1998

SUSTAINABLE DRYLAND AGROECOSYSTEM MANAGEMENT[1]

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A Cooperative Project

of the

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RESEARCH APPLICATION SUMMARY

We established the Dryland Agroecosystem Project in the fall of 1985 and the first crop year was 1986. Grain yields, stover yields, crop residue amounts, soil water measurements, and crop nutrient content are reported annually in previously published technical bulletins. This summary updates our findings for the 12 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 12 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).

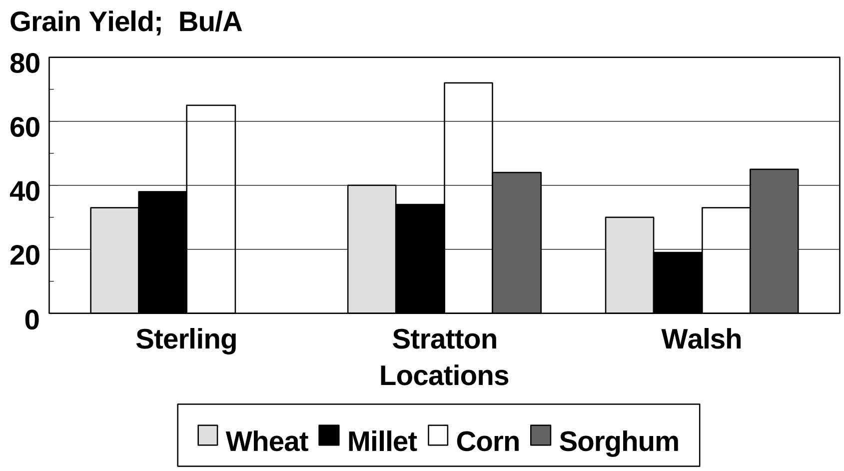


Figure 1. Grain yields averaged over soil positions and 12 years of production for each location.

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 72 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. 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 72 bu/A for the past 7 years, making it a better choice for this environment. At Walsh grain sorghum yields have averaged 45 bu/A (ranging from 27 to 74 bu/A), including the results from the very dry 1995 season.

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 expensive residual materials have shown promise.

No-till management allows more water storage than conventional tillage, but it also costs more to control the weeds with herbicides used at labeled rates than by tillage. By inserting summer crops like corn, grain sorghum, and annual forages into the rotation the additional water stored is converted to additional production that results in more profit than with wheat-fallow.

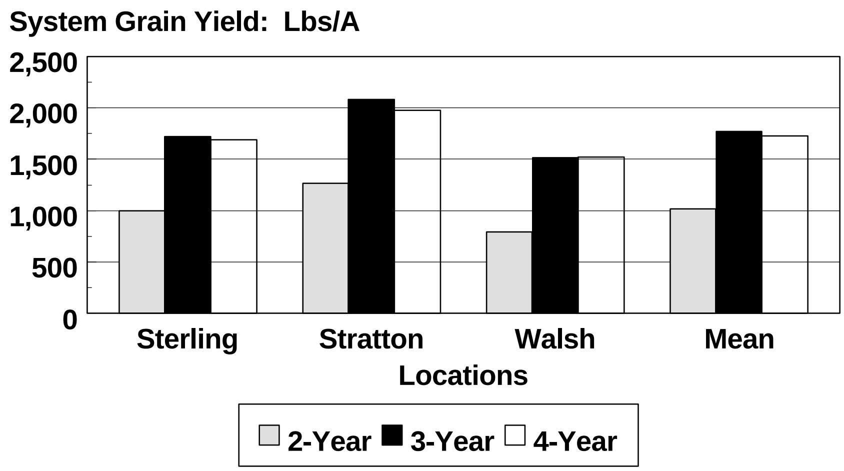


Figure 2 . System grain yield for each location.

Dryland corn yields in northeastern Colorado are highly related to rainfall during the period of 15 July through 25 August (Nielsen, et al. 1996). This is not surprising because this time period includes the tasseling, silking and pollinating period. You may estimate potential long-term corn yields in your area by using the equation:

Grain Yield = 33.9 + 7.49*(Rainfall from 15 July through 25 August)

First obtain the long-term precipitation records from a site near your farm for the 15 July through 25 August period. Then multiply this value by 7.49 and add 33.9. The resulting number is the expected yield in Bu/A. Refer to the publication by Nielsen, et al. (1996) for more detail.

Producers in northeastern Colorado have been adopting the more intensive cropping systems at an increasing rate since 1990. Since corn is one of the principle crops used in more intensive systems, its acreage can be used as an index of adoption rate by producers (see Table below). Area planted to dryland corn has increased from about 20,000 acres per year in years previous to 1990 to over 138,000 acres in 1997. Data for sunflower and proso millet in similar rotations are not available, but individual producers report larger acreages of these crops as well.

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 from 1971 to 1997.

YEAR	ACRE
1971-1988	21,200
1989	27,000
1990	26,000
1991	32,500
1992	48,500
1993	79,000
1994	92,500
1995	95,500
1996	104,000
1997	138,500

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

CONCURRENT RESEARCH PROJECTS

Wheat - Corn Rotation at Sterling: {Established in fall 1993}

Objective:

Maximize time in crop and minimize weed control costs between crops.

Procedure:

i) Roundup, Atrazine, and Command applied after winter wheat harvest.

ii) Corn planted into the wheat stubble the following May with an Atrazine + Prowl weed control program. If needed Banvel is used for kochia control.

iii) Corn is harvested in late September and wheat is planted the same day, directly into the corn stalks.

iv) Roundup sprayed at planting for downy brome control.

Results:

i) Corn yields in 1997 averaged 98 bu/A.

ii) Wheat was cut for hay in 1996 because of excessive amounts of downy brome. The downy brome was not caused by the rotation, but was a carryover from a time when this plot had been in a wheat-fallow system. Wheat was seeded on 17 October 1996, germinated, but winter killed.

Expectations:

Since wheat yield is most dependent on May and June rainfall, wheat yields following corn should be adequate if plants can be established in the dry soil following corn harvest. To date our wheat production has not been very successful. Corn yields would be expected to be similar to those obtained in other rotations.

Experiment Managers:

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

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 into the triticale stubble the following May with an Atrazine + Prowl weed control program. If needed Banvel used for kochia control.

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 in 1997.

ii) Hay millet yields were non-harvestable the first 3 years, but in 1997 averaged 2.0 T/A. The dry summers in 1994 and 1995 were not conducive to hay millet production. In 1996 the sandbur problem was large and we destroyed the crop with Roundup.

iii) Triticale “Harvested” yields have averaged 2.2 T/A over the 4 years, even though we left a 10-12" stubble remaining in the field for cover (Following table)

Triticale and corn grain yields by year and soil.

Year	Crop	Production	Soil Positions			
			Summit	Sideslope	Toeslope	Average
			----------------Tons/A or Bu/A------------------			
1994	Triticale	Total	2.6	2.2	3.5	2.8
		Harvested[1]	1.5	1.2	2.0	1.6
	Corn	Grain	All yields < 3 bu/A			
1995	Triticale	Total	4.6	4.3	3.7	4.2
		Harvested[1]	3.8	3.6	2.9	3.4
	Corn	Grain	26	2	38	22
1996	Triticale	Total	3.0	2.5	3.6	3.0
		Harvested[1]	2.0	1.7	2.5	2.1
	Corn	Grain	61	66	99	75
1997	Triticale	Total	2.0	1.5	2.8	2.1
		Harvsted[1]	1.7	1.3	2.3	1.7
	Corn	Grain	82	94	98	91
	Hay Millet	Total	1.5	2.7	2.2	2.1
		Harvested[2]	1.4	2.5	2.0	2.0

[1]Harvested leaving 10" stubble; [2]Harvested leaving 4" 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 ten year period of years. The hay millet, given a normal spring moisture pattern, should yield in the 2 T/A range as it did in 1997.

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) Austrian winter pea at Sterling yielded 3479 lbs/acre and 1919 lbs/ac. Since the Trapper spring pea results have been erratic and undesirable, we decided to try other legumes in 1997. We spring planted Trapper spring pea, Profi spring pea, Austrian winter pea, and black lentils. The yields were as follows (all planted on March 31, 1997):

	Sterling	Stratton
	-----------Lbs/A-----------	
Trapper spring	2610	1967
Austrian Winter	3387	2221

Profi peas and black lentils were planted for seed production. The profi pea seed was too large to permit a consistent stand, so no yields were taken. The black lentils were too short to harvest and did not appear to have many seeds. It was interesting that the Austrian winter peas planted in the spring yielded as much as those planted in the fall.

ii) Total nitrogen left in above ground biomass of the peas were as follows:

	Planting Date	Sterling	Stratton
		------------Lbs/A----------	
AWP (100% left)	Fall	57.8	33.6
AWP (50% left)	Fall	24.7	19.4
AWP (100% left)	Spring	55.9	50.2
Trapper (100% left)	Spring	37.8	33.6

iii) Wheat yields at Sterling were decreased by 4 bu/A following winter peas, compared to yields where no peas had been grown. The precipitation level after pea harvest in 1996 did not result in adequate stored water for the wheat.

Changes for 1998:

We have not been able to track the nitrogen from the pea biomass in the field into the following crops. We speculate the biomass may be blowing off the plots. So, in 1998 we will trap areas with screen to decrease potential blowing losses.

Expectations:

Soil water measurements are being 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.

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

Using Natural Soil Variability in Landscapes: Site Specific Management of N on Dryland Corn

Objectives:

1) To quantify the spatial variability of corn yields, soil N and "*in-situ*" net N mineralization over "typical" landscapes of eastern Colorado.

2) To study the spatial relationships among corn yields, soil properties, soil N and N mineralization.

3) To attempt to develop a N recommendation model for dryland corn.

Procedure:

Three landscapes, two located near Sterling, CO and one in Stratton, CO were selected for study. The elevation difference within each landscape was 18 and 12 ft. at Sterling and Stratton, respectively. Soil samples were collected from a maximum depth of four feet across each landscape. *In situ* N mineralization, as described by Kolberg et al. (1997), was measured at strategic positions across each landscape. The landscapes were cropped with dryland corn under no-till management in a WCF cropping system. The corn was fertilized with five N rates (30, 60, 90 and 120 lb N/A) and planted in parallel strips across landscapes. In all cases N was applied as UAN solution, and a base P fertilization of 15 lb P_2O_5/A was applied to all treatments. At maturity, corn was harvested at 40 and 20 ft. intervals across the Sterling and Stratton landscapes respectively and yields were expressed at 15.5% moisture. Total N was determined in grain and plant material by dry combustion.

Results:

Corn yields of the 0 lb N/A treatment described the variation in soil properties over the landscapes. Higher yields were associated with depositional areas that had higher SOM content and available N, lower pH values, and lower lime contents. Soil profile NO_3-N varied 300 and 1200% at the Sterling 1996 and Stratton landscapes, respectively. At Sterling, lowest residual NO_3-N was found on the eroded sideslope, but all other positions were generally low. We developed a "soil index" made of a standardized linear combination of SOC, SON, SIC, pH, profile NO_3-N and mineralization rates. Soil organic C, SON, NO_3-N, and N mineralization rates, positively influenced the value of the "soil index". Conversely, SIC and soil pH weighted negatively on the "soil index" value. Soil index value explained between 36 and 60% of the total variability in the corn yield of the unfertilized treatment.

We developed models using several independent variables to explain total N uptake and for computing N fertilizer recommendations. Models solely based on profile NO_3-N did not perform well. Models using the “balance Method” performed well as long as May-July mineralization rates were included in the model. The only weakness of this model is that it does not have provisions for maximum N uptake, and may overestimate N rates. Models that used "soil index" alone or N mineralization rates in combination with profile NO_3-N had a better prediction ability than did any other model. Models that include an index of soil productivity potential (i.e. soil index, or N mineralization rates) can be successful across environments of similar soil variability. Results of this study show promise for improving N fertilizer recommendations in dryland corn either under conventional or VRT soil fertility management.

Literature Cited:

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

Experiment Managers: W.J. Gangloff, D.G. Westfall, G.A. Peterson, and R.A. Ortega

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.

Specific objectives are to:

1. Determine if cropping sequences with fewer and/or shorter summer fallow periods are feasible.
2. Quantify the relationship of 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 of the soil 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 - 1996 crop years were reported by Peterson, et al. (1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, and 1997). 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.

MATERIALS AND METHODS

We are studying interactions of climate, soils and cropping systems. Three sites, located near Sterling, Stratton, and Walsh, were chosen in Eastern Colorado that represent a gradient in potential evapotranspiration (PET) (Fig. 3). All sites have long-term precipitation averages of approximately 16-17 inches (400-425 mm), but increase in PET from north to south. Open pan evaporation, an index of PET for the cropping season, ranges from 40 inches (1,050 mm) in the north to 75 inches (1,900 mm) in the south. Elevations are 4400 (1341 m), 4380 (1335 m), and 3720 (1134 m) feet above sea level at Sterling, Stratton, and Walsh, respectively.

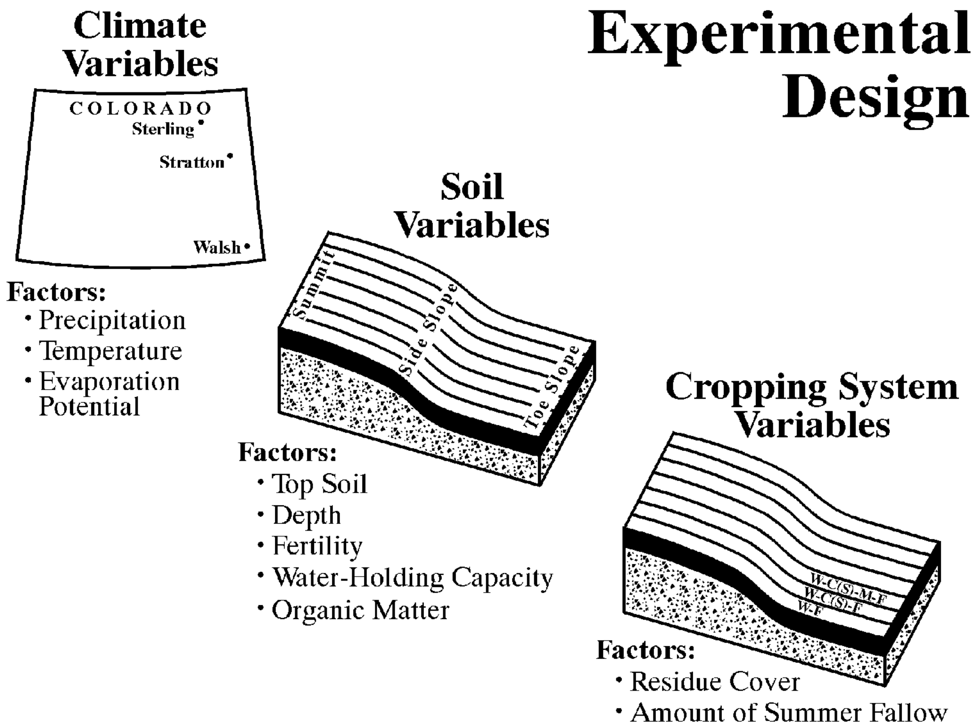


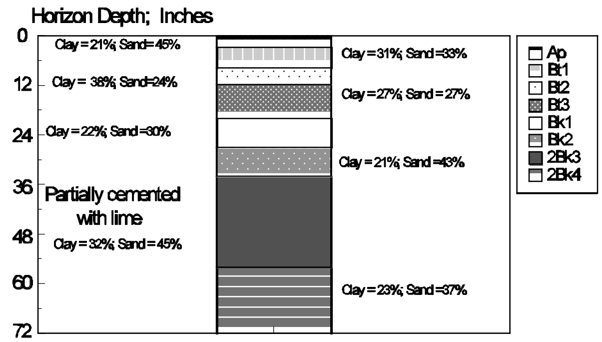
Figure 3. Experimental locations on a climatic gradient, soil variables by slope position, and cropping systems over soil positions.

Each site 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 NRSCS 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.

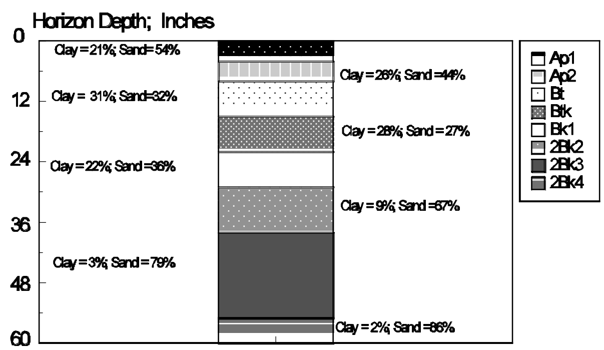
The summit soil profile at Sterling (Figure 4a) changes from a clay content of 21% at the surface(Ap) to 31% in the 3-8" depth (Bt1) to a clay content of 38% in the layer between the 8-12" depth (Bt2). At the 12" depth the clay content drops abruptly to 27%. The water infiltration in this soil is greatly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

Sterling Summit Soil Profile



Sterling Sidelope Soil Profile



Sterling Toeslope Soil Profile

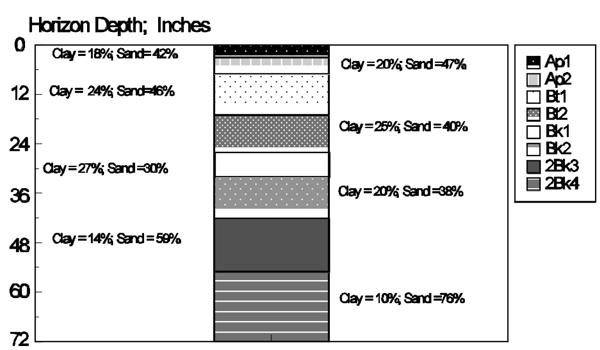
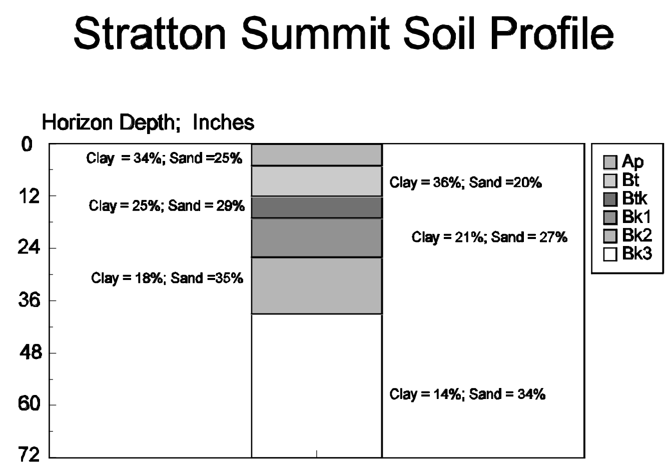
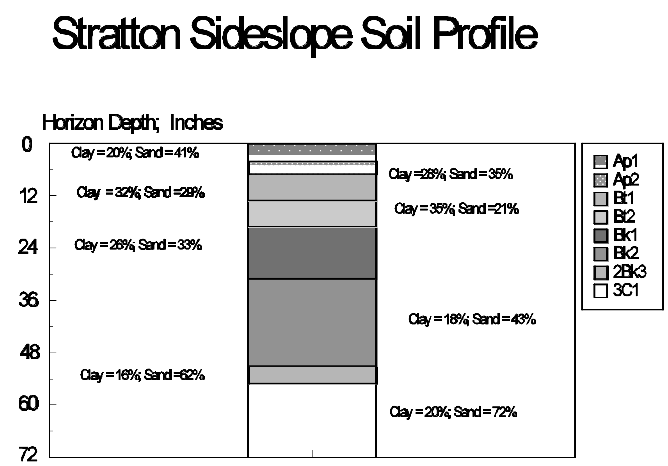


Figure 4a. Soil profile textural characteristics for soils at the Sterling site.





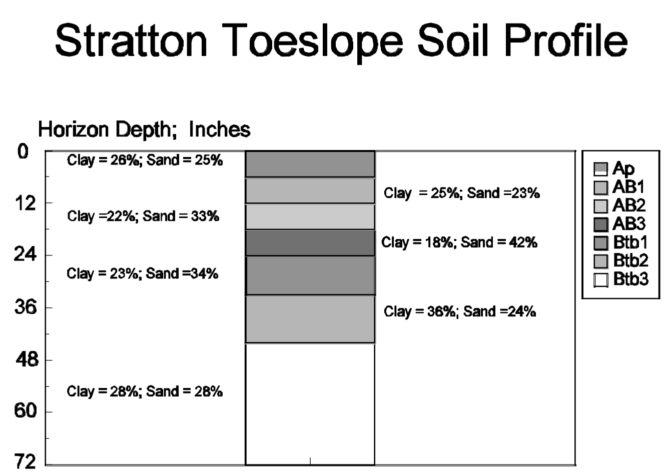


Figure 4b. Soil profile textural characteristics for soils at the Stratton site.

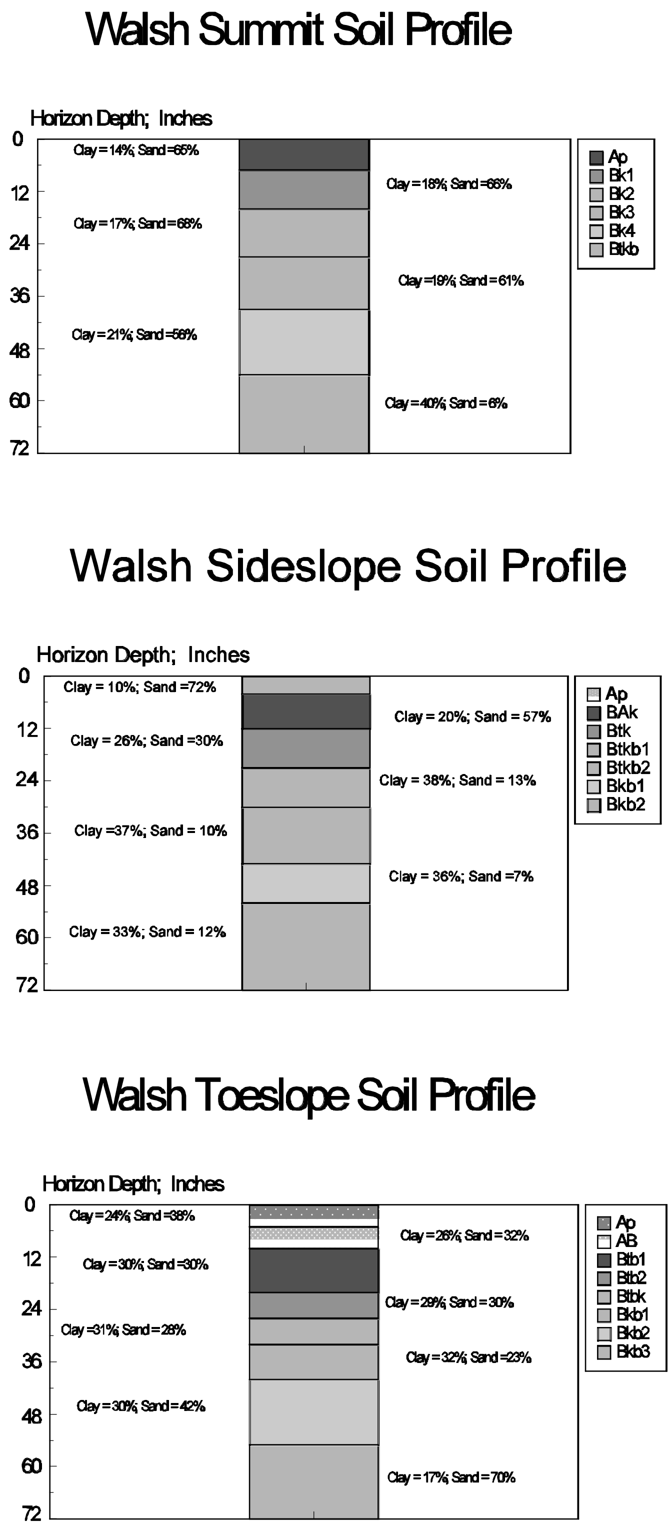


Figure 4c. Soil profile textural characteristics for soils at the Walsh site.

summit soil at Sterling. Profile plant available water holding capacity is 12" in the upper 72 inches of soil.

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.

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. We placed cropping system treatments over the soil sequence at each site (Fig.3) and they are identified in Table 1. Each system is managed with no-till techniques, and herbicide programs are reported in Appendix Tables 1, 2 and 3. Complete details on measurements being made and reasons for treatment choices are given by Peterson, et al.(1988). Wheat, TAM 107, was planted at 60 lbs/A (67 kg/ha) on 2 October, 24 September, and 25 September 1996 at Sterling, Stratton, and Walsh, respectively. Corn, Pioneer 3752, was planted on 5 and 6 May 1997 at 17,100 seeds/A (42,240 seeds/ha) at Sterling and Stratton, respectively. Corn, Northrup King N4640Bt, was planted at Walsh on 19 May 1997 at 17,100 seeds/A (42,240 seeds/ha). Sorghum, Northrup King KS310, was planted at Walsh on 12 June 1997 at a seeding rates of 43,000 seeds/A (106,210 seeds/ha) in the WSF and WSSF treatments. Sunflower, Triumph 505C, was planted at a rate of 17,000 seeds/A (41,990 seeds/ha) on 17 and 5 June 1997 at Sterling and Stratton, respectively.

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 2). 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.

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, but applied to the entire plot in the case of wheat . 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 deficiency.

Table 1. Cropping systems for each site in 1997.

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

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

Opportunity Cropping History

Year	Site: Sterling	Site: Stratton	Site: 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

We measured soil water with the neutron-scatter technique. Aluminum access tubes were installed, two per soil position, in each treatment at each 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 were 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.

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 1996, the period prior to wheat planting, was above the normals by 1.4 in. (35 mm) at Sterling, by 0.9 in. (23 mm) at Stratton, and by 5.3 in. (135 mm) at Walsh (Table 3a). The first half of 1997 was substantially below normal at Sterling (-2.4 in. or 61 mm) , about normal at Stratton, and 1.6 in. (41 mm) below normal at Walsh. Precipitation was well above normal during the second half of 1997 at all sites; especially at Sterling where rainfall exceeded the long-term normal by 7.6 in. (193 mm) (Table 3a).

Hail damage in 1997 occurred twice at the Stratton site, mid and late July, and the corn plants were seriously damaged. The corn still averaged 49 bu/A, which is about 25 bu/A less than would have been expected with the high rainfall in July and August.

Wheat

Wheat yields in 1997 were a function of weather and insect related factors. Yields at Sterling were near the 12 year average at this site, but yields at Stratton were 15 bu/A (1000 kg/ha) below the long-term mean because of damage due to a combination of Brown Wheat Mite [*Petrobia latens*], Russian Wheat Aphid [*Diuraphis noxia (Mordvilko*)] and a minor Wheat Streak Mosaic Virus infestation (Tables 5 & 6). Conversely wheat yields at Walsh were 11 bu/A (740 kg/ha) above the 10 year average for this site because of good fall planting moisture conditions and timely spring rains (Table 7). Note in Tables 4a & 4b that soil position also affected yield, with toeslopes always having the highest yields due to their greater chance for additional water and having no root restrictions (Figures 4a, 4b, & 4c)

Cropping system effects on wheat yields were very apparent at Sterling and Stratton (Tables 4a & 4b) where WF yielded about 10 bu/A (670 kg/ha) less than wheat in either the WCF or WCSF rotations. Downy brome (*Bromus tectorum L.)* infestations in the WF damaged 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. However, the 4-year systems have yielded about 5 bu/A more than either WF or WCF at Sterling and Stratton. The reason is not obvious. At Walsh all systems have yielded essentially the same. It is important to note that the shorter fallows in the more intensive systems have never decreased wheat yield and potential profit for that crop.

Corn and Sorghum

Corn yields at Sterling exceeded the 12-year average by 42 bu/A (2630 kg/ha) (Table 9), but were 23 bu/A (1440 kg/ha) below the average at Stratton (Table 10). The high Sterling yields were directly attributable to the above average rainfall during the corn growing season (Tables 3b). July and August precipitation at Sterling totaled 10.9 in., which is 6.5 in. above the normal. The rainfall from 15 July to 25 August, the critical period for corn production, was 9.5 in. at Sterling. Using the equation published by Nielsen, et al. (1996) we would predict a yield of 105 bu/A with this amount of rainfall, which is very near the 107 bu/A yield reported in Tables 8a & 9. The corn at Stratton was damaged by hail on two different dates in July. During the critical period rainfall totaled nearly 6 in., and the Nielsen, et al. (1996) equation predicted a corn yield of

76 bu/A. This suggests that the hail reduced yields by at least 25 bu/A.

The toeslope soil position produced the highest yields at both sites as was expected because of its more favorable water regime (Figures 4a & 4b).   Compared to other years the summit and sideslope soil positions at Sterling produced proportionately more grain than usual. For example the summit and sideslope produced 77 and 90% of the yield of the toeslope, respectively. The long-term means are 63 and 74% for the summit and sideslope postions, respectively. In years with favorable precipitation during the critical period, soil water storage capacity and slope position have less influence on yield.

Phosphorus fertilization increased corn grain yield on both the summit and sideslope positions at Sterling, but had essentially no effect on these same soils at Stratton (Tables 8a & 8b). 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. Using both the 1996 and 1997 corn yield data, we still can not be definitive regarding the value of the carryover P to the corn from the fertilized wheat crop.

Sorghum yields at Walsh ranged from 33 to 83 bu/A (2070 to 5200 kg/ha) (Tables 8a & 8b), which is above the long-term average (Table 11). The excellent spring rainfall plus the above average August rainfall, 4.6 in. (117 mm), gave us excellent yield potential (Table 3a).

Long-term sorghum yields (Tables 11 & 12) are about 45 bu/A for the WSF and WSSF-1 rotation and about 35 bu/A for the second year sorghum in the WSSF-2 rotation. The second year sorghum yield is very similar to the average yield for continuous sorghum. Our sorghum yields the first year after wheat are 15 bu/A (940 kg/ha) higher than the Baca County average sorghum yield [30 Bu/A = 1880 kg/ha (1986-1996)], and our second year yields in the WSSF rotation are 5 bu/A (310 kg/ha) higher than the mean.

A continuous row-crop system (Tables 8a, 8b & 12) has been included at the Walsh site since its beginning. We planted grain sorghum every year from 1986-1992. By 1992 the shatter cane weed problem was so severe that we planted corn in 1993 to allow use of herbicides that could control the shatter cane. Two additional plots were added to the experiment in 1993 so that we could test a rotation effect within the continuous row-crop system. This year the corn, with P applied, yielded 42, 50 and 70 bu/A for the summit, sideslope and toeslope respectively (Table 8a). These yields are 2 to 2.5 times greater than our previous average. For the first time in 1997 we were able to plant later, 19 May, and 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 our corn with an insecticide for corn borer control because we considered treatment was too expensive for a dryland system. Corn in the opportunity system yielded even better, averaging 62 Bu/A (3860 kg/ha) over all soils. The opportunity system had an apparent advantage because it had been fallowed the previous year. However, soil water data at planting, Tables 26b and 27 do not indicate any difference in stored water at planting.

Phosphorus fertilizer effects differed by rotation. In rotations with first year sorghum after wheat P fertilizer appeared to have adverse effects on yields on all soils (Tables 8a & 8b). In contrast the second year sorghum in the WSSF rotation and the sorghum and corn in the continuous row crop system responded positively to P fertilization, even on the toeslopes which have high soil test P levels. The average response to P over all soils in these more intensive systems averaged 6 Bu/A (380 kg/ha). Sometimes response to P fertilization relates to effects on maturity in terms of either timely rainfall events or earlier than expected frost dates. In 1997 neither of these maturity related issues was a factor.

Sunflower

Sunflower was planted following corn in the 4-year system (WCSF) at Sterling and Stratton beginning in 1994. We replaced proso millet with sunflower to help reduce grassy weed problems that were increasing in the four-year system. This year sunflower stands were excellent at Sterling and weed control also was good. However, at Stratton stands were poor and Kochia was uncontrolled by the herbicide program.

Seed yields ranged from 1060 to 1720 lbs/A (1190 to 1930 kg/ha) and from 130 to 310 lbs/A(150 to 340 kg/ha) at Sterling and Stratton, respectively (Tables 13a & 13b). With adequate weed control, yields at Sterling were good, but the high weed pressure, primarily kochia, at Stratton ruined the crop. Herbicides were applied identically at both sites and both were incorporated with a Lilliston rolling cultivator, but the results were widely different. We did accomplish our goal of grassy weed control and were able to essentially eliminate sandbur from the sunflower plots.

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 1997 we grew hay millet in the opportunity system at Sterling and Stratton and corn at Walsh (Tables 8a, 14a, & 14b). Yields were excellent in all cases, and especially the corn at Walsh, which was the highest corn yield ever achieved at that site. From the beginning of our experiment in fall 1985 we have grown 10, 10, and 8 crops in 12 years at Sterling, Stratton and Walsh, respectively in the opportunity system (Tables 15, 16 & 17). Productivity in opportunity cropping has been excellent, especially at Sterling and Stratton. Note that in 12 years at these two sites the system has produced a total of 93 to 130 bushels of wheat, 305 to 334 bushels of corn or sorghum, and 4.7 tons of forage per acre. Crop productivity at Walsh over 12 years has been 93 bushels of wheat, 195 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 common grain and forage prices, the average total gross value of the 12 year production averaged over soils was $1324, $1543, and $881 at Sterling, Stratton and Walsh, respectively (Tables 15, 16 & 17). Average total value was $110, $129, and $73/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 $80/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 $112/A, which is similar to the $110 and $129/A/year produced in the opportunity system at Sterling and Stratton, respectively.

Above average annual precipitation has been a major factor contributing to the excellent productivity; annual precipitation has been 2 to 3 inches above the long-term normals for all sites during the 11 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 in 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. The plan has been to harvest the forage early enough to plant wheat in the fall, which has been successful. We have preliminary data that shows that we might be able to plant wheat directly in the corn stalks in early October and omit the need for a forage crop. 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 in late September or early October.

One of the great advantages of continuous cropping is avoidance of seedbed preparation costs and the short intervals between crops. Secondly, we have observed distinct advantages in residue cover when we avoid fallow periods. Thirdly the 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 example of differences 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. We have resorted to shallow sweep tillage to control these grasses in all of our systems except opportunity. The opportunity system has remained free of these weeds. These 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. Since glyphosate is not very effective on these plants, tillage is the only economically feasible control. 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 greatly reduces erosion, both by wind and water.

Residue amount is being monitored by soil and crop within each system (Tables 18, 19 & 20). 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 historically, has usually had the lowest residue levels over all years.

Residue levels present just prior to wheat planting are the minimum point in all systems 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. Residues present at wheat planting (Table 18) for WF are usually less than for either the 3- or 4-year systems on all soils at all sites, but exceptions did occur as can be noted in Table 20. The WF system produces less biomass compared to the more intensive systems. Residue levels generally are lowest at the Walsh site because less biomass is produced and decomposition is greater because of the longer growing season at that site. However, at wheat planting in the fall of 1996 the Walsh location had residue levels similar to the other sites. This is an example of how year to year variability affects residue levels and why it is unwise to make decisions regarding system residue levels based on a single year of observation.

Opportunity cropping has no planned summer fallow periods, but is cropped as intensively as possible. In general opportunity cropping has more residue than all others. 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 12 years there have been crops produced in 10 of the 12 at Sterling and Stratton and in 8 of the 11 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. An additional benefit of the opportunity system is that continuous cropping with no-till results in soil surfaces that are very resistant to soil erosion by wind or water.

<u>Soil Water</u>

Soil water supplies plant demand between rainfall events. 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 21 to 28).

Wheat:

Soil profile available water was near field capacity at all soil positions in all systems at wheat planting in the fall of 1996 at all sites (Tables 21, 22 & 23). Note that at all sites the amount of available water at planting was essentially equal in all systems despite the fact that the 3- and 4-year systems have fewer months of time to store water than does the 2-year wheat-fallow.

Water use by the wheat crop was similar for all systems at all sites, but there was more water remaining in the soil profile at harvest than normally occurs. At Walsh late rains near harvest replenished the upper soil profile.

Wheat can extract soil water from depths as great as 6 feet (150-180 cm), and note that at

Walsh in 1997 the lower profile was totally exhausted of available water.

Corn and Sorghum:

Soil water contents at corn and sorghum planting were excellent (Tables 24, 25 & 26). Even the second year sorghum in the WSSF rotation at Walsh had a large quantity of of available water at planting, which is not always the case because of the short recharge period from the previous fall (Table 26). Rains in the late summer and fall of 1996 allowed this treatment to have higher than average soil water content at sorghum planting in spring 1997 (Table 3a).

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. The above average rainfall in July and August probably accounts for this (Table 3a). Our long-term average data show water use from depths greater than 5 feet (150 cm) for both corn and sorghum, even though it was not very apparent in 1997.

Sunflower:

Available soil water at sunflower planting in May at Sterling and Stratton in the WCSun-F rotation was excellent as is shown in Table 26. Sunflower effectively used water to the 5 foot depth (155 cm) as evidenced by the water data on on the toeslope at Sterling. Poor plant populations at Stratton accounted for the minimal water use by sunflower at that site.

Opportunity and Continuous Cropping Systems:

Soil water data for opportunity and continuous cropping systems are shown in Tables 27a, 27b, & 28). Note that in all cases in 1997 there was adequate water remaining in the profile at harvest to favor cropping again in 1998. Wheat was planted into the hay millet residue at Sterling and Stratton in fall 1997. At Walsh the opportunity cropping was in corn in 1997 and wheat was planted after corn harvest in fall 1997.

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 site (Tables 29-32). The reader can calculate crude protein content of grain by multiplying wheat grain N content by 5.7; corn or sorghum grain N content by 6.3; and hay millet or triticale forage N by 6.3. All nutrient concentrations are on a dry weight basis, consequently crude protein levels will appear high compared to market levels. Therefore, a grain moisture correction must be applied to obtain market levels.

On a dry matter basis, wheat proteins averaged 12.6% at Sterling, 13.7% at Stratton and 13.0 % at Walsh (Table 29a). 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. These values indicate that N fertilization was adequate for the wheat crop based on research by Goos, et al. (1984). They established that if grain protein levels were above 11.1%, yield was not likely to be limited by N deficiency.

Wheat straw N concentrations ranged from 0.51 to 1.01% and averaged 0.70 % over all sites; thus each ton of straw contained about 14 lbs of N (Table 29b). The highest straw N levels were found at Stratton, which was the site with the lowest grain yields. The insect damage stunted growth and reduced grain yield, which caused more N to remain in the straw at this site.

Nitrogen levels in corn and sorghum grain varied from 1.27 to 1.71 %, which is equivalent to

6.8 to 9.1% protein on a market moisture basis (Table 30a). Corn and sorghum stover N contents varied from 0.51 to 1.08% and averaged 0.78% (Table 30b). Each ton of corn or sorghum stalks thus contained an average of 16 lbs of N. Note that second year grain sorghum in the WSSF rotation at Walsh had lower N contents in the stover as compared to all other systems at that site. This may mean we were very near a N deficiency point for this crop.

Nitrogen levels in sunflower seeds (Table 31a) ranged from 2.72 to 3.57%, while levels in the stover ranged from 0.65 to 2.08% (Table 31b). At Stratton where stands and seed yields were low, the stover had N levels that were nearly double those found at Sterling.

Hay millet forage N content ranged from 1.12 to 1.88% and averaged 1.55%, which is equivalent to 9.8% crude protein on a dry matter basis (Table 32).

Soil Nitrate-Nitrogen

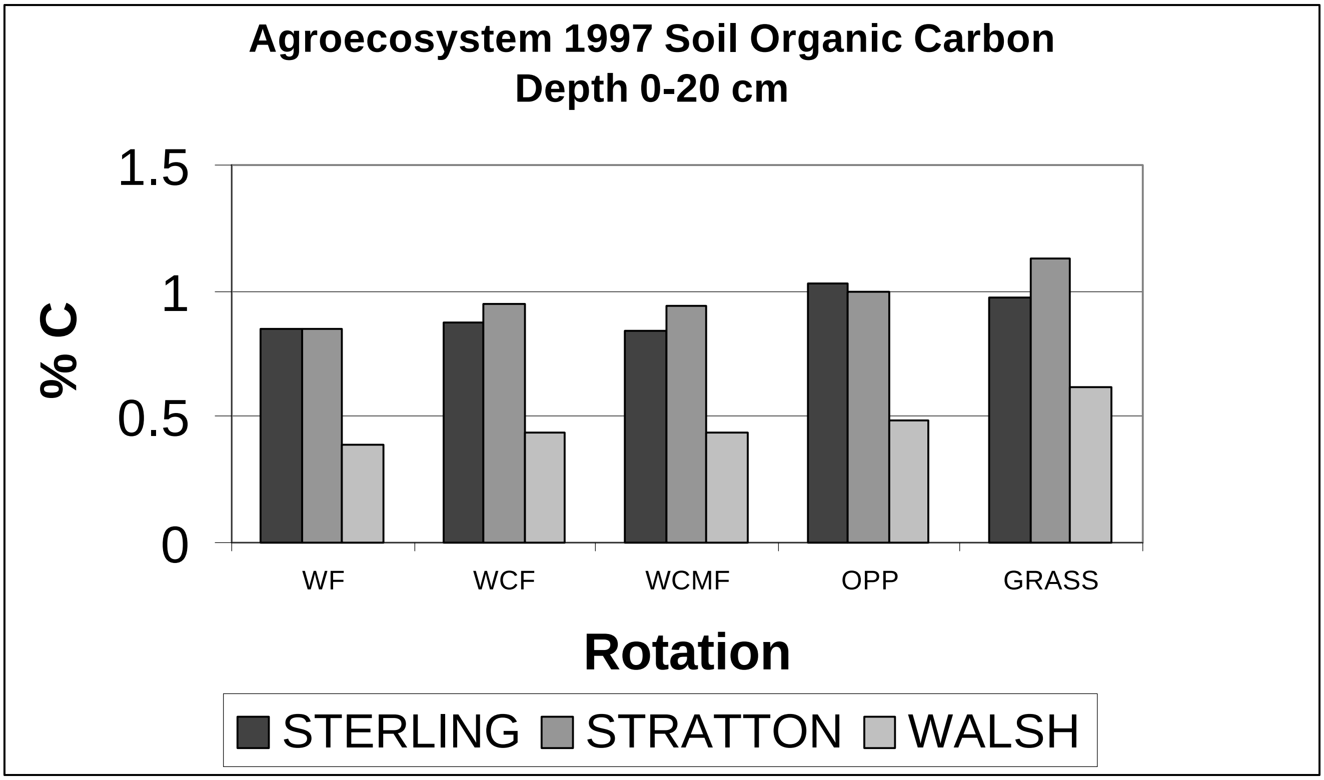
Residual soil NO_3-N analyses are routinely conducted on soil profile samples (0-6 ft or 0-180 cm) taken prior to planting for each crop on each soil at each site (Table 33). These analyses are used to make fertilizer N applications for a particular crop on each soil at each site. Accumulation of residual 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. Generally over the past 5 years, the wheat-fallow system has had higher residual nitrates than the 3- or 4-year rotations at the end of fallow prior to wheat planting. However, in 1997 this pattern was not obvious. Perhaps the use of adequate, but not excessive N rates over the years, has caused the N availability in each system to come to a new equilibrium. The opportunity system at Walsh in 1997 had higher nitrate levels than most other systems at that site. This particular treatment was planted to wheat in 1995 and very low yields were harvested (<18 bu/A). It was then fallowed in 1996; thus nitrates were higher than usual because of little removal and a fallow that allowed mineralized N to accumulate.

Soil Organic Carbon

Soils were sampled for organic carbon (C) analysis in August 1997 in the fallow phase of the WF, WC(S)F, and WCS(S)F rotations plus the Opportunity and Continuous Grass treatments. By summer 1997 all systems had been in place for 12 years. Samples were taken to a depth of 20 cm in increments of 0-2.5, 2.5-5, 5-10, and 10-20 cm and organic C was determined by Walkley-Black titration.

Organic C increased as cropping intensity increased (Table 34). All rotations at all depths at all sites had higher C levels than did WF with the exception of the 10-20 cm depth in WCF at Sterling. Opportunity and Continuous grass had the highest organic C contents across all sites and soil depths. Figure 5 depicts the soil C concentrations for the complete 20 cm depth. Increases in soil organic C are an indication that the systems are improving overall soil conditions. Aggregate structure in surface soils should be strengthened by increases in C and thus become more open to water infiltration.

Figure 6. Soil organic carbon in 1997 by site and cropping system (0-20 cm depth).



SUMMARY & CONCLUSIONS

The 1997 cropping season provided the usual variability in yields. Wheat, corn, and sunflower at Stratton yielded less than expected because of insect damage to the wheat, hail damage to the corn, and poor stands of sunflower with large kochia infestations. Sterling had average wheat yields and the highest corn and sunflower yields observed in our 12 years of work. Walsh had outstanding wheat yields, normal sorghum yields, and the highest corn yields we have ever observed at that site. Summer rainfall was excellent at all sites and was the reason for the excellent warm season crop yields, but the hail and poor stands at Stratton did not allow the potential yields to be realized. Long-term averages of summer crops, corn and sorghum, are 65, 72 and 45 bu/A for Sterling, Stratton and Walsh, respectively. These means include years of near crop failure due to drought, hail, and early frost. Our data show that cropping intensification is certainly possible in the central Great Plains.

More intensive rotations like wheat-corn(sorghum)-fallow and wheat-corn(sorghum)-millet-fallow have more than doubled grain water use efficiency in all three study environments when compared over years. Water conserved in the no-till systems has been converted into increased grain production. In northeastern Colorado intensive rotations have increased dollar returns to land, labor, capital, management and risk by 25-40% compared to wheat-fallow practiced either with no-till or with conventional tillage (Peterson, et al., 1993a). Because, historically, millet prices are relatively low, the wheat-corn-fallow has been more profitable than wheat-corn-millet-fallow. In southeastern Colorado, even though the increased water use efficiency is achieved, the net returns favor wheat-fallow over the intensive rotations. The cost of sorghum production in our systems has been too high compared to the added yield received. Lower cost weed control systems are being tested at Walsh in an attempt to improve the profit potential of the intensive systems in that environment.

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Table 2. Nitrogen fertilizer application by soil and crop for 1997.

SITE	SOIL	CROP	WF	WCF	WCMF	OPP	
				ROTATION			
			----------------------------Lbs/A----------------------------				
Sterling	Summit	Wheat	46	46	46		
	Sideslope	"	46	46	46		
	Toeslope	"	46	46	46		
	Summit	Corn	-	100	100		
	Sideslope	"	-	100	100		
	Toeslope	"	-	100	100		
	Summit	Sunflower	-	-	31		
	Sideslope	"	-	-	31		
	Toeslope	"	-	-	31		
	Summit	Hay Millet				75	
	Sideslope	"				75	
	Toeslope	"				75	
			WF	WCF	WCMF	OPP	
Stratton	Summit	Wheat	46	46	46		
	Sideslope	"	46	46	46		
	Toeslope	"	46	46	46		
	Summit	Corn	-	100	100		
	Sideslope	"	-	100	100		
	Toeslope	"	-	100	100		
	Summit	Sunflower	-	-	31		
	Sideslope	"	-	-	31		
	Toeslope	"	-	-	0		
	Summit	Hay Millet				75	
	Sideslope	"				75	
	Toeslope	"				75	
			WF	WSF	WSSF	OPP	CONT. CROP
Walsh	Summit	Wheat	50	50	50		
	Sideslope	"	50	50	50		
	Toeslope	"	50	50	50		
	Summit	Sorghum1	-	35	35		
	Sideslope	"	-	35	35		
	Toeslope	"	-	35	35		
	Summit	Sorghum2	-	-	60		
	Sideslope	"	-	-	60		
	Toeslope	"	-	-	60		
	Summit	Corn	-	-	-	35	35
	Sideslope	“	-	-	-	35	35
	Toeslope	“	-	-	-	35	35

Table 3a. Monthly precipitation for each site for the 1996-97 growing season.

MONTH	LOCATION					
	STERLING		STRATTON		WALSH	
	Inches					
1996	1996	Normals	1996	Normals	1996	Normals
JULY	2.43	2.40	6.06	2.60	4.39	3.10
AUGUST	2.89	2.00	2.32	2.30	4.82	2.30
SEPTEMBER	3.55	1.20	0.68	1.60	4.24	1.30
OCTOBER	0.39	1.00	0.07	1.00	0.29	1.10
NOVEMBER	0.00	0.70	0.28	0.70	0.28	0.60
DECEMBER	0.03	0.60	0.09	0.40	0.00	0.30
SUBTOTAL	9.29	7.90	9.50	8.60	14.02	8.70
1997	1997	Normals	1997	Normals	1997	Normals
JANUARY	0.24	0.50	0.46	0.40	0.27	0.40
FEBRUARY	0.36	0.50	1.27	0.40	0.68	0.30
MARCH	0.11	1.30	0.05	1.00	0.08	0.70
APRIL	0.55	2.00	0.98	1.60	2.20	1.30
MAY	2.51	3.00	2.29	2.70	0.73	2.50
JUNE	3.93	2.80	2.94	2.40	2.37	2.70
SUBTOTAL	7.70	10.10	7.99	8.50	6.33	7.90
1997	1997	Normals	1997	Normals	1997	Normals
JULY	7.86	2.40	9.11	2.60	0.53	3.10
AUGUST	3.05	2.00	4.24	2.30	4.63	2.30
SEPTEMBER	1.69	1.20	0.45	1.60	0.60	1.30
OCTOBER	2.31	1.00	4.21	1.00	2.47	1.10
NOVEMBER	0.18	0.70	0.96	0.70	0.00	0.60
DECEMBER	0.41	0.60	1.16	0.40	1.94	0.30
SUBTOTAL	15.50	7.90	20.13	8.60	10.17	8.70
YEAR TOTAL	23.20	18.00	28.12	17.10	16.50	16.60
18 MONTH TOTAL	32.49	25.90	37.62	25.70	30.52	25.30

Table 3b. Precipitation summary by growing season segments for Sterling from 1987-1997.

Year	Wheat: Vegetat. Sep - Mar	Wheat: Reprod. Apr - Jun	Corn: Preplant Jul - Apr	Corn: Growing Season May - Oct
	Growing Season Segments			
	----------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
Long Term Average	5.8	7.8	12.2	12.4

Table 3c. Precipitation summary by growing season segment for Stratton from 1986-1997.

Year	Wheat: Vegetat. Sep - Mar	Wheat: Reprod. Apr - Jun	Corn: Preplant Jul - Apr	Corn: Growing Season May - Oct
	Growing Season Segments			
	----------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
Long Term Average	5.5	6.7	12.0	12.6

Table 3d. Precipitation summary by growing season segments for Walsh from 1986-1997.

	Growing Season Segments			
	Wheat		Sorghum	
	Vegetat.	Reprod.	Preplant	Growing Season
	Sep - Mar	Apr - Jun	Jul - Apr	May - Oct
Year	Inches			
1987-88	4.3	7.6	7.4	11.1
1988-89	4.1	11.5	8.1	20.2
1989-90	5.7	7.4	14.1	12.5
1990-91	5.0	7.7	11.7	12.2
1991-92	2.7	5.8	7.1	13.2
1992-93	6.1	9.2	13.8	14.5
1993-94	3.2	5.3	8.7	16.3
1994-95	4.6	7.2	16.6	7.2
1995-96	1.7	3.5	1.9	17.1
1996-97	5.8	5.3	17.2	11.3
Long Term Average	4.7	6.5	11.4	13.0

Table 4a. Grain and stover yields for WHEAT in English units in 1997.

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. ------	
WF	18	20	1634	1757	24	23	1950	1680	18	20	1795	2084
WCF	24	26	2097	2109	25	28	2053	2499	32	34	2852	2972
WCSF	26	25	2212	2196	25	31	2419	1566	39	35	3463	3153
	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. ------	
WF	16	19	2155	2162	9	15	1310	1802	14	20	3038	3319
WCF	25	23	3196	1790	19	20	2158	2835	32	36	5068	5428
WCSF	25	27	2537	2684	16	19	1699	2359	28	29	4867	4763
	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. ------	
WF	33	34	3076	3036	46	43	4405	4010	45	49	4249	4527
WSF	48	42	4033	4163	48	36	4310	4328	45	43	4257	4141
WSSF	36	39	3414	3665	32	34	3124	3224	44	43	4498	4198

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

Table 4b. Grain, stover and total biomass yields for WHEAT in 1997.

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					
WF	1183	1322	1830	1967	2871	3130	1614	1513	2183	1881	3603	3212	1234	1336	2010	2333	3096	3509
WCF	1626	1765	2349	2362	3780	3915	1668	1885	2299	2799	3767	4458	2158	2311	3194	3328	5093	5362
WCSF	1773	1664	2477	2459	4037	4623	1704	2066	2709	1753	4209	3571	2596	2359	3878	3531	6162	5607
	NP*	NP	NP*	NP	NP*	NP	NP*	NP	NP*	NP	NP*	NP	NP*	NP	NP*	NP	NP*	NP
STRATTON:	Kg/ha						Kg/ha						Kg/ha					
WF	1058	1272	2413	2421	3344	3540	635	1035	1467	2018	2026	2929	913	1355	3402	3716	4205	4908
WCF	1684	1536	3579	2005	5061	3357	1271	1376	2416	3174	3534	4385	2145	2445	5675	6078	7563	8230
WCSF	1692	1843	2841	3006	4330	4628	1081	1252	1903	2642	2854	3744	1856	1929	5451	5334	7084	7032
	NP*	NP	NP*	NP	NP*	NP	NP*	NP	NP*	NP	NP*	NP	NP*	NP	NP*	NP	NP*	NP
WALSH:	Kg/ha						Kg/ha						Kg/ha					
WF	2245	2316	3444	3400			3080	2911	4933	4490	7643	7052	3009	3317	4759	5069	7407	7988
WSF	3209	2791	4516	4661			3250	2441	4827	4847	7687	6995	3046	2917	4767	4638	7447	7205
WSSF	2451	2615	3823	4105			2144	2318	3498	3610	5385	5650	2968	2875	5036	4701	7648	7231

Table 5. Wheat yields at optimum fertility by year soil position at STERLING from 1986-1997.

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
MEAN	30	30	38	33

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

Table 6. Wheat yields at optimum fertility by year and soil position at Stratton from 1986-1997.

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
MEAN	38	34	51	40

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

Table 7. Wheat yields at optimum fertility by year and soil position at Walsh from 1986-1997.

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
MEAN	26	29	36	30

Table 8a. Grain and stover yields for CORN AND SORGHUM in English units in 1997.

SITE & ROTATION	SUMMIT GRAIN N	SUMMIT GRAIN NP	SUMMIT STOVER N	SUMMIT STOVER NP	SIDESLOPE GRAIN N	SIDESLOPE GRAIN NP	SIDESLOPE STOVER N	SIDESLOPE STOVER NP	TOESLOPE GRAIN N	TOESLOPE GRAIN NP	TOESLOPE STOVER N	TOESLOPE STOVER NP
STERLING:	------ Bu./A. ------		------ lbs./A. ------		------ Bu./A. ------		------ lbs./A. ------		------ Bu./A. ------		------ lbs./A. ------	
WCF	80	87	3627	3618	93	115	3432	3869	120	125	4412	4012
WCSF	83	96	2749	3676	81	101	2717	2596	119	117	4015	4269
	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	47	43	1964	1456	49	50	2283	1588	69	65	3287	2785
WCSF	28	37	986	1416	37	30	1357	1243	70	64	5133	3180
	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	40	33	1122	950	44	37	1134	940	73	54	2073	1770
WSSF-1	43	37	1200	942	54	46	1478	1065	78	56	2150	1525
WSSF-2	41	47	584	1423	43	49	1147	1470	52	50	1415	1301
OPP(Corn)	40	54	2848	3893	41	63	2872	4622	52	83	3665	6060
CS (Sorghum)	39	43	1087	1315	46	52	1278	1245	74	78	1903	1960
CS (Corn)	25	42	1808	2728	36	50	2456	3795	67	70	4594	4793

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

Table 8b. Grain, stover and total biomass yields for CORN and SORGHUM in 1997.

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	4995	5453	3792	3782	8013	8390	5859	7201	3587	4045	8538	10130	7536	7860	4612	4193	10980	10835
WCSF	5191	6034	2873	3842	7259	8941	5094	6318	2840	2714	7144	8306	7480	7353	4197	4462	10518	10675
	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	2924	2728	2053	1522	4524	3827	3059	3165	2387	1660	4972	4334	4311	4076	3436	2911	7079	6355
WCSF	1728	2299	1031	1480	2491	3423	2308	1883	1418	1299	3368	2890	4382	4028	5366	3324	9069	6728
	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	2538	2091	3232	2675	5415	4473	2768	2322	3435	2858	5815	4855	4558	3367	5846	4552	9766	7448
WSSF-1	2698	2311	3451	2850	5771	4837	3357	2892	4268	3455	7155	5942	4909	3495	6179	4405	10401	3006
WSSF-2	2597	2965	2705	3879	4938	6429	2711	3084	3394	4075	5725	6727	3280	3124	4136	3934	6957	6621
OPP (Corn)	2519	3390	2977	4069	5143	6984	2553	3973	3002	4832	5198	8249	3240	5205	3831	6334	6617	10810
CS (Sorghum)	2432	2709	3115	3574	5207	5904	2863	3259	3664	3936	6126	6739	4612	4880	5713	5997	9679	10194
CS (Corn)	1542	2606	1890	2852	3216	5093	2272	3148	2567	3967	4521	6674	4176	4417	4802	5010	8393	8809

Table 9. **Corn yields at optimum fertility by year and soil position at STERLING from 1986-1997.**

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
MEAN	52	61	82	65

Table 10. Corn and sorghum yields at optimum fertility by year and soil position at STRATTON from 1986-1997.

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
MEAN	64	61	91	72

Table 11. Rotation sorghum yields at optimum fertility by year and soil position at Walsh from 1986-1997.

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
MEAN	36	42	59	45

*Average of WSF and WSSF-1.

Table 12. Continuous row crop yields at optimum fertility by year and soil position at Walsh from 1986-1997.

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
MEAN	33	30	41	35

Table 13a. Grain and stover yields for SUNFLOWER in English units in 1997.

SITE & ROTATION	SUMMIT GRAIN N	SUMMIT GRAIN NP	SUMMIT STOVER N	SUMMIT STOVER NP	SIDESLOPE GRAIN N	SIDESLOPE GRAIN NP	SIDESLOPE STOVER N	SIDESLOPE STOVER NP	TOESLOPE GRAIN N	TOESLOPE GRAIN NP	TOESLOPE STOVER N	TOESLOPE STOVER NP
STERLING:	lbs/A				lbs/A				lbs/A			
WCSF	1063	1317	1870	2317	1546	1410	2856	2605	1432	1724	2142	2578
	N	NP	N	NP	N	NP	N	NP	N	NP	N	NP
STRATTON:	lbs/A				lbs/A				lbs/A			
WCSF	131	177	299	406	237	271	564	643	263	307	786	917

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

Table 13b. Grain, stover and total biomass yields for SUNFLOWER in 1997.

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-----------------------					
WCSF	1190	1475	2095	2595	3142	3893	1731	1579	3199	2918	4722	4308	1603	1930	2399	2888	3810	4586
	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-----------------------					
WCSF	146	199	335	454	463	629	266	303	632	721	866	988	294	343	880	1027	1139	1329

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

Table 14a. Hay Millet yields in Opportunity cropping in English units in 1997.

SITE & ROTATION	SLOPE POSITION					
	SUMMIT		SIDESLOPE		TOESLOPE	
	HAY		*HAY*		*HAY*	
	N	NP	N	NP	N	NP
	----------------lbs/A---------------		----------------lbs/A---------------		----------------lbs/A---------------	
STERLING:						
Opportunity	4650	4249	4091	3772	4630	3272
	N	NP	N	NP	N	NP
STRATTON:						
Opportunity	4567	4899	4283	5066	2961	3232

1. Yields expressed on a dry matter basis.

Table 14b. Hay Millet yields in Opportunity cropping in 1997.

SITE & ROTATION	SLOPE POSITION					
	SUMMIT		SIDESLOPE		TOESLOPE	
	HAY		*HAY*		*HAY*	
	N	NP	N	NP	N	NP
	----------------kg/ha---------------		----------------kg/ha---------------		----------------kg/ha--------------	
STERLING:						
Opportunity	5209	4759	4582	4224	5185	3664
	N	NP	N	NP	N	NP
STRATTON:						
Opportunity	5115	5487	4797	5673	3316	3620

1. Yields expressed on a dry matter basis.

Table 15. 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
Total	Wheat (3)	81	96	102	93
Yields	Corn (5)	253	297	366	305
	Forage (3)	4.57	4.42	5.15	4.71
	Sunflower (1)	0	0	0	0
		-----------------------------$----------------------------			
Value*	Wheat (3)	324.00	384.00	408.00	372.00
	Corn (5)	632.50	742.50	915.00	763.33
	Forage (3)	182.80	176.80	206.00	188.53
	Sunflower (1)	0.00	0.00	0.00	0.00
Total Value for 12 Years		1139.30	1303.30	1529.00	1323.87

*Wheat @ $4.00/Bu; Corn @ $2.50/bu; Sorghum @ $2.50/Bu;
Hay Millet & Forage @ $40.00/T

Table 16. 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
Total	Wheat (3)	132	108	151	130
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 (3)	528.00	432.00	604.00	521.33
	Corn (5)	767.50	772.50	962.50	834.17
	Forage (3)	204.80	194.40	164.00	187.73
	Sunflower (1)	0.00	0.00	0.00	0.00
Total Value for 12 Years		1500.30	1398.90	1730.50	1543.23

*Wheat @ $4.00/Bu; Corn @ $2.50/bu; Sorghum @ $2.50/Bu;
Hay Millet & Forage @ $40.00/T

Table 17. 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
Total	Wheat (3)	85	87	108	93
Yields	Sorghum & Corn (4)	151	172	263	195
	Forage (1)	0.39	0.32	0.71	0.47
	Sunflower (1)	0	0	0	0
	Millet (1)	0	0	0	0
		-----------------------------	--$--	-----------------------------	
Value*	Wheat (3)	340.00	348.00	432.00	373.33
	Sorghum & Corn (4)	377.50	430.00	657.50	488.33
	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 12 Years		733.10	790.80	1117.90	880.60

*Wheat @ $4.00/Bu; Corn @ $2.50/bu; Sorghum @ $2.50/Bu;
Hay Millet & Forage @ $40.00/T

Table 18. Crop residue weights on all plots in WHEAT during the 1996-1997 crop year.

	SLOPE POSITION					
	SUMMIT		SIDESLOPE		TOESLOPE	
SITE & ROTATION	*Pre-Plant*		*Pre-Plant*		*Pre-Plant*	
	NP*	NP	NP*	NP	NP*	NP
STERLING:	----------Kg/ha-----------		----------Kg/ha----------		----------Kg/ha-----------	
WF	2916	2364	4489	2613	9538	5911
WCF	5369	2498	2587	3324	6800	4951
WCSF	4222	2720	4347	3564	7547	4738

	NP*	NP	NP*	NP	NP*	NP
STRATTON:	----------Kg/ha-----------		----------Kg/ha--------		----------Kg/ha--------	
WF	4604	3724	4667	2711	5671	3351
WCF	4231	3938	5742	4560	5760	5778
WCSF	4213	5956	3902	4044	7076	6667
	NP*	NP	NP*	NP	NP*	NP
WALSH:	----------Kg/ha--------		----------Kg/ha--------		----------Kg/ha--------	
WF	5298	2489	4889	3573	3884	5022
WSF	3298	3707	4373	5316	6596	5307
WSSF	3324	3076	4089	4107	5867	4018

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

Table 19. Crop residue weights on all plots in Corn or Sorghum during the 1997 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	4662	4151	4889	5702	6471	9004
WCSF	5124	5289	5244	4835	6964	8142
	NP*	NP	NP*	NP	NP*	NP

	Summit NP*	Summit NP	Sideslope NP*	Sideslope NP	Toeslope NP*	Toeslope NP
STRATTON:	------kg ha-1--------		-------kg ha-1--------		-------kg ha-1--------	
WCF	4640	5089	4267	5889	7276	10280
WCSF	2533	4004	5027	4631	11364	6044
	NP*	NP	NP*	NP	NP*	NP
WALSH:	-------kg ha-1--------		-------kg ha-1--------		-------kg ha-1--------	
WCF	178	213	702	1289	2138	2049
WSSF	436	916	489	578	880	498
WSSF	3320	3431	4542	4898	5280	4093
OPP (CORN)	1560	1858	1960	2542	1636	2480
CS (SORGHUM)	5916	5538	6556	9573	7680	7769

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

Table 20. Crop residue weights on all plots in SUNFLOWER in the 1997 crop year.

SITE & ROTATION	**SLOPE POSITION**					
	SUMMIT		**SIDESLOPE**		**TOESLOPE**	
	Pre-Plant		***Pre-Plant***		***Pre-Plant***	
	NP*	NP	NP*	NP	NP*	NP
STERLING:	-------kg ha-1--------		-------kg ha-1--------		-------kg ha-1--------	
WCSF	9173	8587	10907	7938	7058	9698
	NP*	NP	NP*	NP	NP*	NP
STRATTON:	------kg ha-1--------		-------kg ha-1--------		-------kg ha-1--------	
WCSF	8422	8418	9280	8573	7560	9467

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

* Only receives phosphorus in wheat phase of each rotation.

Table 21 . Available soil water by soil depth in the WHEAT phase of the WF rotation at Sterling, Stratton, and Walsh in 1997.

SITE & DEPTH (cm)	SUMMIT Planting	SUMMIT Harvest	SUMMIT Change	SIDESLOPE Planting	SIDESLOPE Harvest	SIDESLOPE Change	TOESLOPE Planting	TOESLOPE Harvest	TOESLOPE Change
	------------mm/30cm------------			------------mm/30cm------------			------------mm/30cm------------		
STERLING:									
15	49	36	13	46	23	23	41	27	14
45	61	22	39	47	12	35	44	15	29
75	44	24	20	67	40	27	59	35	24
105	31	23	8	48	34	14	52	25	27
135	-	0	-	-	-	-	27	14	13
155	-	-	-	-	-	-	30	16	14
TOTAL	185	105	80	208	109	99	253	132	121
STRATTON:									
15	37	23	14	49	43	6	60	78	-18
45	42	16	26	40	15	25	55	70	-15
75	34	12	22	45	15	30	70	79	-9
105	34	14	20	34	10	24	82	58	24
135	40	20	20	45	27	18	58	38	20
155		18	-18		37	-37		37	-37
TOTAL	187	103	84	213	147	66	325	360	-35
WALSH:									
15	18	49	-31	18	26	-8	18	15	3
45	26	34	-8	33	13	20	32	0	32
75	25	16	9	38	7	31	36	0	36
105	37	0	37	41	1	40	44	21	23
135	57	0	57	31	0	31	35	22	13
155	50	0	50	44	0	44	58	8	50
TOTAL	213	99	114	205	47	158	223	66	157

1. To convert from millimeters of H20/30 centimeters of soil to inches of H20/foot of soil multiply by 0.04.

Table 22 . Available soil water by soil depth in the WHEAT phase of the WCF rotation at Sterling and Stratton and Walsh in 1997.

SITE	SLOPE POSITION

& DEPTH (cm)	SUMMIT			SIDESLOPE			TOESLOPE		
	Planting	Harvest	Change	Planting	Harvest	Change	Planting	Harvest	Change
	-------------mm/30cm-------------			-------------mm/30cm-------------			------------mm/30cm-------------		
STERLING:									
15	46	23	23	40	23	17	43	22	21
45	55	8	47	54	13	41	37	13	24
75	47	9	38	47	22	25	52	23	29
105	28	19	9	43	11	32	57	24	33
135							44	17	27
155							38	15	23
TOTAL	176	59	117	184	69	115	271	114	157
STRATTON:									
15	31	12	19	47	23	24	48	76	-28
45	42	11	31	41	5	36	62	73	-11
75	35	5	30	42	6	36	82	84	-2
105	31	9	22	32	0	32	82	83	-1
135	31	12	19	30	6	24	50	38	12
155		13	-13		13	-13		38	-38
TOTAL	170	62	108	192	53	139	324	392	-68
WALSH:									
15	19	50	-31	16	26	-10	15	29	-14
45	33	33	0	38	14	24	35	5	30
75	33	10	23	45	7	38	42	0	42
105	50	0	50	44	10	34	56	16	40
135	52	0	52	23	0	23	50	13	37
155	49	0	49	37	0	37	68	0	68
TOTAL	236	93	143	203	57	146	266	63	203

1. To convert from millimeters of H20/30 centimeters of soil to inches of H20/foot of soil multiply by 0.04.

Table 23. Available soil water by soil depth in the WHEAT phase of the WCSF rotation at Sterling and Stratton and the WHEAT phase of the WSSF rotation at Walsh in 1997. he t

SITE & DEPTH (cm)	SLOPE POSITION								
	SUMMIT			SIDESLOPE			TOESLOPE		
	Planting	Harvest	Change	Planting	Harvest	Change	Planting	Harvest	Change
	-------------mm/30cm-------------			-------------mm/30cm-------------			------------mm/30cm-------------		

STERLING:									
15	44	18	26	41	31	10	43	24	19
45	57	8	49	52	7	45	44	13	31
75	33	7	26	109	25	84	59	25	34
105	27	12	15	50	30	20	57	19	38
135							32	13	19
155							31	11	20
TOTAL	161	45	116	352	93	159	266	105	161
STRATTON:									
15	43	3	40	47	26	21	42	75	-33
45	45	6	39	38	5	33	33	72	-39
75	35	5	30	47	14	33	44	63	-19
105	37	10	27	43	11	32	48	35	13
135	38	15	23	37	4	33	40	27	13
155		17	-17		13	-13		34	-34
TOTAL	198	56	142	212	73	139	207	306	-99
WALSH:									
15	1	30	-29	0	13	-13	0	15	-15
45	21	16	5	24	1	23	27	0	27
75	21	0	21	26	6	20	38	0	38
105	27	0	27	32	1	31	43	19	24
135	44	0	44	1	0	1	43	10	33
155	52	0	52	26	0	26	65	0	65
TOTAL	166	46	120	109	21	88	216	44	172

1. To convert from millimeters of H20/30 centimeters of soil to inches of H20/foot of soil multiply by 0.04.

Table 24 . 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 1997.

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	24	12	27	31	-4	38	51	-13
45	45	9	36	49	22	27	42	34	8
75	25	26	-1	46	11	35	49	38	11
105	25	23	2	12	3	9	55	37	18
135							26	20	6
155								22	-22
TOTAL	131	82	49	134	67	67	210	202	8
STRATTON:									
15	15	20	-5	32	26	6	35	47	-12
45	37	24	13	34	10	24	47	36	11
75	23	17	6	29	20	9	35	57	-22
105	21	24	-3	19	18	1	23	53	-30
135	20	25	-5	22	21	1	12	35	-23
155	16	25	-9	27	19	8	6	31	-25
TOTAL	132	135	-3	163	114	49	158	259	-101
WALSH:									
15	5	11	-6	0	3	-3	0	8	-8
45	27	28	-1	25	21	4	27	36	-9
75	25	21	4	35	18	17	38	39	-1
105	27	12	15	42	23	19	44	44	0
135	40	27	13	22	13	9	44	42	2
155	32	26	6	56	32	9	50	58	-8
TOTAL	156	124	32	180	110	70	203	226	-23

1. To convert from millimeters of H20/30 centimeters of soil to inches of H20/foot of soil multiply by 0.04.

Table 25 . Available soil water by soil depth in the CORN phase of the WCSF rotation at Sterling and Stratton and the SORGHUM phase of the W(S)SF rotation at Walsh in 1997.

SITE	SLOPE POSITION

& DEPTH (cm)	SUMMIT			SIDESLOPE			TOESLOPE		
	Planting	Harvest	Change	Planting	Harvest	Change	Planting	Harvest	Change
	------------mm/30cm------------			------------mm/30cm------------			------------mm/30cm------------		
STERLING:									
15	27	24	3	21	34	-13	29	47	-18
45	43	9	34	40	21	19	40	38	2
75	39	34	5	46	29	17	46	43	3
105	42	35	7	39	28	11	35	25	10
135							14	8	6
155							0	11	-11
TOTAL	151	102	49	146	112	34	164	172	-8
STRATTON:									
15	14	7	7	32	30	2	39	59	-20
45	26	12	14	35	14	21	49	41	8
75	18	12	6	31	23	8	52	69	-17
105	18	10	8	26	22	4	18	56	-38
135	19	14	5	25	21	4	6	37	-31
155	22	23	-1	61	27	34	30	47	-17
TOTAL	117	78	39	210	137	73	194	309	-115
WALSH:									
15	5	12	-7	0	6	-6	0	12	-12
45	27	32	-5	27	30	-3	29	37	-8
75	25	28	-3	26	26	0	34	37	-3
105	29	27	2	34	27	7	42	41	1
135	43	39	4	7	4	3	37	31	6
155	38	36	2	28	13	15	55	51	4
TOTAL	167	175	-8	122	106	16	197	209	-12

1. To convert from millimeters of H20/30 centimeters of soil to inches of H20/foot of soil multiply by 0.04.

Table 26 . Available soil water by soil depth in the SUNFLOWER phase of the WCSF rotation at Sterling and Stratton and the SORGHUM phase of the WS(S)F rotation at Walsh in 1997.

SITE & DEPTH (cm)	SLOPE POSITION								
	SUMMIT			SIDESLOPE			TOESLOPE		
	Planting	Harvest	Change	Planting	Harvest	Change	Planting	Harvest	Change

SITE & DEPTH (cm)	Summit Planting	Summit Harvest	Summit Change	Sideslope Planting	Sideslope Harvest	Sideslope Change	Toeslope Planting	Toeslope Harvest	Toeslope Change
	mm/30cm			mm/30cm			mm/30cm		
STERLING:									
15	60	29	31	32	25	7	53	36	17
45	59	9	50	45	27	18	48	26	22
75	34	11	23	51	17	34	46	23	23
105	28	15	13	45	17	28	52	28	24
135							31	14	17
155							22	17	5
TOTAL	181	64	117	173	86	87	252	144	108
STRATTON:									
15	23	29	-6	35	30	5	42	46	-4
45	35	29	6	29	25	4	32	48	-16
75	11	20	-9	26	23	3	24	54	-30
105	18	28	-10	20	17	3	24	52	-28
135	21	31	-10	27	27	0	25	39	-14
155	21	31	-10	24	25	-1	22	42	-20
TOTAL	129	168	-39	161	147	14	169	281	-112
WALSH:									
15	17	27	-10	15	28	-13	0	18	-18
45	24	28	-4	31	32	-1	15	34	-19
75	26	26	0	34	35	-1	32	30	2
105	33	29	4	44	35	9	41	40	1
135	39	28	11	30	19	11	47	39	8
155	0	27	-27	21	33	-12	56	57	-1
TOTAL	139	166	-27	175	182	-7	191	218	-27

1. To convert from millimeters of H20/30 centimeters of soil to inches of H20/foot of soil multiply by 0.04.

Table 27a. Available soil water by soil depth in the SORGHUM phase of the Continuous Cropping rotation at Walsh in 1997.

SITE & DEPTH (cm)	SLOPE POSITION								
	SUMMIT			SIDESLOPE			TOESLOPE		
	Planting	Harvest	Change	Planting	Harvest	Change	Planting	Harvest	Change
	mm/30cm			mm/30cm			mm/30cm		
WALSH:									
15	10	19	-9	1	15	-14	0	7	-7
45	27	30	-3	36	38	-2	28	34	-6

75	26	26	0	35	34	1	33	27	6
105	52	50	2	33	21	12	50	31	19
135	47	39	8	12	0	12	41	32	9
155	0	27	-27	40	12	28	0	0	
TOTAL	162	190	-28	157	120	37	152	131	21

1. To convert from millimeters of H20/30 centimeters of soil to inches of H20/foot of soil multiply by 0.04.

Table 27b. Available soil water by soil depth in the CORN phase of the Continuous Cropping rotation at Walsh in 1997.

SITE & DEPTH (cm)	SLOPE POSITION								
	SUMMIT			SIDESLOPE			TOESLOPE		
	Planting	Harvest	Change	Planting	Harvest	Change	Planting	Harvest	Change
	-------------mm/30cm-------------			-------------mm/30cm-------------			------------mm/30cm-------------		
WALSH:									
15	18	17	1	3	8	-5	10	11	-1
45	31	29	2	27	21	6	26	20	6
75	36	34	2	31	17	14	40	25	15
105	50	45	5	30	6	24	48	34	14
135	48	38	10	14	0	14	38	32	6
155	36	22	14	27	0	27	66	0	66
TOTAL	219	185	34	132	52	80	228	122	106

1. To convert from millimeters of H20/30 centimeters of soil to inches of H20/foot of soil multiply by 0.04.

Table 28 . Available soil water by soil depth in the HAY MILLET phase of the Opportunity rotation at Sterling and Stratton and the SORGHUM phase of the Opportunity rotation at Walsh in 1997.

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	34	28	44	33	11	60	34	17
45	56	13	43	52	34	18	48	26	22
75	28	27	1	58	37	21	40	47	23
105	31	40	-9	58	48	10	42	35	24
135							26	17	17
155							22	23	5
TOTAL	177	114	63	212	152	60	238	180	108
STRATTON:									
15	27	36	-9	49	37	12	59	56	-4
45	32	37	-5	33	21	12	43	51	-16
75	14	26	-12	16	29	-13	48	76	-30
105	19	30	-11	37	47	-10	27	61	-28
135	15	21	-6	24	34	-10	28	44	-14
155	17	28	-11	26	37	-11	32	43	-20
TOTAL	124	178	-54	185	205	-20	237	331	-112
WALSH:									
15	8	10	-2	0	3	-3	0	-1	1
45	26	26	0	32	30	2	26	27	-1
75	33	30	3	37	22	15	31	29	2
105	42	34	8	30	15	15	47	43	4
135	50	37	13	17	0	17	29	29	8
155	37	37	0	35	16	19	43	40	0
TOTAL	196	174	22	151	86	65	176	167	9

Table 29a. Total Nitrogen and Phosphorus content of WHEAT GRAIN in the 1996-1997 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:	-------------- % -------------				-------------- % -------------				-------------- % -------------			
WF	2.36	0.48	2.30	0.49	2.21	0.43	2.39	0.44	2.19	0.47	2.17	0.44
WCF	2.32	0.41	2.28	0.46	2.31	0.42	2.18	0.43	2.09	0.46	2.09	0.48
WCSF	2.21	0.44	2.22	0.46	2.29	0.44	2.13	0.46	2.11	0.46	2.07	0.47
	N	**P**	**N**	**P**	**N**	**P**	**N**	**P**	**N**	**P**	**N**	**P**
STRATTON:	-------------- % -------------				-------------- % -------------				-------------- % -------------			
WF	2.33	0.45	2.20	0.45	2.56	0.44	2.41	0.47	2.40	0.48	2.37	0.50
WCF	2.34	0.44	2.38	0.44	2.48	0.42	2.43	0.42	2.36	0.50	2.30	0.43
WCSF	2.36	0.46	2.33	0.48	2.65	0.44	2.59	0.46	2.40	0.48	2.38	0.46
	N	**P**	**N**	**P**	**N**	**P**	**N**	**P**	**N**	**P**	**N**	**P**
WALSH:	-------------- % -------------				-------------- % -----------				-------------- % -------------			
WF	2.29	0.31	2.29	0.31	2.25	0.27	2.26	0.30	2.12	0.30	2.21	0.27
WSF	2.43	0.29	2.38	0.27	2.49	0.29	2.49	0.27	2.17	0.33	2.06	0.32
WSSF	2.35	0.29	2.34	0.30	2.29	0.28	2.37	0.27	2.01	0.35	2.17	0.35

* Only receives phosphorus in wheat phase of each rotation.

Table 29b. Total Nitrogen and Phosphorus content of WHEAT STRAW in the 1996-1997 crop.

	SLOPE POSITION		
	SUMMIT	**SIDESLOPE**	**TOESLOPE**
SITE			

& ROTATION	N Side* N	N Side* P	NP Side N	NP Side P	N Side* N	N Side* P	NP Side N	NP Side P	N Side* N	N Side* P	NP Side N	NP Side P
STERLING:	-------------- % -------------				-------------- % -------------				-------------- % -------------			
WF	.80	.12	.73	0.10	.57	0.09	.60	0.08	.81	.14	.79	.16
WCF	.77	.09	.62	0.09	.71	0.07	.56	0.08	.72	.12	.59	.13
WCSF	.71	.08	.68	0.10	.62	0.08	.64	0.09	.62	.10	.66	.12
	N	**P**	**N**	**P**	**N**	**P**	**N**	**P**	**N**	**P**	**N**	**P**
STRATTON:	-------------- % -------------				-------------- % -------------				-------------- % -------------			
WF	.72	.10	.60	.09	.87	.11	.73	.11	1.01	.20	.93	.20
WCF	.78	.10	.68	.08	.79	.10	.81	.10	.84	.17	.89	.18
WCSF	.63	.09	.65	.15	.87	.11	.97	.12	.99	.15	.86	.17
	N	**P**	**N**	**P**	**N**	**P**	**N**	**P**	**N**	**P**	**N**	**P**
WALSH:	-------------- % -------------				-------------- % -----------				-------------- % -------------			
WF	.55	.06	.61	.06	.59	.05	.59	.05	.61	.07	.51	.07
WSF	.61	.06	.83	.07	.66	.06	.80	.08	.51	.06	.65	.09
WSSF	.68	.06	.69	.06	.56	.04	.60	.05	.54	.07	.53	.08

* Only receives phosphorus in wheat phase of each rotation.

Table 30a. Total Nitrogen and Phosphorus content of CORN & SORGHUM GRAIN in the 1997 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	1.48	.26	1.51	.23	1.27	.23	1.24	.28	1.31	.33	1.27	.33
WCSF	1.53	.25	1.45	.24	1.33	.18	1.22	.28	1.29	.35	1.33	.34

	N	P	N	P	N	P	N	P	N	P	N	P
STRATTON:	%				%				%			
WCF	1.49	.34	1.54	.34	1.39	.26	1.45	.30	1.30	.33	1.41	.36
WCSF	1.43	.27	1.47	.35	1.47	.30	1.47	.34	1.40	.36	1.41	.34

	N	P	N	P	N	P	N	P	N	P	N	P
WALSH:												
	%				%				%			
WSF	1.66	.35	1.66	.34	1.71	.34	1.63	.33	1.51	.44	1.53	.40
WSSF-1	1.66	.28	1.62	.32	1.66	.39	1.60	.31	1.70	.52	1.56	.42
WSSF-2	1.44	.27	1.49	.30	1.40	.29	1.53	.30	1.38	.43	1.40	.41
OPP(Corn)	1.50	.31	1.47	.32	1.39	.33	1.54	.34	1.60	.44	1.67	.47
CS(Corn)	1.56	.31	1.54	.32	1.55	.25	1.67	.33	1.59	.39	1.63	.46
CS(Sorghum)	1.42	.28	1.39	.25	1.42	.25	1.51	.33	1.52	.41	1.49	.39

* Only receives phosphorus in wheat phase of each rotation.

Table 30b. Total Nitrogen and Phosphorus content of CORN & SORGHUM STOVER in the 1997 crop.

SITE & ROTATION	SUMMIT N Side* N	SUMMIT N Side* P	SUMMIT NP Side N	SUMMIT NP Side P	SIDESLOPE N Side* N	SIDESLOPE N Side* P	SIDESLOPE NP Side N	SIDESLOPE NP Side P	TOESLOPE N Side* N	TOESLOPE N Side* P	TOESLOPE NP Side N	TOESLOPE NP Side P
STERLING:	%				%				%			
WCF	.76	.05	.78	.06	.51	.08	.46	.06	.55	.10	.55	.07
WCSF	.69	.06	.68	.07	.60	.06	.53	.07	.60	.09	.56	.14
	N	P	N	P	N	P	N	P	N	P	N	P
STRATTON:	%				%				%			
WCF	.83	.10	.93	.10	.82	.07	.90	.08	.83	.25	.91	.28
WCSF	.90	.10	.93	.12	1.03	.11	1.08	.16	.89	.25	.91	.30
	N	P	N	P	N	P	N	P	N	P	N	P
WALSH:	%				%				%			
WSF	1.05	.16	1.02	.12	1.07	.16	.94	.12	.65	.10	.56	.09
WSSF-1	.99	.15	1.00	.14	.78	.09	.86	.10	.77	.10	.66	.10
WSSF-2	.57	.08	.52	.08	.45	.05	.67	.10	.46	.08	.52	.08
OPP(Corn)	.97	.10	1.01	.11	.88	.06	.96	.06	1.04	.29	1.06	.27
CS(Corn)	.90	.09	.85	.09	.83	.10	.64	.06	.57	.13	.71	.13
CS(Sorghum)	.88	.09	.81	.08	.99	.05	.82	.08	.91	.22	.76	.22

* Only receives phosphorus in wheat phase of each rotation.

Table 31a. Total Nitrogen and Phosphorus content of SUNFLOWER GRAIN in the 1997 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:	------------- % -------------				------------- % -------------				------------- % -------------			
WCSF	3.29	.76	3.09	.81	2.92	.74	3.03	.79	3.11	.95	2.72	.94
STRATTON:	------------- % -------------				------------- % -------------				------------- % -------------			
WCSF	3.18	.79	3.29	.86	3.27	.74	3.33	.92	3.57	1.02	3.62	.99

* Only receives phosphorus in wheat phase of each rotation.

Table 31b. Total Nitrogen and Phosphorus content of SUNFLOWER STOVER in the 1997 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:	------------- % -------------				------------- % -------------				------------- % -------------			
WCSF	.82	.09	.73	.13	.84	.18	.77	.18	.72	.20	.65	.21
STRATTON:	------------- % -------------				------------- % -------------				------------- % -------------			
WCSF	1.20	.30	1.32	.36	1.26	.25	1.17	.33	1.78	.60	2.08	.69

* Only receives phosphorus in wheat phase of each rotation.

Table 32. Total Nitrogen and Phosphorus content of HAY MILLET in the 1997 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:	-------------- % -------------				-------------- % -------------				-------------- % -------------			
OPP	1.66	.19	1.65	.18	1.45	.15	1.55	.16	1.88	.32	1.87	.37
STRATTON:	-------------- % -------------				-------------- % -------------				-------------- % -------------			
OPP	1.44	.20	1.26	.28	1.28	.11	1.12	.19	1.76	.27	1.72	.31

* Only receives phosphorus in wheat phase of each rotation.

Table 33. Nitrate-N content of the soil profile at Planting for each crop during the 1996-1997 crop year.												
	SLOPE POSITION											
Site & Rotation	**SUMMIT**				**SIDESLOPE**				**TOESLOPE**			
	Crop and Time				**Crop and Time**				**Crop and Time**			
	Wheat Fall 96	**Corn S 97**	**Sun S 97**	**HM S 97**	**Wheat Fall 96**	**Corn S 97**	**Sun S 97**	**HM S 97**	**Wheat S 97**	**Corn S 97**	**Sun S 97**	**HM S 97**
STERLING	------------kg NO3-N /ha^{-}------------				------------kg NO3-N /ha^{-}------------				------------kg NO3-N /ha^{-}------------			
WF	88				74				97			
WCF	106	92			59	33			68	35		
WCSF	98	75	55		76	32	46		83	44	40	
OPP				49				48				39
GRASS	37				33				30			
Stratton												
WF	81				119				175			
WCF	97	56			101	61			139	203		
WCSF	67	98	85		73	126	42		193	249	136	
OPP				32				48				188
GRASS	34				38				37			
Walsh												
WF	71				83				108			
WSF	99	117			152	107			106	90		
W(S)SF	92	103			94	77			97	118		
WS(S)F		63				34				53		
CC (C)		70				138				74		
CC (S)		100				107				102		
OPP		104				150				119		

Table 34. Soil Organic Carbon at Sterling, Stratton, and Walsh Colorado in 1997.

CROPPING SYSTEM					
DEPTH:	WF	WCF	WCMF	OPP	GRASS
	------------------------------------- % Organic Carbon--------------------------------------				
	STERLING				
0-2.5 CM	1.21	1.33	1.31	1.67	1.39
2.5-5 CM	.88	.96	.95	1.19	1.19
5-10 CM	.78	.83	.77	.98	1.01
10-20 CM	.79	.76	.73	1.08	.79
	STRATTON				
0-2.5 CM	1.25	1.52	1.53	1.66	1.90
2.5-5 CM	1.02	1.11	1.10	1.16	1.47
5-10 CM	.83	.90	.90	.92	1.05
10-20 CM	.72	.80	.78	.83	.89
	WALSH				
0-2.5 CM	.46	.67	.66	.75	.99
2.5-5 CM	.40	.47	.52	.53	.74
5-10 CM	.37	.40	.43	.44	.58
10-20 CM	.38	.40	.38	.44	.52

Note: To calculate percent organic matter, multiply by 1.72.

APPENDIX I

ANNUAL HERBICIDE PROGRAMS
FOR EACH SITE

Table 1. Herbicide rate, cost and date applied at STERLING in 1997 season.

Rotation Crop	Herbicide	Rate English	Rate Metric	Weed Pressure	Cost	Date Applied
Rotation: Wheat-Fallow						
Wheat:	Banvel 2,4-D Amine Fallowmaster	8 oz/A 8 oz/A 32 oz/A	.60 l/ha .60 l/ha 2.37l/ha	II II I	$5.42 $0.13 $4.56	5-5-97 5-5-97 9-24-97
Fallow:	Landmaster BW Landmaster BW Roundup Ultra	40 oz/A 40 oz/A 48 oz/A	2.96 l/ha 2.96 l/ha 3.55 l/ha	I I III	$6.83 $6.83 $20.24	5-5-97 8-15-97 9-24-97
Rotation: Wheat-Corn-Fallow						
Wheat:	Banvel 2,4-D Amine Fallowmaster	8oz/A 8 oz/A 32 oz/A	.60 l/ha .60 l/ha 3.55 l/ha	II II II	$5.42 $0.13 $4.56	5-5-97 5-5-97 9-24-97
Corn:	Prowl Atrazine 4L Landmaster Bw	1 Qt/A 1 Qt/A 40 oz/A	2.37 l/ha 2.37 l/ha 2.96 l/ha	II	$6.62 $2.99 $6.83	5-5-97
Fallow:	Landmaster Bw Landmaster Bw Roundup Ultra	40 oz/A 40 oz/A 48 oz/A	2.96 l/ha 2.96 l/ha 3.55 l/ha	I I III	$6.83 $6.83 $20.24	5-5-97 8-15-97 9-24-97
Rotation:Wheat-Corn-Sunflower-Fallow:						
Wheat:	Banvel 2,4-D Fallowmaster	8 oz/A 8 oz/A 32 oz/A	.60 l/ha .60 l/ha 3.55 l/ha	II II II	$5.24 $0.13 $4.56	5-5-97 5-5-97 9-27-97
Corn:	Prowl Atrazine 4L Landmaster Bw	1 Qt/A 1 Qt/A 40 oz/A	2.37 l/ha 2.37 l/ha 2.96 l/ha	I	$6.62 $2.99 $6.83	5-5-97
Sunflower:	Roundup Ultra Poast Crop Oil	24 oz/A 24 oz/A 1 Qt/A	1.77 l/ha 1.77 l/ha 2.37 l/ha	I I I	$10.12 $14.02 $ 1.28	6-19-97 7-14-97 7-14-97
Fallow:	Landmaster Bw Roundup Ultra Landmaster BW Roundup Ultra	40 oz/A 24 oz/A 40 oz/A 48 oz/A	2.96 l/ha 1.77 l/ha 2.96 l/ha 3.55 l/ha	I I I III	$6.83 $10.12 $6.83 $20.24	5-5-97 6-19-97 8-15-97 9-27-97
Rotation: Opportunity						
Opportunity	Landmaster BW Roundup Ultra Landmaster BW Roundup Ultra	40 oz/A 24 oz/A 40 oz/A 48 oz/A	2.96 l/ha 1.77 l/ha 2.96 l/ha 3.55 l/ha	I I I III	$ 6.83 $10.12 $ 6.83 $20.24	5-5-97 6-19-97 7-14-97 9-24-97
Weed Pressure Ratings: 1=Farmer would need to spray. 2= Farmer would delay application. 3=Farmer would not plan a spray application.						
Note: Atrazine is applied at 75 % of the rate on sideslope soils.						

Table 2. Herbicide rate, cost and date applied at STRATTON in 1997 season.

Rotation Crop	Herbicide	Rate English	Rate Metric	Weed Pressure	Cost	Date Applied
Rotation: Wheat-Fallow						
Wheat:	Banvel 2,4-D Amine	8 oz/A 8 oz/A	.60 l/ha .60 l/ha	II	$5.42 $0.13	5-5-97
	Fallowmaster	32 oz/A	2.37 l/ha	I	$4.56	8-26-97
Fallow:	Landmaster BW Landmaster BW Roundup Ultra	40 oz/A 54 oz/A 48 oz/A	2.96 l/ha 3.00 l/ha 3.55 l/ha	I I III	$6.83 $9.21 $20.24	5-5-97 8-26-97 9-29-97
Rotation: Wheat-Corn-Fallow						
Wheat:	Banvel 2,4-D Amine	8oz/A 8 oz/A	.60 l/ha .60 l/ha	II	$5.42 $0.13	5-5-97
	Fallowmaster	32 oz/A	2.37 l/ha	I	$4.56	8-26-97
Corn:	Prowl Atrazine 4L Landmaster Bw	1 Qt/A 1 Qt/A 40 oz/A	2.37 l/ha 2.37 l/ha 2.96 l/ha	I	$6.62 $2.99 $6.83	5-5-97
Fallow:	Landmaster Bw Landmaster Bw Roundup Ultra	40 oz/A 54 oz/A 48 oz/A	2.96 l/ha 3.00 l/ha 3.55 l/ha	I I III	$6.83 $9.21 $20.24	5-5-97 8-26-97 9-29-97
Rotation:Wheat-Corn-Sunflower-Fallow:						
Wheat:	Banvel 2,4-D	8 oz/A 8 oz/A	.60 l/ha .60 l/ha	II	$5.42 $0.13	5-5-97
	Fallowmaster	32 oz/A	2.37 l/ha	I	$4.56	8-26-97
Corn:	Prowl Atrazine 4L Landmaster Bw	1 Qt/A 1 Qt/A 40 oz/A	2.37 l/ha 2.37 l/ha 2.96 l/ha	I	$6.62 $2.99 $6.83	5-5-97
Sunflower	Roundup Ultra Poast Crop Oil	24 oz/A 24 oz/A 1 Qt/A	1.77 l/ha 1.77 l/ha 2.37 l/ha	I I I	$10.12 $14.02 $ 1.28	6-19-97 7-14-97 7-14-97
Fallow:	Landmaster Bw Roundup Ultra Landmaster BW Roundup Ultra	40 oz/A 24 oz/A 54 oz/A 48 oz/A	2.96 l/ha 1.77 l/ha 4.00 l/ha 3.55 l/ha	I I I III	$ 6.83 $10.12$9. 21 $20.24	5-5-97 6-19-97 8-26-97 9-29-97
Rotation: Opportunity						
Opp:	Landmaster BW Roundup Ultra Landmaster BW Roundup Ultra	40 oz/A 24 oz/A 40 oz/A 48 oz/A	2.96 l/ha 1.77 l/ha 2.96 l/ha 3.55 l/ha	I I I III	$ 6.83 10.12 6.83 $20.24	5-5-97 6-19-97 7-14-97 9-24-97
Weed Pressure Ratings: 1=Farmer would need to spray. 2= Farmer would delay application. 3= Farmer would not plan a spray application. Note: Atrazine is applied at 75 % of the rate on the sideslope soils.						

Table 3. Herbicide rate, cost and date applied at WALSH in 1997 season.

Rotation	Herbicide	Rate (Eng)	Rate (M)	Pressure	Cost	Date
Rotation: Wheat-Fallow						
Wheat:	Ally Banvel x-90 Atrazine 4L Landmaster BW Tillage - Sweep	.1 oz/A 2 oz/A 4 oz/A 12 oz/A 54 oz/A	.01 l/ha .15 l/ha .30 l/ha .9 l/ha 4 l/ha	I I I I I II	\$2.46 \$0.13 \$0.53 \$1.08 \$9.21	3-21-97 3-21-97 3-21-97 7-19-97 7-19-97 8-1-97
Fallow:	Landmaster BW Landmaster BW Tillage - Sweep Landmaster BW Tillage - Sweep	48 oz/A 40 oz/A 54 oz/A	3.55 l/ha 2.96 l/ha 4 l/ha	I I I I II	\$8.260 \$7.60 \$9.21	3-26-97 5-26-97 6-12-97 7-19-97 8-21-97
Rotation: Wheat-Sorghum-Fallow						
Wheat:	Ally Banvel x-90 Atrazine 4L Landmaster BW Tillage - Sweep	.1 oz/A 2 oz/A 4 oz/A 12 oz/A 54 oz/A	.01 l/ha .15 l/ha .30 l/ha .9 l/ha 4 l/ha	I I I I I II	\$2.46 \$0.13 \$0.53 \$1.08 \$9.21	3-21-97 3-21-97 3-21-97 7-19-97 7-19-97 8-1-97
Sorghum:	Landmaster BW Roundup Tillage - Cultivation	40 oz/A 16 oz/A	2.96 l/ha 1.17 l/ha	I I III	\$6.83 \$5.45	5-26-97 6-17-97 7-18-97
Fallow:	Landmaster BW Landmaster BW	40 oz/A 54 oa/A	2.96 l/ha 4.0 l/ha	I I	\$6.83 \$9.21	5-26-97 7-19-97
Rotation: Wheat-Sorghum-Sorghum-Fallow:						
Wheat:	Ally Banvel x-90 Atrazine 4L Landmaster BW Tillage - Sweep	.1 oz/A 2 oz/A 4 oz/A 12 oz/A 54 oz/A	.01 l/ha .15 l/ha .30 l/ha .9 l/ha 4.0 l/ha	I I I I I II	\$2.46 \$0.13 \$0.53 \$1.08 \$9.21	3-21-97 3-21-97 3-21-97 7-19-97 7-19-97 8-1-97
Sorghum:	Landmaster BW Roundup Tillage - Cultivation	40 oz/A 16 oz/A	2.96 l/ha 1.17 l/ha	I I III	\$6.83 \$5.45	5-26-97 6-17-97 7-18-97
Sorghum:	Landmaster BW Roundup Tillage - Cultivation	40 oz/A 16 oz/A	2.96 l/ha 1.17 l/ha	I I III	\$6.83 \$5.45	5-26-97 6-17-97 7-18-97
Fallow:	Landmaster BW Landmaster BW	40 oz/A 54 oz/A	2.96 l/ha 4.0 l/ha	I I	\$6.83 \$9.21	5-26-97 7-19-97
Opportunity						
Sorghum	Landmaster BW Roundup Tillage - Cultivation	40 oz/A 16 oz/A	2.96 l/ha 1.17 l/ha	I I	\$6.83 \$5.45	5-26-97 6-17-97 7-18-97
Continuous Cropping:						
Corn	Landmaster BW Atrazine Prowl Accent Banvel	40 oz/A 12 oz/A 48 oz/A .66 oz/A 2 oz/A	2.96 l/ha .9 l/ha 3.55 l/ha .05 l/ha .15 l/ha	I I I III III	\$6.83 \$1.12 \$10.08 \$19.67 \$1.36	5-21-97 5-21-97 5-21-97 6-27-97 6-27-97
Sorghum	Landmaster BW	40 oz/A	2.96 l/ha	I	\$6.83	5-26-97

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.

Peterson, G.A., A.J. Schlegel, D.L. Tanaka, and O.R. Jones. 1996. Precipitation use efficiency as affected by cropping and tillage systems. J. of Prod. Agric. 9:180-186.

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.

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.

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.

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