------------kg/ha--------------------						-------------------kg/ha-------------------					
WCF	18807	22002	31100	38003	49908	53100	18807	17100	27901	28101	46706	4520	28904	31201	63302	65603	9220	9700
WCP	16807	20302	26204	35803	43002	56201	21204	19908	34503	35805	55807	55604	2760	29301	60302	64201	8790	9350
(W)WCP	1860	20501	27304	29403	45904	48007	20504	1840	27006		47504		24908	22004	45602	56804	7050	7890
W(W)CP	16807	21801	25302	36706	42100	58504	21402	23002	32701	34100	54103	57002	29908	30302	75204	67706	105100	9790
OPP	16005	1980	25302	36403	41302	56201	20001	18302	2990	26803	49901	45100	21706	25104	41807	5070	6350	7580
WALSH:	-----------------kg/ha--------------------						---------------------kg/ha--------------------						-------------------kg/ha-------------------					
WSF	17605	18404	36403	31000	53903	4940	18303	18501	38100	36908	36804	55403	21504	23003	57100	57908	7850	8090
WCSa	15502	14404	39904	29504	55504	43908	18303	18101	30706	49902	49002	68003	23803	23002	4950	77403	7330	100302
W)WSSa	380	570	1830	2220	2210	2780	660	710	1180	3104	1850	3814	1230	1060	2460	2240	3690	3300
W(W)SSa	17302	14706	31204	43603	4850	58302	17204	17002	32908	39302	50101	56304	19100	19706	49703	54605	6880	7420

* Only receives phosphorus in wheat phase of each rotation.

Table 7. **Wheat yields at optimum fertility by year and soil position at STERLING from 1986-1998.**

YEAR	SLOPE POSITION			
	SUMMIT	SIDE	TOE	MEAN
	----------Bu/A----------			
1986	27	25	28	27
1987	22	15	25	21
1988	18	27	19	21
1989	36	38	46	40
1990	35	34	47	39
1991	31	29	41	34
1992	17	18	35	23
1993	41	38	52	44
1994	22	28	36	29
1995*	27	28	30	28
1996	53	53	66	57
1997*	26	30	35	30
1998 [1]	31	28	39	33
MEAN	30	30	38	33

*Averages do not include wheat-fallow, which was infested with downy brome. [1]Averages do not include opportunity cropping.

Table 8. **Wheat yields at optimum fertility by year and soil position at Stratton from 1986-1998.**

YEAR	SLOPE POSITION			
	SUMMIT	SIDE	TOE	MEAN
	----------Bu/A----------			
1986	32	29	23	28
1987	27	20		24
1988	38	43	49	43
1989	43	31	87	54
1990	48	53	72	58
1991	49	40	56	48
1992	29	29	31	30
1993	36	35	51	41
1994	37	35	51	41
1995	46	36	48	43
1996	40	35	62	46
1997*	25	20	31	25
1998	35	33	46	38
MEAN	37	30	51	39

*Averages do not include wheat-fallow, which was infested with downy brome.

Table 9. Wheat yields at optimum fertility by year and soil position at Walsh from 1986-1998.

YEAR	SLOPE POSITION			
	SUMMIT	SIDE	TOE	MEAN
	--------------------------Bu/A--------------------------			
1986	No wheat produced this year			
1987	34	32	48	38
1988	No wheat produced this year			
1989	24	27	28	26
1990	24	28	32	28
1991	32	34	48	38
1992	25	39	53	39
1993	34	39	42	38
1994	33	37	44	38
1995	13	14	17	15
1996	0	0	0	0
1997	39	40	45	41
1998 [1]	28	30	36	31
MEAN	26	29	36	30

[1] Average does not include 1st year wheat in (W)WSSa

Table 10. Grain yields for the Nunn, Akron, and Lamar sites for 1998.

Site & Crop	**Previous Crop**	
Nunn	**Wheat**	**Fallow**
	--Bu/A--	--Bu/A--
Wheat – HALT variety	29	52
Wheat – AKRON variety	29	5
Proso Millet	18	29
	--Lbs/A--	--Lbs/A--
Sunflower	434	469
Akron	**Rotation**	
	Other Rotations	**W-C-M**
	--Bu/A--	--Bu/A--
Wheat – HALT variety	32	12
Wheat – TAM 107 variety	32	12
Corn	43	--
	--Lbs/A--	--Lbs/A--
Sunflower	682	--
Proso Millet	Weeds - No yield	Weeds - No yield
Lamar	**Grazing Treatment**	
	Ungrazed	**Grazed**
	--Bu/A--	--Bu/A--
Wheat – HALT variety	45	39
Wheat – TAM 107 variety	43	37
Grain Sorghum	19	9

Table 11a. Grain and stover yields for CORN AND SORGHUM in English units in 1998.

	SLOPE POSITION											
	SUMMIT				SIDESLOPE				TOESLOPE			
SITE & ROTATION	*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	53	48	1700	1600	46	42	1500	1400	61	48	2000	1600
WCP	53	60	1800	2000	71	71	2300	2400	99	92	3300	3100
WWCP	45	44	1500	1500	53	57	1800	1900	84	83	2800	2800
	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	132	113	4700	4000	102	87	3400	3100	115	119	4400	5600
WCP	100	121	4200	4400	89	100	4000	5600	113	135	9200	6600
WWCP	125	119	4500	3600	105	96	3200	3000	128	106	5900	3800
	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	54	67	1600	2000	74	79	1900	3700	77	75	2600	3000
WCSa	40	37	1600	1200	53	59	2100	2200	99	101	3000	2900
WWSSa	55	67	2200	2600	67	81	3100	3100	77	84	3900	2700
OPP(Sorghum)	58	72	1800	2400	65	80	2600	2000	81	87	3200	3700
CS (Corn)	55	53	1700	1700	57	66	1800	1900	78	81	3100	2400
CS (Sorghum)	58	61	1700	2700	62	65	2100	2800	65	56	2600	1900

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 1998.

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	2780	2550	1960	1880	4740	4350	2410	2240	1700	1580	4110	3830	3210	2560	2260	1800	5470	4350
WCP	2830	3160	1990	2230	4820	5390	3740	3750	2630	2640	6370	6380	5270	4870	3710	3430	8980	8300
WWCP	2360	2320	1660	1640	4020	3960	2810	3040	198079	2140	4790	5180	4470	4380	3150	3090	7620	7470
	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	6990	5980	5270	4450	1230	1040	5380	4620	38401	3470	9220	8090	6070	6300	4930	6300	11000	126009
WCP	5320	6410	4750	4920	10070	11330	4730	5270	4490	6270	9220	11540	5980	7170	10330	7350	16310	14520
WWCP 6600	6600	6330	5030	4040	11630	10370	5570	5110	3540	3530	9110	8640	6800	5590	6600	4280	13400	9870
	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	2940	3610	1740	2200	4680	5810	4000	425047	211009	4130	6110	8370	4180	4050	2920	3300	7100	7350
WCSa	2150	1970	1800	1380	3950	3350	2800	3130	232019	2470	5120	5610	5240	5350	3400	3270	8640	8610
WWSSa	2960	3600	2420	2910	5380	6510	3600	4380	34502	3490	7060	7880	4170	4520	4420	3050	8590	7570
OPP	3120	3880	2040	2730	5150	9030	3530	4290	29401	2300	6470	6590	4360	4670	3580	4110	7950	8780
CS (Corn)	2920	2830	1860	1920	4780	4750	3030	3500	20404	1940	5080	5440	4150	4270	3480	2640	7630	6920
CS	3110	3310	1870	3000	4980	6320	3330	3480	23004	3140	5630	6620	3530	3000	2900	2100	6420	5100

Table 12. **Corn yields at optimum fertility by year and soil position at STERLING from 1986-1998.**

YEAR	SLOPE POSITION			
	SUMMIT	SIDE	TOE	MEAN
	--------Bu/A--------			
1986	48	34	70	51
1987	47	59	70	59
1988	61	71	78	70
1989	52	74	102	76
1990	66	80	104	83
1991	55	69	105	76
1992	84	87	120	97
1993	43	50	70	54
1994	4	17	22	14
1995	10	12	29	17
1996	57	67	94	73
1997	92	108	120	107
1998	50	57	78	62
MEAN	51	60	82	65

Table 13. **Corn and sorghum yields at optimum fertility by year and soil position at STRATTON from 1986-1998.**

YEAR	SLOPE POSITION			
	SUMMIT	SIDE	TOE	MEAN
	--------Bu/A--------			
1986	52	38	99	63
1987	30	34	51	38
1988	42	46	78	55
1989	21	15	24	20
MEAN	36	33	63	44
	Corn replaced sorghum beginning in 1990			
1990	54	54	88	65
1991	89	79	117	95
1992	82	76	111	90
1993	64	74	94	77
1994	48	34	68	50
1995	26	29	56	37
1996	106	101	128	112
1997	40	40	67	49
1998	118	96	119	111
MEAN	70	65	94	76

Table 14. Rotation sorghum yields at optimum fertility by year and soil position at Walsh from 1986-1998.

YEAR	SLOPE POSITION			
	SUMMIT	SIDE	TOE	MEAN
	--------------------------Bu/A----------------------------			
1986	35	26	44	35
1987	29	31	20	27
1988	43	47	72	54
1989	18	28	85	44
1990	24	37	76	46
1991	33	49	64	49
1992	44	54	56	51
1993	50	54	56	53
1994	62	63	97	74
1995*	27	34	35	32
1996	25	30	38	31
1997	38	45	65	49
1998	67	80	78	75
MEAN	38	44	60	48

*Average of WSF and WSSF-1(1986-1997) and average of WSF and WWSSa (1998).

Table 15. Continuous row crop yields at optimum fertility by year and soil position at Walsh from 1986-1998 (Sorghum & Corn).

YEAR	SLOPE POSITION			
	SUMMIT	SIDE	TOE	MEAN
	--------------------------Bu/A----------------------------			
1986	35	26	44	35
1987	29	26	13	23
1988	39	21	66	42
1989	31	27	70	43
1990	44	33	47	41
1991	43	41	38	41
1992	42	48	49	46
1993	22	20	31	24
1994	24	20	21	22
1995	27	30	26	28
1996	18	21	22	20
1997	42	50	68	53
1998	57	62	70	63
MEAN	35	33	43	37

Table 16a. Grain and stover yields for PROSO and SAFFLOWER at Walsh in English units in 1998.

	SLOPE POSITION											
	SUMMIT				SIDESLOPE				TOESLOPE			
SITE & ROTATION	***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. ------	
WCP	NOT HARVESTED				NOT HARVESTED				NOT HARVESTED			
						WWCP						
	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. ------	
WCP	44	51	2100	3000	39	45	1400	2500	41	45	2600	2800
WWCP	31	22	2200	1700	39	23	1800	2200	30	8	1800	1900
	N	NP	N	NP	N	NP	N	NP	N	NP	N	NP
WALSH:	--------lb./A------		--------lb./A------		--------lb./A------		------ lbs./A. ------		--------lb./A------		------ lbs./A. ------	
WCSa	434	595			431	595			481	607		
WWSSa	402	613			392	677			591	757		

1. Proso grain yield expressed at 10.0% moisture.
2. Safflower grain yield expressed at 12% moisture.

Table 16b. Grain, stover and total biomass yields for PROSO at Sterling and Stratton and Safflower at Walsh in 1998.

	SLOPE POSITION																	
	SUMMIT						SIDE						TOE					
SITE &	*GRAIN*		*STOVER*		*TOTAL*		*GRAIN*		*STOVER*		*TOTAL*		*GRAIN*		*STOVER*		*TOTAL*	
ROTATION	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---------------------					
WCP	NOT HARVESTED						NOT HARVESTED						NOT HARVESTED					
WWCP																		
	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-------------------					
WCP	2370	2740	2390	3280	4760	6020	2110	2390	2440	2000	2270	2190	2210	2410	2940	3110	5150	5510
WWCP	1670	1190	2460	1930	4120	3120	2090	1250	2060	2420	2070	1840	1640	430	2050	2148	3680	2580
	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-------------------					
WCSa	430	590					430	590					470	600				
WWSSa	400	600					390	670					580	750				

Table 17. 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
Total Yields	Wheat (4)	105	120	128	118
	Corn (5)	253	297	366	305
	Forage (3)	4.57	4.42	5.15	4.71
	Sunflower (1)	0	0	0	0
		-----------------------------$-----------------------------			
Value*	Wheat (4)	364.35	416.40	444.16	409.46
	Corn (5)	650.21	763.29	940.62	783.85
	Forage (3)	182.80	176.80	206.00	188.53
	Sunflower (1)	0.00	0.00	0.00	0.00
Total Value for 13 Years		1197.36	1356.49	1590.78	1381.84

*Wheat @ $3.47/Bu; Corn @ $2.57/bu; Sorghum @ $2.31/Bu;
Hay Millet & Forage @ $40.00/T (1989-1997 average prices)

Table 18. 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
Total	Wheat (4)	162	140	191	164
Yields	Corn & Sorghum (5)	307	309	385	334
	Forage (3)	5.12	4.86	4.10	4.69
	Sunflower (1)	0	0	0	0
		-----------------------------$----------------------------			
Value*	Wheat (4)	562.14	485.80	662.77	569.08
	Corn (5)	789.99	794.13	989.45	858.38
	Forage (3)	204.80	194.40	164.00	187.73
	Sunflower (1)	0.00	0.00	0.00	0.00
Total Value for 13 Years		1556.93	1474.33	1816.22	1615.19

*Wheat @ $3.47/Bu; Corn @ $2.57/bu; Sorghum @ $2.31/Bu;
Hay Millet & Forage @ $40.00/T (1989-1997 average prices)

Table 19. 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
Total	Wheat (3)	85	87	108	93
Yields	Sorghum & Corn (5)	223	252	192	274
	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)	540.87	610.46	837.71	665.41
	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 13 Years		851.42	925.15	1240.87	1007.05

*Wheat @ $3.47/Bu; Corn @ $2.57/bu; Sorghum @ $2.31/Bu; Hay Millet & Forage @ $40.00/T (1989-1997 average prices)

Table 20. Crop residue weights on all plots in WHEAT during the 1997-1998 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	7330	6520	3970	6380	7610	6990
WCP	2320	1870	1930	2630	3810	3630
(W)WCP	8960	5160	7120	7780	6860	7950
W(W)CP	2080	2400	2300	4390	6560	5320
OPP	4100	8040	5050	5590	10430	6060
	NP*	NP	NP*	NP	NP*	NP
STRATTON:	----------Kg/ha-----------		----------Kg/ha--------		----------Kg/ha--------	
WCF	7780	5330	6910	4900	5150	7200
WCP	1330	1100	1200	1280	2300	2830
(W)WCP	3990	4080	4320	3900	2690	2530
W(W)CP	2890	3090	4450	4240	4590	8090
	4890	3830	2400	3690	2000	3360
	NP*	NP	NP*	NP	NP*	NP
WALSH:	----------Kg/ha--------		----------Kg/ha--------		----------Kg/ha--------	
WSF	1750	1910	1120	2280	2300	3410
WCSa						
(W)WSSa						
W(W)SSa	2020	2170	1950	2480	4070	3900

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

Table 21. Crop residue weights on all plots in Corn or Sorghum during the 1998 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	2660	3270	2320	3740	3510	3960
WCP	2360	2600	2390	2630	2120	2520
WWCP	3500	2510	3110	3560	4140	3850
	NP*	NP	NP*	NP	NP*	NP
STRATTON:	------kg ha^{-1}--------		-------kg ha^{-1}--------		-------kg ha^{-1}--------	
WCF	2400	2840	2490	2670	4080	4200
WCP	4180	4070	3520	3530	5150	6000
WWCP	4000	3850	3870	3320	3320	4710
	NP*	NP	NP*	NP	NP*	NP
WALSH:	-------kg ha^{-1}--------		-------kg ha^{-1}--------		-------kg ha^{-1}--------	
WSF	2710	3080	4490	5130	3960	4610
WCSa	3080	3120	5760	4070	4790	3850
WWSSa	3120	3090	1610	2740	3760	4040
OPP (S)	3050	6040	4100	5080	4090	5190
CC (C)	3380	6960	5540	6230	5480	3610
CC (S)	5830	4110	3420	4730	4400	4350

1. For conversion to lbs/Acre multiply Kg/ha by 0.893.

* Only receives phosphorus in wheat phase of each rotation.

Table 22. Crop residue weights on all plots in Proso or Safflower during the 1998 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}--------	
WCP	6570	4630	5820	4300	7790	5950
WWCP	6440	5980	5360	5450	4240	4460
	NP*	NP	NP*	NP	NP*	NP
STRATTON:	------kg ha^{-1}--------		-------kg ha^{-1}--------		-------kg ha^{-1}--------	
WCP	1840	3080	1670	2420	3160	1950
WWCP	3890	4430	6270	3380	5610	5490
	NP*	NP	NP*	NP	NP*	NP
WALSH:	-------kg ha^{-1}--------		-------kg ha^{-1}--------		-------kg ha^{-1}--------	
WCSa						
WWSSa						

1. For conversion to lbs/Acre multiply Kg/ha by 0.893.

* Only receives phosphorus in wheat phase of each rotation.

Table 23 . Available soil water by soil depth in the WHEAT phase of the WCF rotation at Sterling and Stratton and WSF at Walsh in 1998.

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	62	13	49	48	13	35	58	19	39
45	51	9	42	49	27	22	52	16	36
75	32	10	22	25	15	10	58	17	41
105	24	13	11	25	15	10	56	22	34
135	-	-	-	-	-	-	25	12	13
155	-	-	-	-	-	-	22	9	13
TOTAL	169	45	124	147	70	77	271	95	176
STRATTON:									
15	35	11	24	46	33	13	72	43	29
45	42	12	30	38	13	25	67	19	48
75	37	3	34	50	21	29	75	18	57
105	41	12	29	38	21	17	70	20	50
135	39	22	17	38	30	8	51	18	33
155	40	24	16	29	31	(+2)	54	47	7
TOTAL	234	84	150	239	149	90	389	165	224
WALSH:									
15	4	0	4	2	0	2	0	0	0
45	26	0	26	31	0	31	29	0	29
75	29	0	29	40	0	40	41	0	41
105	38	5	33	35	0	35	56	5	51
135	50	25	25	12	0	12	44	8	36
155	34	19	15	30	5	25	62	32	30
TOTAL	181	49	132	150	5	145	232	45	187

1. To convert from millimeters of $H_2$0/30 centimeters of soil to inches of $H_2$0/foot of soil multiply by 0.04.
2. ( ) Indicates a positive change in available soil water.

Table 24 . Available soil water by soil depth in the WHEAT phase of the WCP rotation at Sterling, Stratton, and WCSa at Walsh in 1998.

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	61	17	44	53	3	50	52	24	28
45	53	7	46	38	0	38	46	11	35
75	31	6	25	70	10	60	52	16	36
105	30	21	9	72	25	47	54	23	31
135	-	-	-	-	-	-	42	24	18
155	-	-	-	-	-	-	34	21	13
TOTAL	175	51	124	233	38	195	280	119	161
STRATTON:									
15	41	0	41	50	24	26	67	51	16
45	40	4	36	35	3	32	63	27	36
75	33	5	28	45	8	37	67	18	49
105	38	11	27	42	27	15	53	11	42
135	41	31	10	42	13	29	44	45	(+1)
155	42	31	11	38	16	22	37	24	13
TOTAL	235	82	153	252	91	161	331	176	155
WALSH:									
15	2	0	2	0	0	0	0	0	0
45	25	0	25	25	0	25	27	0	27
75	22	0	22	41	0	41	28	0	28
105	37	0	37	52	17	35	44	3	41
135	36	0	36	38	3	35	44	5	39
155	0	11	(+11)	43	24	19	0	22	(+22)
TOTAL	122	11	111	199	44	155	143	30	113

1. To convert from millimeters of H_20/30 centimeters of soil to inches of H_20/foot of soil multiply by 0.04.
2. ( ) Indicates a positive change in available soil water.

Table 25 . Available soil water by soil depth in the WHEAT phase of the (W)WCP rotation at Sterling and Stratton and the WHEAT phase of the (W)WSSa rotation at Walsh in 1998.

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	12	17	25	0	25	36	15	21
45	9	5	4	27	12	15	26	13	13
75	11	5	6	17	18	(+1)	23	18	5
105	15	31	(+16)	17	19	(+2)	28	32	(+40)
135	-	-	-	-	-	-	14	21	(+7)
155	-	-	-	-	-	-	17	18	(+1)
TOTAL	64	53	11	86	49	37	144	117	27
STRATTON:									
15	29	12	17	23	19	4	28	17	11
45	29	4	25	38	6	32	41	9	32
75	20	3	17	30	12	18	34	11	23
105	28	12	16	29	8	21	37	14	23
135	28	21	7	26	22	4	54	33	21
155	30	24	6	25	31	(+6)	55	38	17
TOTAL	164	76	88	171	98	73	249	122	127
WALSH:									
15	12	0	12	6	0	6	12	0	12
45	32	0	32	30	0	30	37	0	37
75	28	0	28	26	0	26	37	0	37
105	27	3	24	27	9	18	41	18	23
135	39	33	6	4	0	4	31	18	13
155	36	46	(+10)	13	31	18	51	49	2
TOTAL	174	82	92	106	40	66	209	85	124

1. To convert from millimeters of H_20/30 centimeters of soil to inches of H_20/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 W(W)CP rotation at Sterling and Stratton and the WHEAT phase of the W(W)SSa rotation at Walsh in 1998.

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	63	27	36	46	9	37	49	19	30
45	51	9	42	45	3	42	41	6	35
75	43	18	25	29	6	23	49	12	37
105	48	41	7	25	10	15	51	10	41
135	-	-	-	-	-	-	40	21	19
155	-	-	-	-	-	-	34	15	19
TOTAL	205	95	110	145	28	117	264	83	181
STRATTON:									
15	37	11	26	48	26	22	72	27	45
45	30	4	26	33	7	26	60	4	56
75	23	0	23	27	11	16	58	0	58
105	24	5	19	20	11	9	56	6	50
135	20	15	5	8	17	(+9)	39	16	23
155	1	15	(+14)	9	19	(+10)	40	23	17
TOTAL	135	50	85	145	91	54	325	76	249
WALSH:									
15	7	0	7	3	0	3	7	0	7
45	26	0	26	37	1	36	32	0	32
75	28	0	28	38	1	37	39	0	39
105	37	3	34	44	3	41	46	0	46
135	49	21	28	21	0	21	44	0	44
155	33	14	19	25	0	25	63	34	25
TOTAL	180	38	142	168	5	163	231	34	197

1. To convert from millimeters of $H_2$0/30 centimeters of soil to inches of $H_2$0/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 OPP rotation at Sterling and Stratton in 1998.

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	34	21	13	33	11	22	34	28	6
45	13	5	8	34	14	20	26	13	13
75	27	6	21	37	34	3	47	21	26
105	40	16	24	48	42	6	35	28	7
135	-	-	-	-	-	-	17	20	(+3)
155	-	-	-	-	-	-	23	18	5
TOTAL	114	48	66	152	101	51	182	128	54
STRATTON:									
15	36	6	30	37	26	11	56	28	28
45	37	3	34	21	3	18	51	24	27
75	26	2	24	29	7	22	76	52	24
105	30	13	17	47	25	22	61	36	25
135	21	11	10	34	29	5	44	37	7
155	28	13	15	37	32	5	43	42	1
TOTAL	178	48	130	205	122	83	331	219	112

1. To convert from millimeters of H_20/30 centimeters of soil to inches of H_20/foot of soil multiply by 0.04.
2. ( ) Indicates a positive change is available soil water.

Table 28 . Available soil water by soil depth in the CORN phase of the WCF rotation at Sterling and Stratton and the SORGHUM phase of the WSF rotation at Walsh in 1998.

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	36	22	14	33	19	14	41	30	9
45	41	7	34	47	8	39	48	11	37
75	45	10	35	44	15	29	50	13	37
105	28	9	19	37	20	17	63	16	47
135	-	-	-	-	-	-	37	14	23
155	-	-	-	-	-	-	27	12	15
TOTAL	150	48	102	161	62	99	266	96	170
STRATTON:									
15	17	0	17	43	14	29	44	14	30
45	44	9	35	39	12	27	64	26	38
75	36	10	26	46	13	33	71	54	17
105	31	16	15	29	8	21	84	74	10
135	30	21	9	24	9	15	61	60	1
155	33	19	14	26	14	12	43	45	(+2)
TOTAL	191	75	116	207	70	137	367	273	94
WALSH:									
15	0	0	0	0	0	0	0	0	0
45	20	9	11	30	15	15	24	6	18
75	25	13	12	38	4	34	30	22	8
105	40	30	10	42	12	30	44	30	14
135	46	28	8	27	5	22	44	23	11
155	38	13	25	42	19	23	61	35	26
TOTAL	169	93	76	179	55	124	203	116	87

1. To convert from millimeters of H_20/30 centimeters of soil to inches of H_20/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 WCP rotation at Sterling and Stratton and WCSa rotation at Walsh in 1998.

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	35	22	13	31	24	7	31	27	4
45	56	17	39	42	7	35	39	19	20
75	40	11	29	54	29	25	57	17	40
105	26	20	6	39	27	12	49	9	40
135	-	-	-	-	-	-	23	8	15
155	-	-	-	-	-	-	23	13	10
TOTAL	157	70	87	166	87	79	222	93	129
STRATTON:									
15	19	0	19	30	0	30	40	22	18
45	45	8	37	42	14	28	63	25	38
75	31	7	24	44	27	17	68	47	21
105	33	14	19	31	10	21	79	69	10
135	35	24	11	37	20	17	53	53	0
155	33	24	9	40	19	21	-	-	-
TOTAL	196	77	119	224	90	134	303	216	87
WALSH:									
15	0	8	(+8)	0	7	(+7)	0	4	(+4)
45	18	21	(+3)	15	28	(+13)	24	33	(+9)
75	15	11	4	23	31	(+8)	31	33	(+2)
105	26	20	6	26	42	(+16)	35	41	(+6)
135	44	53	(+9)	26	34	(+8)	26	32	(+6)
155	38	60	(+22)	52	62	(+10)	43	56	(+13)
TOTAL	141	173	(+32)	142	204	(+62)	159	199	(+40)

1. To convert from millimeters of H_20/30 centimeters of soil to inches of H_20/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 WWCP rotation at Sterling and Stratton and the SORGHUM phase of the WWSSa rotation at Walsh in 1998.

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	28	16	12	32	20	12	33	22	11
45	51	11	40	45	5	40	42	17	25
75	20	0	20	45	17	28	56	13	43
105	13	0	13	44	28	16	55	10	45
135	-	-	-	-	-	-	25	9	16
155	-	-	-	-	-	-	22	11	11
TOTAL	112	27	85	166	70	96	233	82	151
STRATTON:									
15	20	2	18	32	10	22	44	11	33
45	45	12	33	38	12	26	67	30	37
75	32	9	23	42	23	19	72	46	26
105	30	18	12	36	18	18	77	65	12
135	30	25	5	31	17	14	52	52	0
155	26	26	0	27	21	6	53	54	(+1)
TOTAL	183	92	91	206	101	105	365	258	107
WALSH:									
15	0	18	(+18)	0	8	(+8)	0	0	0
45	14	39	(+25)	33	13	(+20)	25	3	22
75	12	21	(+9)	40	4	36	34	0	34
105	16	15	1	45	8	37	31	2	29
135	35	1	34	13	0	13	24	14	10
155	32	0	32	29	0	29	57	43	14
TOTAL	109	94	15	160	33	127	171	62	109

1. To convert from millimeters of H_20/30 centimeters of soil to inches of H_20/foot of soil multiply by 0.04.
2. ( ) Indicates a positive change in available soil water.

Table 31a. Total Nitrogen and Phosphorus content of WHEAT GRAIN in the 1997-1998 crop.

SITE & ROTATION	SLOPE POSITION											
	SUMMIT				SIDESLOPE				TOESLOPE			
	*N Side**		*NP Side*		*N Side**		*NP Side*		*N Side**		*NP Side*	
	N	P	N	P	N	P	N	P	N	P	N	P
STERLING:	-------------- % -------------				-------------- % -------------				-------------- % -------------			
WCF	2.59	0.38	2.42	0.21	2.55	0.29	2.45	0.30	2.84	0.35	2.56	0.45
WCP	2.50	0.28	2.54	0.37	2.56	0.36	2.44	0.46	2.68	0.39	2.54	0.38
(W)WCP												
W(W)CP	2.51	0.21	2.58	0.36	2.67	0.28	2.52	0.36	2.32	0.38	2.27	0.43
OPP	2.81	0.35	2.74	0.44	2.86	0.38	2.73	0.48	2.65	0.51	2.64	0.51
	N	P	N	P	N	P	N	P	N	P	N	P
STRATTON:	-------------- % -------------				-------------- % -------------				-------------- % -------------			
WCF	2.57	0.33	2.39	0.28	2.49	0.24	2.48	0.26	2.56	0.40	2.46	0.40
WCP	2.42	0.28	2.35	0.24	2.39	0.25	2.35	0.27	2.40	0.39	2.42	0.37
(W)WCP	2.29	0.30	2.15	0.30	2.29	0.26	2.29	0.24	2.59	0.47	2.36	0.39
W(W)CP	2.56	0.30	2.46	0.30	2.48	0.29	2.38	0.29	2.55	0.36	2.67	0.36
OPP	2.51	0.31	2.41	0.35	2.47	0.39	2.32	0.35	2.55	0.34	2.56	0.40
	N	P	N	P	N	P	N	P	N	P	N	P
WALSH:	-------------- % -------------				-------------- % -----------				-------------- % -------------			
WSF	2.65	0.40	2.62	0.40	2.66	0.38	2.65	0.34	2.54	0.41	2.55	0.49
WCSa	2.63	0.31	2.64	0.36	2.59	0.41	2.64	0.36	2.36	0.41	2.48	0.38
(W)WSSF	2.58	0.40	2.60	0.39	2.56	0.37	2.53	0.38	2.37	0.48	2.38	0.41
W(W)SSF	2.66	0.34	2.68	0.34	2.71	0.35	2.71	0.42	2.55	0.47	2.48	0.47

* Only receives phosphorus in wheat phase of each rotation.

Table 31b. Total Nitrogen and Phosphorus content of WHEAT STRAW in the 1997-1998 crop.

	SLOPE POSITION											
	SUMMIT				SIDESLOPE				TOESLOPE			
SITE &	N Side*		NP Side		N Side*		NP Side		N Side*		NP Side	
ROTATION	N	P	N	P	N	P	N	P	N	P	N	P
STERLING:	-------------- % -------------				-------------- % -------------				-------------- % -------------			
WCF	0.50	0.01	0.41	0.30	0.46	0.04	0.40	0.05	0.55	0.04	0.61	0.07
WCP	0.49	0.05	0.51	0.10	0.54	0.05	0.42	0.04	0.48	0.04	0.52	0.05
(W)WCP	1.03	0.10	0.55	0.05	0.86	0.08	0.73	0.10	0.46	0.05	0.51	0.04
W(W)CP	0.50	0.03	0.39	0.03	0.44	0.09	0.49	0.01	0.41	0.03	0.37	0.04
OPP	0.49	0.04	0.52	0.04	0.55	.05	0.59	0.06	0.63	0.12	0.68	0.15
	N	P	N	P	N	P	N	P	N	P	N	P
STRATTON:	-------------- % -------------				-------------- % -------------				-------------- % -------------			
WCF	0.49	0.03	0.46	0.02	0.41	0.02	0.42	0.07	0.50	0.10	0.56	0.11
WCP	0.53	0.03	0.35	0.02	0.38	0.02	0.41	0.02	0.54	0.10	0.54	0.08
(W)WCP	0.41	0.03	0.34	0.03	0.45	0.02	0.39	0.02	0.73	0.10	0.70	0.11
W(W)CP	0.42	0.03	0.41	0.02	0.38	0.06	0.41	0.02	0.61	0.14	0.70	0.14
OPP	0.52	0.04	0.54	0.05	0.40	0.02			0.58	0.10	0.60	0.08
	N	P	N	P	N	P	N	P	N	P	N	P
WALSH:	-------------- % -------------				-------------- % -----------				-------------- % -------------			
WSF	0.57	0.06	0.44	0.09	0.64	0.04	0.66	0.11	0.65	0.09	0.72	0.11
WCSa	0.64	0.05	0.67	0.05	0.71	0.04	0.64	0.04	0.68	0.06	0.76	0.09
(W)WSSF	0.88	0.16	0.75	0.06	0.60	0.10	0.67	0.04	0.63	0.08	0.48	0.07
W(W)SSF	0.55	0.05	0.60	0.05	0.53	0.03	0.50	0.04	0.67	0.10	0.68	0.12

* Only receives phosphorus in wheat phase of each rotation.

Table 32a. Total Nitrogen and Phosphorus content of CORN and/or SORGHUM GRAIN in the 1998 crop.

SITE & ROTATION	SLOPE POSITION											
	SUMMIT				SIDESLOPE				TOESLOPE			
	*N Side**		*NP Side*		*N Side**		*NP Side*		*N Side**		*NP Side*	
	N	P	N	P	N	P	N	P	N	P	N	P
STERLING:	-------------- % -------------				-------------- % -------------				-------------- % -------------			
WCF	1.47	0.27	1.57	0.28	1.38	0.26	1.32	0.33	1.10	0.33	1.06	0.37
WCP	1.64	0.35	1.54	0.29	1.48	0.26	1.46	0.29	1.45	0.24	1.40	0.38
WWCP	1.63	0.31	1.58	0.35	1.55	0.30	1.56	0.30	1.43	0.32	1.48	0.30
	N	P	N	P	N	P	N	P	N	P	N	P
STRATTON:	-------------- % -------------				-------------- % -------------				-------------- % -------------			
WCF	1.34	0.32	1.38	0.38	1.39	0.23	1.52	0.40	1.39	0.38	1.46	0.43
WCP	1.31	0.27	1.40	0.32	1.41	0.42	1.44	0.37	1.41	0.33	1.44	0.33
WWCP	1.38	0.29	1.39	0.38	1.45	0.32	1.44	0.30	1.43	0.38	1.42	0.38
	N	P	N	P	N	P	N	P	N	P	N	P
WALSH:	-------------- % -------------				-------------- % -----------				-------------- % -------------			
WSF	1.38	0.33	1.36	0.33	1.33	0.31	1.42	0.33	1.06	0.33	1.16	0.39
WCSa	1.38	0.36	1.42	0.33	1.39	0.38	1.41	0.41	1.19	0.35	1.31	0.39
(W)WSSa	1.54	0.34	1.47	0.37	1.61	0.32	1.52	0.39	1.30	0.36	1.15	0.28
CC (Corn)	1.20	0.26	1.19	0.24	1.21	0.28	1.27	0.32	1.21	0.38	1.21	0.33
CC (Sorg.)	1.52	0.37	1.49	0.35	1.35	0.39	1.54	0.39	1.42	0.48	1.20	0.31
OPP(Sorg)	1.62	0.30	1.63	0.33	1.68	0.36	1.60	0.42	1.20	0.43	1.14	0.30

* Only receives phosphorus in wheat phase of each rotation.

Table 32b. Total Nitrogen and Phosphorus content of CORN and/or SORGHUM STOVER in the 1998 crop.

	SLOPE POSITION											
	SUMMIT				SIDESLOPE				TOESLOPE			
SITE & ROTATION	*N Side**		*NP Side*		*N Side**		*NP Side*		*N Side**		*NP Side*	
	N	P	N	P	N	P	N	P	N	P	N	P
STERLING:	-------------- % -------------				-------------- % -------------				-------------- % -------------			
WCF	0.83	0.06	0.59	0.04	0.59	0.04	0.49	0.03	0.43	0.07	0.40	.10
WCP	0.96	.08	0.79	0.08	0.78	0.06	0.79	0.05	0.92	0.15	0.71	0.17
WWCP	0.81	0.06	0.87	0.07	0.68	0.04	0.53	0.04	0.68	0.08	0.69	0.13
	N	P	N	P	N	P	N	P	N	P	N	P
STRATTON:	-------------- % -------------				-------------- % -------------				-------------- % -------------			
WCF	0.43	0.07	0.54	0.05	0.58	0.05	0.48	0.04	0.65	0.22	0.78	0.27
WCP	0.68	0.06	0.55	0.05	0.78	0.10	0.55	0.04	0.87	0.41	0.65	0.27
WWCP	0.49	0.07	0.61	0.07	0.74	0.05	0.69	0.07	0.62	0.23	0.62	0.20
	N	P	N	P	N	P	N	P	N	P	N	P
WALSH:	-------------- % -------------				-------------- % -----------				-------------- % -------------			
WSF	0.71	0.13	0.58	0.12	0.67	0.10	0.71	0.10	0.77	0.12	0.78	0.11
WCSa	0.72	0.14	0.78	0.12	0.81	0.10	0.77	0.11	0.66	0.12	0.74	0.13
(W)WSSa	0.74	0.13	0.69	0.10	0.94	0.10	0.68	0.13	0.54	0.13	0.53	0.12
CC (Corn)	0.62	0.08	0.66	0.10	0.66	0.07	0.60	0.06	0.52	0.13	0.65	0.13
CC (Sorg.)	0.62	0.08	0.76	0.10	0.91	0.07	1.05	0.11	0.89	0.08	0.60	0.10
OPP(Sorg)	1.08	0.11	0.89	0.08	0.89	0.09	0.77	0.09	0.67	0.10	0.85	0.10

*** Only receives phosphorus in wheat phase of each rotation.**

Table 33a. Total Nitrogen and Phosphorus content of PROSO AND SAFFLOWER GRAIN in the 1998 crop .

SITE & ROTATION	SLOPE POSITION											
	SUMMIT				SIDESLOPE				TOESLOPE			
	*N Side**		*NP Side*		*N Side**		*NP Side*		*N Side**		*NP Side*	
	N	P	N	P	N	P	N	P	N	P	N	P
STERLING:	-------------- % -------------				-------------- % -------------				-------------- % -------------			
WCP		No data				No data				No data		
WWCP												
	N	P	N	P	N	P	N	P	N	P	N	P
STRATTON:	-------------- % -------------				-------------- % -------------				-------------- % -------------			
WCP	1.56	0.38	1.48	0.32	1.50	0.35	1.55	0.36	1.74	0.45	1.64	0.35
WWCP	1.73	0.39	1.55	0.35	1.71	0.39	1.48	0.37	1.56	0.33	1.54	0.39
	N	P	N	P	N	P	N	P	N	P	N	P
WALSH:	-------------- % -------------				-------------- % -----------				-------------- % -------------			
WCSa	3.2		3.2		3.0		3.2		3.1		2.7	
(W)WSSa												

*** Only receives phosphorus in wheat phase of each rotation.**

Table 33b. Total Nitrogen and Phosphorus content of PROSO STOVER in the 1998 crop .

	SLOPE POSITION											
	SUMMIT				SIDESLOPE				TOESLOPE			
SITE & ROTATION	*N Side**		*NP Side*		*N Side**		*NP Side*		*N Side**		*NP Side*	
	N	P	N	P	N	P	N	P	N	P	N	P
STERLING:	-------------- % -------------				-------------- % -------------				-------------- % -------------			
WCP	1.12	0.23	1.20	0.30	0.52	0.11	0.45	0.08	1.48	0.14	1.13	0.19
WWCP	0.62	0.20	1.02	0.14	0.48	0.37	0.48	0.13	0.58	0.19	0.49	0.38
	N	P	N	P	N	P	N	P	N	P	N	P
STRATTON:	-------------- % -------------				-------------- % -------------				-------------- % -------------			
WCP	0.70	0.23	0.67	0.13	0.55	0.10	0.59	0.34	1.00	0.43	0.83	0.18
WWCP	0.78	0.21	0.73	0.09	0.61	0.16	0.46	0.14	0.60	0.33	0.75	0.18
	N	P	N	P	N	P	N	P	N	P	N	P
WALSH:	-------------- % -------------				-------------- % -----------				-------------- % -------------			
WCSa		No Data	Data			No	Data			No	Data	
(W)WSSa												

* Only receives phosphorus in wheat phase of each rotation.

Table 34a. Total Nitrogen content of WHEAT GRAIN in the 1997-1998 crop at the Nunn site.

ROTATION	SUMMIT		Shoulder/ Toe	
	Variety		Variety	
	Halt	*Akron*	*Halt*	*Akron*
	--------% N ---------	----------% N --------	-------% N -------	-------% N -------
WCM	1.86	1.82	1.84	1.92
WSF	1.84	1.82	1.90	1.82

Table 34b. Total Nitrogen content of WHEAT GRAIN in the 1997-1998 crop at the Akron site.

ROTATION	Variety	
	Halt	*Tam 107*
	--------% N ---------	----------% N --------
WF	2.29	2.21
WCF	2.20	2.17
WCM	1.95	2.32
WCSF	2.29	2.20

Table 34c. Total Nitrogen content of WHEAT GRAIN in the 1997-1998 crop at the Lamar site.

	Not grazed		Grazed	
	Variety		Variety	
ROTATION	Halt	*Tam 107*	*Halt*	*Tam 107*
	--------% N ---------	----------% N --------	-------% N -------	-------% N -------
WF	2.06	2.00	1.98	1.98
WSF	2.03	2.69	2.02	2.05

Table 35. Nitrate-N content of the soil profile at Planting for each crop during 1997-1998 crop year.

Site & Rotation	SLOPE POSITION											
	SUMMIT				SIDESLOPE				TOESLOPE			
	Crop and Time				Crop and Time				Crop and Time			
	Wheat Fall 97	Corn S 98	Sorghum S 98	Saff S 98	Wheat Fall 97	Corn S 98	Sorghum S 98	Saff S 98	Wheat S 98	Corn S 98	Sorghum S 98	Saff S 98
Sterling	------------kg NO3-N ha $^{-1}$------------				----------kg NO3-N ha $^{-1}$------------				-------------kg NO3-N ha $^{-1}$-----------			
WCF	71	72			40	55			42	59		
WCP	75	119			67	48			52			
(W)WCP		119				50				51		
W(W)CP	74				42				66	73		
OPP												
Stratton												
WCF	54	21			43	48			69	38		
WCP	87	16			84	24			123	44		
(W)WCP		15				29				57		
W(W)CP	32				36				72			
OPP												
Walsh												
WSF	109		66		56		101		69		112	
WCSa	78	91			137	95			91	104		
(W)WSSa			64				110				73	
W(W)SSa	73				76				77			
CC (C)		66				83				85		
CC (S)			47				130				79	
OPP			88				116				95	

Table 36. Soil Organic Carbon Percent at Sterling, Stratton and Walsh in 1998 for selected Cropping Systems by Site, Slope, and Depth.

SITE by SLOPE and CROPPING SYSTEM	SLOPE POSITION											
	SUMMIT				SIDESLOPE				TOESLOPE			
	WCF	WCP	OPP	GRASS	WCF	WCP	OPP	GRASS	WCF	WCP	OPP	GRASS
STERLING:												
	---------------% Carbon -------------				---------------% Carbon -------------				---------------% Carbon -------------			
0-5 cm	0.74	1.11	0.98	0.82	0.78	1.08	0.94	1.08	0.91	1.35	1.39	1.42
5-10 cm	0.68	0.79	0.85	0.79	0.69	0.75	0.88	0.82	0.80	0.95	1.08	1.09
10-15 cm	0.66	0.83	0.86	0.84	0.65	0.72	0.85	0.71	0.71	0.86	1.00	0.90
15-20 cm	0.47	0.82	0.83	0.71	0.62	0.72	0.80	0.54	0.65	0.83	0.90	0.73
STRATTON:												
	---------------% Carbon -------------				---------------% Carbon -------------				---------------% Carbon -------------			
0-5 cm	1.05	1.02	1.33	1.25	0.96	1.05	1.02	1.06	1.18	1.56	1.55	2.80
5-10 cm	0.79	0.91	0.89	0.98	0.81	0.79	0.76	0.94	1.05	1.05	1.08	1.39
10-15 cm	0.77	0.79	0.87	0.89	0.73	0.69	0.62	0.79	0.86	0.83	0.82	1.45
15-20 cm	0.50	0.77	0.78	0.69	0.69	0.64	0.56	0.67	0.76	0.74	0.76	0.95
WALSH:												
	---------------% Carbon -------------				---------------% Carbon -------------				---------------% Carbon -------------			
0-5 cm	0.24	0.29	0.33	0.51	0.23	0.35	0.42	0.63	1.02	0.93	0.91	1.56
5-10 cm	0.22	0.29	0.26	0.44	0.27	0.35	0.32	0.44	0.68	0.54	0.59	0.96
10-15 cm	0.25	0.23	0.31	0.44	0.17	0.33	0.45	0.44	0.55	0.49	0.55	0.64
15-20 cm	0.32	0.21	0.22	0.31	0.30	0.34	0.45	0.50	0.56	0.45	0.60	0.70

Analysis of Variance	P > F	P > F	P > F	P > F
Depth	0-5 cm	5-10 cm	10-15 cm	15-20 cm
SITE	0.0036	0.0167	0.0252	0.1456
SLOPE	0.0001	0.0005	0.0248	0.0115
SITE X SLOPE	0.0601	0.3381	0.6370	0.2266
CROPPING	0.0015	0.0060	0.0107	0.1856
SITE X CROPPING	0.1259	0.3353	0.1601	0.2207
SLOPE X CROPPING	0.0001	0.0061	0.2226	0.2434
SITE X SLOPE X CROPPING	0.0031	0.4118	0.0538	0.1577

Table 37. Extractable NaHCO3 Phosphorus at Sterling, Stratton and Walsh in 1998 for selected Cropping Systems by Slope and Depth.

SITE by SLOPE and CROPPING SYSTEM	SLOPE POSITION											
	SUMMIT				SIDESLOPE				TOESLOPE			
	WCF	WCP	OPP	GRASS	WCF	WCP	OPP	GRASS	WCF	WCP	OPP	GRASS
STERLING:												
	-------------- mg/kg Phosphorus ------------				-------------- mg/kg Phosphorus ------------				------------ mg/kg Phosphorus ------------			
0-5 cm	13.3	30	17.2	7.5	5.4	19.9	13.9	5.7	18.4	20.4	32.8	10
5-10 cm	4.7	9.5	8.0	3.3	3.1	4.2	6.1	2.9	9.1	10.1	18.5	9.0
10-15 cm	2.6	4.6	4.4	2.7	2.2	2.3	5.3	1.9	4.3	5.0	7.8	6.6
15-20 cm	3.1	5.4	4.1	2.2	2.4	3.0	4.9	2.2	3.9	3.9	7.3	5.0
STRATTON:												
	-------------- mg/kg Phosphorus ------------				-------------- mg/kg Phosphorus ------------				------------ mg/kg Phosphorus ------------			
0-5 cm	8.5	16.9	11.7	6.3	10.4	17.5	6.1	5.4	30.9	33.7	28.1	27.9
5-10 cm	3.8	6.9	2.2	3.2	7.5	6.9	4.0	2.8	20.7	26.7	22.2	23.0
10-15 cm	2.2	4.0	4.2	2.6	3.6	4.9	1.3	1.9	16.8	19.0	16.8	20.3
15-20 cm	1.8	2.9	2.5	2.2	3.7	2.5	1.4	2.0	19.3	17.7	14.7	19.3
WALSH:												
	-------------- mg/kg Phosphorus ------------				-------------- mg/kg Phosphorus ------------				------------ mg/kg Phosphorus ------------			
0-5 cm	12.2	6.6	12.3	12.9	6.8	7.3	11.2	5.3	34.3	23.5	24.9	24.3
5-10 cm	6.9	24.4	6.5	2.4	4.1	3.5	7.4	3.3	29.8	15.8	29.3	21.5
10-15 cm	2.4	1.8	3.6	1.8	2.0	1.76	9.5	1.7	17.4	10.6	16.6	19.7
15-20 cm	2.1	1.5	2.2	0.9	1.8	1.8	10.1	0.7	12.0	10.2	8.2	14.1

Analysis of Variance	P > F	P > F	P > F	P > F
Depth	0-5 cm	5-10 cm	10-15 cm	15-20 cm
SITE	0.1529	0.0571	0.3175	0.2463
SLOPE	0.0001	0.0002	0.0001	0.0010
SITE X SLOPE	0.0011	0.0506	0.0102	0.0273
CROPPING	0.0552	0.1301	0.4587	0.8853
SITE X CROPPING	0.1161	0.5743	0.4457	0.6769
SLOPE X CROPPING	0.4138	0.1368	0.2280	0.1652
SITE X SLOPE X CROPPING	0.3514	0.3243	0.6545	0.4068

Table 38. Soil water pH (1:2) at Sterling, Stratton and Walsh in 1998 for selected Cropping Systems by Site, Slope, and Depth.

SITE by SLOPE and CROPPING SYSTEM	SLOPE POSITION											
	SUMMIT				SIDESLOPE				TOESLOPE			
	WCF	WCP	OPP	GRASS	WCF	WCP	OPP	GRASS	WCF	WCP	OPP	GRASS
STERLING:												
	------------------------ pH ------------------------				-------------------------- pH ------------------------				----------------------- pH ----------------------			
0-5 cm	6.7	6.3	6.6	7.4	7.7	6.8	7.4	7.6	6.9	7.4	6.8	7.2
5-10 cm	7.4	6.8	6.9	7.4	8.0	7.7	7.7	7.8	7.2	7.6	7.0	7.0
10-15 cm	7.6	7.1	7.5	7.6	8.1	8.0	7.9	7.9	7.5	7.6	7.3	7.1
15-20 cm	7.9	7.3	7.6	7.8	8.2	8.0	8.0	8.0	7.5	7.7	7.4	7.2
STRATTON:												
	------------------------ pH ------------------------				---------------------- pH ----------------------				----------------------- pH ----------------------			
0-5 cm	7.7	7.3	7.2	7.5	7.6	7.6	7.8	7.9	7.9	7.9	7.9	7.7
5-10 cm	7.8	7.6	7.5	7.7	7.6	7.8	8.0	7.9	8.0	8.0	8.2	8.0
10-15 cm	7.9	7.7	7.8	7.9	7.9	7.9	8.1	8.0	8.1	8.1	8.2	8.0
15-20 cm	8.0	7.8	7.9	8.1	7.9	7.9	8.1	8.0	8.1	8.1	8.1	8.0
WALSH:												
	------------------------ pH ------------------------				-------------------- pH ---------------------				----------------------- pH ----------------------			
0-5 cm	8.3	8.1	8.3	8.3	8.5	8.1	8.4	8.2	8.0	8.0	8.2	8.0
5-10 cm	8.3	8.1	8.4	8.3	8.3	8.1	8.4	8.3	8.2	8.1	8.2	8.1
10-15 cm	8.3	8.0	8.3	8.3	8.3	8.2	8.3	8.2	8.2	8.1	8.2	8.1
15-20 cm	8.3	8.1	8.4	8.2	8.3	8.2	8.4	8.3	8.0	8.0	8.1	8.0

Analysis of Variance	P > F	P > F	P > F	P > F
Depth	0-5 cm	5-10 cm	10-15 cm	15-20 cm
SITE	0.0437	0.0219	0.0202	0.0508
SLOPE	0.1111	0.0864	0.1050	0.0756
SITE X SLOPE	0.2849	0.0936	0.1076	0.1220
CROPPING	0.0593	0.4767	0.5714	0.2507
SITE X CROPPING	0.1794	0.4514	0.7953	0.6294
SLOPE X CROPPING	0.0662	0.0489	0.0017	0.0311
SITE X SLOPE X CROPPING	0.2783	0.3384	0.1314	0.3378

APPENDIX I

ANNUAL HERBICIDE PROGRAMS FOR EACH SITE

Table 1. Weed control methods including herbicide rate, cost and date applied at STERLING in 1998.

Crop	Herbicide/Tillage	Rate (English)	Rate (Metric)	Weed Pressure	Cost	Date Applied
Rotation: Wheat-Corn-Fallow						
Wheat:	Ally	1/10 oz/A	7.0 g/ha	II	$2.32	4-8-98
	2,4-D Ester 6#	5.3 oz/A	0.39 l/ha	II	$0.80	4-8-98
	Atrazine 4L	32 oz/A	2.34 l/ha	II	$2.98	7-29-98
	Fallowmaster *	32 oz/A	2.34 l/ha	I	$4.68	7-29-98
	Fallowmaster*	32 oz/A	2.34 l/ha	I	$4.68	9-29-98
Corn:	Round-up Ultra	16 oz/A	1.17 l/ha	II	$5.35	4-8-98
	Atrazine 4L	32 oz/A	2.34 l/ha	I	$2.98	5-5-98
	Prowl	32 oz/A	2.34 l/ha	I	$7.03	5-5-98
	Fallowmaster	32 oz/A	2.34 l/ha	I	$4.68	5-5-98
Fallow:	Fallowmaster	32 oz/A	2.34 l/ha	I	$4.68	5-5-98
	Fallowmaster *	32 oz/A	2.34 l/ha	I	$4.68	6-10-98
	Fallowmaster*	32 oz/A	2.34 l/ha	I	$4.68	7-29-98
	Tillage–sweeps					9-10-98
Rotation: Wheat-Corn-Proso Millet						
Wheat:	Ally	1/10 oz/A	7.0 g/ha	II	$2.32	4-8-98
	2,4-D Ester 6#	5.3 oz/A	0.39 l/ha	II	$0.80	4-8-98
	Atrazine 4L	32 oz/A	2.34 l/ha	II	$2.98	7-29-98
	Fallowmaster *	32 oz/A	2.34 l/ha	I	$4.68	7-29-98
	Fallowmaster*	32 oz/A	2.34 l/ha	I	$4.68	9-29-98
Corn:	Round-up Ultra	16 oz/A	1.17 l/ha	II	$5.35	4-8-98
	Atrazine 4L	32 oz/A	2.34 l/ha	I	$2.98	5-5-98
	Prowl	32 oz/A	2.34 l/ha	I	$7.03	5-5-98
	Fallowmaster	32 oz/A	2.34 l/ha	I	$4.68	5-5-98
Proso Millet:	Landmaster	40 oz/A	2.92 l/ha	I	$6.83	5-5-98
	Landmaster	40 oz/A	2.92 l/ha	I	$6.83	5-27-98
	Banvel	3 oz/A	0.22 l/ha	II	$2.08	7-9-98
	2,4-D amine 4#	12 oz/A	0.88 l/ha	II	$1.09	7-9-98
	Gramoxone Extra*	32 oz/A	2.34 l/ha	II	$8.20	9-10-98
Rotation: Wheat-Wheat-Corn-Proso Millet:						
Wheat:	Ally	1/10 oz/A	7.0 g/ha	II	$2.32	4-8-98
	2,4-D Ester 6#	5.3 oz/A	0.39 l/ha	II	$0.80	4-8-98
	Fallowmaster *	32 oz/A	2.34 l/ha	I	$4.68	7-29-98
	Landmaster	40 oz/A	2.92 oz/ha	I	$6.83	9-29-98
Wheat:	Ally	1/10 oz/A	7.0 g/ha	II	$2.32	4-8-98
	2,4-D Ester 6#	5.3 oz/A	0.39 l/ha	II	$0.80	4-8-98
	Atrazine 4L	32 oz/A	2.34 l/ha	II	$2.98	7-29-98
	Fallowmaster *	32 oz/A	2.34 l/ha	I	$4.68	7-29-98
	Fallowmaster*	32 oz/A	2.34 l/ha	I	$4.68	9-29-98
Corn:	Round-up Ultra	16 oz/A	1.17 l/ha	II	$5.35	4-8-98
	Atrazine 4L	32 oz/A	2.34 l/ha	I	$2.98	5-5-98
	Prowl	32 oz/A	2.34 l/ha	I	$7.03	5-5-98
	Fallowmaster	32 oz/A	2.34 l/ha	I	$4.68	5-5-98
Proso Millet:	Landmaster	40 oz/A	2.92 l/ha	I	$6.83	5-5-98
	Landmaster	40 oz/A	2.92 l/ha	I	$6.83	5-27-98
	Banvel	3 oz/A	0.22 l/ha	II	$2.08	7-9-98
	2,4-D amine 4#	12 oz/A	0.88 l/ha	II	$1.09	7-9-98
	Gramoxone Extra*	32 oz/A	2.34 l/ha	II	$8.20	9-10-98
Rotation: Opportunity						
Wheat:	Ally	1/10 oz/A	7.0 g/ha	II	$2.32	4-8-98
	2,4-D Ester 6#	5.3 oz/A	0.39 l/ha	II	$0.80	4-8-98
	Atrazine 4L	32 oz/A	2.34 l/ha	II	$2.98	7-29-98
	Fallowmaster *	32 oz/A	2.34 l/ha	I	$4.68	7-29-98
	Fallowmaster*	32 oz/A	2.34 l/ha	I	$4.68	9-29-98

*Applied 1qt. Quest/100 gallons water with Round-up products and 1 gal. crop oil/100 gallons water with Gramoxone Extra.

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 1998.

Crop	Herbicide/Tillage	Rate (English)	Rate (Metric)	Weed Pressure	Cost	Date Applied
Rotation: Wheat-Corn-Fallow						
Wheat:	Banvel	8 oz/A	0.58 l/ha	II	$5.55	4-9-98
	2,4-D Ester 6#	4 oz/A	0.29 l/ha	II	$0.60	4-9-98
	Fallowmaster*	44 oz/A	3.21 l/ha	I	$6.44	8-18-98
	Atrazine 4L	32 oz/A	2.34 l/ha	II	$2.98	8-18-98
Corn:	Atrazine 4L	32 oz/A	2.34 l/ha	I	$2.98	5-18-98
	Prowl	32 oz/A	2.34 l/ha	I	$7.03	5-18-98
	Fallowmaster	32 oz/A	2.34 l/ha	I	$4.68	5-18-98
Fallow:	Fallowmaster	32 oz/A	2.34 l/ha	I	$4.68	5-18-98
	Fallowmaster*	44 oz/A	3.21 l/ha	I	$6.44	8-18-98
	Tillage–sweeps					9-11-98
Rotation: Wheat-Corn-Proso Millet						
Wheat:	Banvel	8 oz/A	0.58 l/ha	II	$5.55	4-9-98
	2,4-D Ester 6#	4 oz/A	0.29 l/ha	II	$0.60	4-9-98
	Fallowmaster*	44 oz/A	3.21 l/ha	I	$6.44	8-18-98
	Atrazine 4L	32 oz/A	2.34 l/ha	II	$2.98	8-18-98
Corn:	Atrazine 4L	32 oz/A	2.34 l/ha	I	$2.98	5-18-98
	Prowl	32 oz/A	2.34 l/ha	I	$7.03	5-18-98
	Fallowmaster	32 oz/A	2.34 l/ha	I	$4.68	5-18-98
Proso Millet:	Landmaster	40 oz/A	2.92 l/ha	I	$6.83	5-18-98
	Landmaster	40 oz/A	2.92 l/ha	I	$6.83	5-28-98
	Round-up	48 oz/A	3.50 l/ha	III	$16.05	9-15-98
Rotation: Wheat-Wheat-Corn-Proso Millet						
Wheat:	Banvel	8 oz/A	0.58 l/ha	II	$5.55	4-9-98
	2,4-D Ester 6#	4 oz/A	0.29 l/ha	II	$0.60	4-9-98
	Fallowmaster*	44 oz/A	3.21 l/ha	I	$6.44	8-18-98
	Landmaster	40 oz/A	2.92 l/ha	I	$6.83	9-15-98
Wheat:	Banvel	8 oz/A	0.58 l/ha	II	$5.55	4-9-98
	2,4-D Ester 6#	4 oz/A	0.29 l/ha	II	$0.60	4-9-98
	Fallowmaster*	44 oz/A	3.21 l/ha	I	$6.44	8-18-98
	Atrazine 4L	32 oz/A	2.34 l/ha	II	$2.98	8-18-98
Corn:	Atrazine 4L	32 oz/A	2.34 l/ha	I	$2.98	5-18-98
	Prowl	32 oz/A	2.34 l/ha	I	$7.03	5-18-98
	Fallowmaster	32 oz/A	2.34 l/ha	I	$4.68	5-18-98
Proso Millet:	Landmaster	40 oz/A	2.92 l/ha	I	$6.83	5-18-98
	Landmaster	40 oz/A	2.92 l/ha	I	$6.83	5-28-98
	Round-up	48 oz/A	3.50 l/ha	III	$16.05	9-15-98
Rotation: Opportunity						
Wheat:	Banvel	8 oz/A	0.58 l/ha	II	$5.55	4-9-98
	2,4-D Ester 6#	4 oz/A	0.29 l/ha	II	$0.60	4-9-98
	Fallowmaster*	44 oz/A	3.21 l/ha	I	$6.44	8-18-98
	Atrazine 4L	32 oz/A	2.34 l/ha	II	$2.98	8-18-98

*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.

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	$2.32	5-2-98
	X-90	4 oz/A	0.29 l/ha	I	$0.49	5-2-98
	Landmaster BW	54 oz/A	3.94 l/ha	I	$9.21	7-23-98
	Round-up Ultra	3 oz/A	0.22 l/ha	I	$1.00	7-23-98
	Round-up Ultra	16 oz/A	1.17 l/ha	I	$5.35	8-19-98
Sorghum:	Landmaster BW	54 oz/A	3.94 l/ha	I	$9.21	3-13-98
	Landmaster BW	54 oz/A	3.94 l/ha	I	$9.21	6-26-98
	Round-up Ultra	4 oz/A	0.29 l/ha	I	$1.33	6-22-98
	Cultivated			I		7-23-98
	Atrazine	0.75lb ai/A	842 g ai/ha	II	$1.11	7-23-98
	Crop Oil	32 oz/A	2.34 l/ha	II	$1.06	7-23-98
	Banvel	2.5 oz/A	0.18 l/ha	II	$1.73	7-23-98
Fallow:	Landmaster BW	54 oz/A	3.94 l/ha	I	$9.21	3-13-98
	Landmaster BW	54 oz/A	3.94 l/ha	I	$9.21	7-23-98
	Round-up Ultra	3 oz/A	0.22 l/ha	I	$1.00	7-23-98
	Round-up Ultra	16 oz/A	1.17 l/ha	I	$5.35	8-19-98
	Landmaster BW	48 oz/A	3.50 l/ha	I	$8.19	9-19-98
	Round-up Ultra	4 oz/A	0.29 l/ha	I	$1.33	9-19-98
Rotation: Wheat-Corn-Safflower						
Wheat:	Ally	0.10 oz/A	7.02 g/ha	I	$2.32	5-2-98
	X-90	4 oz/A	0.29 l/ha	I	$0.49	5-2-98
	Landmaster BW	54 oz/A	3.94 l/ha	I	$9.21	7-23-98
	Round-up Ultra	3 oz/A	0.22 l/ha	I	$1.00	7-23-98
	Round-up Ultra	16 oz/A	1.17 l/ha	I	$5.35	8-19-98
Corn:	Landmaster BW	54 oz/A	3.94 l/ha	I	$9.21	3-13-98
	Round-up Ultra	16 oz/A	1.17 l/ha	I	$5.35	5-27-98
	X-90	8 oz/A	0.58 l/ha	I	$0.98	5-27-98
	32-0-0 UAN	32 oz/A	2.34 l/ha	I		5-27-98
	Basis Gold	14 oz/A	1.02 l/ha	I	$17.20	7-4-98
	Crop Oil	32 oz/A	2.34 l/ha	I	$1.06	7-4-98
	Banvel	2 oz/A	0.15 l/ha	I	$1.39	7-4-98
	12-0-0-26(S)	1 gal/A	9.34 l/ha	I		7-4-98
Safflower:	Eptam	40 oz/A	2.92 l/ha	III	$10.47	2-20-98
	Eptam	40 oz/A	2.92 l/ha	I	$10.47	3-12-98
	Poast	24 oz/A	1.75 l/ha	I	$14.77	5-27-98
	Crop Oil	32 oz/A	2.34 l/ha	I	$1.06	5-27-98
	Gramoxone	32 oz/A	2.34 l/ha	I	$8.20	8-19-98
	Crop Oil	32 oz/A	2.34 l/ha	I	$1.06	8-19-98
	Landmaster BW	48 oz/A	3.50 l/ha	I	$8.19	9-19-98
	Round-up	4 oz/A	0.29 l/ha	I	$1.33	9-19-98

Rotation: Wheat-Wheat-Sorghum-Safflower						
Wheat:	Ally	0.10 oz/A	7.02 g/ha	I	$2.32	5-2-98
	X-90	4 oz/A	0.29 l/ha	I	$0.49	5-2-98
	Landmaster BW	54 oz/A	3.94 l/ha	I	$9.21	7-23-98
	Round-up Ultra	3 oz/A	0.22 l/ha	I	$1.00	7-23-98
	Round-up Ultra	16 oz/A	1.17 l/ha	I	$5.35	8-19-98
	Landmaster BW	48 oz/A	3.5 l/ha	I	$8.19	9-19-98
	Round-up	4 oz/A	0.29 l/ha	I	$1.33	9-19-98
Wheat:	Ally	0.10 oz/A	7.02 g/ha	I	$2.32	5-2-98
	X-90	4 oz/A	0.29 l/ha	I	$0.49	5-2-98
	Landmaster BW	54 oz/A	3.94 l/ha	I	$9.21	7-23-98
	Round-up Ultra	3 oz/A	0.22 l/ha	I	$1.00	7-23-98
	Round-up Ultra	16 oz/A	1.17 l/ha	I	$5.35	8-19-98
Sorghum:	Landmaster BW	54 oz/A	3.94 l/ha	I	$9.21	3-13-98
	Landmaster BW	54 oz/A	3.94 l/ha	I	$9.21	6-26-98
	Round-up Ultra	4 oz/A	0.29 l/ha	I	$1.33	6-22-98
	Cultivated			I		7-23-98
	Atrazine	0.75lb ai/A	842 g ai/ha	II	$1.11	7-23-98
	Crop Oil	32 oz/A	2.34 l/ha	II	$1.06	7-23-98
	Banvel	2.5 oz/A	0.18 l/ha	II	$1.73	7-23-98
Safflower:	Eptam	40 oz/A	2.92 l/ha	III	$10.47	2-20-98
	Eptam	40 oz/A	2.92 l/ha	I	$10.47	3-12-98
	Poast	24 oz/A	1.75 l/ha	I	$14.77	5-27-98
	Crop Oil	32 oz/A	2.34 l/ha	I	$1.06	5-27-98
	Gramoxone	32 oz/A	2.34 l/ha	I	$8.20	8-19-98
	Crop Oil	32 oz/A	2.34 l/ha	I	$1.06	8-19-98
	Landmaster BW	48 oz/A	3.50 l/ha	I	$8.19	9-19-98
	Round-up	4 oz/A	0.29 l/ha	I	$1.33	9-19-98
Opportunity						
Sorghum:	Landmaster BW	54 oz/A	3.94 l/ha	I	$9.21	3-13-98
	Tillage - Sweeps					5-27-98
	Landmaster BW	54 oz/A	3.94 l/ha	I	$9.21	6-26-98
	Round-up Ultra	4 oz/A	0.29 l/ha	I	$1.33	6-22-98
	Cultivated			I		7-23-98
	Atrazine	0.75lb ai/A	842 g ai/ha	II	$1.11	7-23-98
	Crop Oil	32 oz/A	2.34 l/ha	II	$1.06	7-23-98
	Banvel	2.5 oz/A	0.18 l/ha	II	$1.73	7-23-98
Continuous Cropping:						
Corn:	Landmaster BW	54 oz/A	3.94 l/ha	I	$9.21	3-13-98
	Round-up Ultra	16 oz/A	1.17 l/ha	I	$5.35	5-27-98
	X-90	8 oz/A	0.58 l/ha	I	$0.98	5-27-98
	32-0-0 UAN	32 oz/A	2.34 l/ha	I		5-27-98
	Basis Gold	14 oz/A	1.02 l/ha	I	$17.20	7-4-98
	Crop Oil	32 oz/A	2.34 l/ha	I	$1.06	7-4-98
	Banvel	2 oz/A	0.15 l/ha	I	$1.39	7-4-98
	12-0-0-26(S)	1 gal/A	9.34 l/ha	I		7-4-98
Sorghum:	Landmaster BW	54 oz/A	3.94 l/ha	I	$9.21	3-13-98
	Landmaster BW	54 oz/A	3.94 l/ha	I	$9.21	6-26-98
	Round-up Ultra	4 oz/A	0.29 l/ha	I	$1.33	6-22-98
	Cultivated			I		7-23-98
	Atrazine	0.75lb ai/A	842 g ai/ha	II	$1.11	7-23-98
	Crop Oil	32 oz/A	2.34 l/ha	II	$1.06	7-23-98
	Banvel	2.5 oz/A	0.18 l/ha	II	$1.73	7-23-98
	Weed Pressure Ratings: I =Farmer would need to spray. II = Farmer would delay application. III = Farmer would not plan a spray application.					

Table 4. Weed control program at Nunn in 1998.

Crop	Herbicide/Tillage	Rate (English)	Rate (Metric)	Cost	Date Applied
Rotation: Wheat-Sunflower-Fallow					
Wheat	2,4-D Ester 6# Banvel Fallowmaster	8 oz/A 4 oz/A 32 oz/A	0.58 l/ha 0.29 l/ha 2.34 l/ha	$1.21 $2.77 $4.68	4-15-98 4-15-98 8-10-98
Sunflower	Round-up Ultra* Round-up Ultra*	16 oz/A 11 oz(w/ hoods)	1.17 l/ha 0.80 l/ha	$5.35 $3.68	5-15-98 6-25-98
Fallow	Round-up Ultra* Fallowmaster* Round-up Ultra*	16 oz/A 32 oz/A 16 oz/A	1.17 l/ha 2.34 l/ha 1.17 l/ha	$5.35 $4.68 $5.35	5-15-98 7-10-98 9-4-98
Rotation: Wheat-Proso Millet-Fallow					
Wheat	2,4-D Ester 6# Banvel Fallowmaster*	8 oz/A 4 oz/A 32 oz/A	0.58 l/ha 0.29 l/ha 2.34 l/ha	$1.21 $2.77 $4.68	4-15-98 4-15-98 8-10-98
Proso Millet	Round-up Ultra*	16 oz/A	1.17 l/ha	$5.35	5-15-98
Fallow	Round-up Ultra* Fallowmaster* Round-up Ultra*	16 oz/A 32 oz/A 16 oz/A	1.17 l/ha 2.34 l/ha 1.17 l/ha	$5.35 $4.68 $5.35	5-15-98 7-10-98 9-4-98

*Applied 17 lbs. Ammonium Sulfate per 100 gallons of water.

Table 5. Weed control program at Akron in 1998.

Crop	Herbicide or Tillage	Rate (English)	Rate (Metric)	Cost	Date Applied
Rotation: Wheat-Fallow					
Wheat	Round-up EZ Dry*	19 oz/A	1330 g/ha	$9.16	8-31-98
Fallow	Round-up Ultra* V-blade sweeps Tandem disc V-blade sweeps	32 oz/A	2.34 l/ha	$10.70	4-19-98 5-26-98 7-13-98 8-26-98
Rotation: Wheat-Corn-Fallow					
Wheat	Round-up EZ Dry*	19 oz/A	1332 g/ha	$9.16	8-31-98
Corn	Prowl 3.3 Atrazine 4L Gromoxone Extra 2,4-D	32 oz/A 32 oz/A 32 oz/A 16 oz/A	2.34 l/ha 2.34 l/ha 2.34 l/ha 1.17 l/ha	$7.03 $2.98 $8.20 $1.46	6-10-98 6-10-98 7-15-98 7-15-98
Fallow	Round-up Ultra* V-blade sweeps Tandem disc V-blade sweeps	32 oz/A	2.34 l/ha	$10.70	4-19-98 5-26-98 7-13-98 8-26-98
Rotation: Wheat-Corn-Proso Millet					
Wheat	Round-up EZ Dry*	19 oz/A	1332 g/ha	$9.16	8-31-98
Corn	Prowl 3.3 Atrazine 4L Gromoxone Extra 2,4-D amine 4#	32 oz/A 32 oz/A 32 oz/A 16 oz/A	2.34 l/ha 2.34 l/ha 2.34 l/ha 1.17 l/ha	$7.03 $2.98 $8.20 $1.46	6-10-98 6-10-98 7-15-98 7-15-98
Proso Millet	Round-up Ultra* 2,4-D amine 4#	32 oz/A 18 oz/A	2.34 l/ha 1.32 l/ha	$10.70 $1.64	6-11-98 6-11-98
Rotation: Wheat-Corn-Sunflower-Fallow					
Wheat	Round-up EZ Dry*	19 oz/A	1332 g/ha	$9.16	8-31-98
Corn	Prowl 3.3 Atrazine 4L Gromoxone Extra	32 oz/A 32 oz/A 32 oz/A	2.34 l/ha 2.34 l/ha 2.34 l/ha	$7.03 $2.98 $8.20	6-10-98 6-10-98 7-15-98
Sunflower	Sonolan 10G Sonolan 10G	0.67 lb ai/A 0.33 lb ai/A	752 g/ha 376 g/ha		5-14-98 5-22-98
Fallow	Round-up Ultra* V-blade sweeps Tandem disc V-blade sweeps	32 oz/A	2.34 l/ha	$10.70	4-19-98 5-26-98 7-13-98 8-26-98

*Applied 17 lbs. Ammonium Sulfate per 100 gallons of water.

Table 6. Weed control program at Lamar in 1998.

Rotation Crop	Herbicide or Tillage	Rate (English)	Rate (Metric)	Cost	Date Applied	Timing
Rotation: Wheat-Fallow						
Wheat	Ally 2, 4-D Landmaster BW* Fallowmaster* Landmaster BW* Fallowmaster*	1/10 oz/A 6 oz/A 32 oz/A 32 oz/A 32 oz/A 32 oz/A	7.0 g/ha 0.45 l/ha 2.34 l/ha 2.34 l/ha 2.34 l/ha 2.34 l/ha	$2.32 $0.90 $5.46 $4.68 $5.46 $4.68	4-21-98 4-21-98 7-22-98 7-22-98 9-9-98 9-9-98	Pre-joint Pre-joint Wheat Stubble Wheat Stubble Wheat Stubble Wheat Stubble
Fallow	Tordon 22 K 2,4-D Amine Activator 90 Landmaster BW* Landmaster BW* Fallowmaster*	16 oz/A 32 oz/A 0.1 pt 54 oz/A 32 oz/A 32 oz/A	1.17 l/ha 2.34 l/ha 0.12 l/ha 3.94 l/ha 2.34 l/ha 2.34 l/ha	$10.70 $2.91 $0.24 $9.21 $5.46 $4.68	5-15-98 5-15-98 5-15-98 6-11-98 9-9-98 9-9-98	
Rotation: Wheat-Sorghum-Fallow						
Wheat	Ally 2,4-D Landmaster BW* Fallowmaster* Landmaster BW* Fallowmaster*	1/10 oz/A 6 oz/A 32 oz/A 32 oz/A 32 oz/A 32 oz/A	7.0 g/ha 0.45 l/ha 2.34 l/ha 2.34 l/ha 2.34 l/ha 2.34 l/ha	$2.32 $0.90 $5.46 $4.68 $5.46 $4.68	4-21-98 4-21-98 7-22-98 7-22-98 9-9-98 9-9-98	Pre-joint Pre-joint Wheat Stubble Wheat Stubble Wheat Stubble Wheat Stubble
Sorghum	Landmaster BW*	54 oz/A	3.94 l/ha	$9.21	5-14-98	Pre-plant
Fallow	Tordon 22 K 2,4-D Amine Activator 90 Landmaster BW* Landmaster BW* Fallowmaster*	16 oz/A 32 oz/A 0.1 pt. 54 oz/A 32 oz/A 32 oz/A	1.17 l/ha 2.34 l/ha 0.12 l/ha 3.94 l/ha 2.34 l/ha 2.34 l/ha	$10.76 $2.91 $0.24 $9.21 $5.46 $4.68	5-15-98 5-15-98 5-15-98 6-11-98 9-9-98 9-9-98	

*Applied 16 oz. LI700 and 17 lbs. Ammonium Sulfate per 100 gallons of water.

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.

Paustian, K.A., E.T. Elliott, G.A. Peterson, and K. Kendrick. 1996. Modeling climate, CO_2 and management impacts on soil carbon in semi-arid agroecosystems. Plant and Soil 187:351-365.

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.

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.

Westfall, D.G., W.R. Raun, J.L. Havlin, G.V. Johnson, J.E. Matocha, and F.M. Hons. 1994. Fertilizer management. p. 33-36. IN: B.A. Stewart and W.C. Moldenhauer (eds.) Crop residue management to reduce erosion and improve soil quality: Southern Great Plains. USDA/ARS Cons. Res. Report No. 37. Washington, D.C.

Metherell, A.K., C.A. Cambardella, W.J. Parton, G.A. Peterson, L.A. Harding, and C.V. Cole. 1995. Simulation of soil organic matter dynamics in dryland winter wheat-fallow cropping systems. p.259-270. *IN:* Soil management and greenhouse effect. R. Lal, J. Kimble, E. Levine, and B.A. Stewart. (eds.) Lewis Publishers, Boca Raton, FL.

Peterson, G.A. and D.G. Westfall. 1997. Management of dryland agroecosystems in the Central Great Plains of Colorado. p.371-380. *IN:* Soil organic matter in temperate agroecosystems. Paul, E.A., K.A. Paustian, E.T. Elliot, and C.V. Cole. (eds.) Lewis Publishers, Boca Raton, FL.

Halvorson, A.D., M.F. Vigil, G.A. Peterson, and E.T. Elliott. 1997. Long-term tillage and crop residue management study at Akron, Colorado. p.361-370. *IN:* Soil organic matter in temperate agroecosystems. Paul, E.A., K.A. Paustian, E.T. Elliot, and C.V. Cole. (eds.) Lewis Publishers, Boca Raton, FL.

Farahani, H.J., G.A. Peterson, and D.G. Westfall. 1998. Dryland cropping intensification: A fundamental solution to efficient use of precipitation. Advaces in Agron. 64:197-223.

Publications in Proceedings:

Peterson, G. A. and D. G. Westfall. 1987. Integrated research in soil and crop management. p. 3-5. IN: Proc. Western Phosphate Conf. March 1987. Corvallis, OR.

Kitchen, N. R. , D. G. Westfall and G. A. Peterson. 1988. Nitrogen fertilizer use efficiency in dryland no-till crop rotations. p. 172-179. IN: 1988 Symposium Proc. Fluid Fertilizer Research as a Basis for Efficient Crop Production. March 15-17, 1988.

Wood, C. W., D. G. Westfall and J. M. Ward. 1988. Phosphorus placement in dryland winter wheat. IN: Proc. Great Plains Soil Fert. Workshop 2:79-83.

Peterson, G. A., D. G. Westfall and W. O. Willis. 1988. Systems research: a necessity for the future of agronomic research. p. 739-740. IN: Proc. Int. Conf. Dryland Farming, Aug. 15-19, 1988. Amarillo, TX.

Kitchen, N. R., D. G. Westfall and G. A. Peterson. 1988. Nitrogen fertilizer use efficiency in dryland no-till crop rotations. p. 223-229. IN: Proc. Fluid Fert. Found. Symp., March, 1988, Scottsdale, AZ.

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