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Agronomic & Entomological Results from 7 Years of Dryland Cropping Systems Research at Briggsdale, Colorado

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Abstract

Dryland crop production in the semi-arid Great Plains is limited by both the quantity and timing of precipitation. Sustainable dryland cropping systems maximize precipitation use efficiency by managing precipitation capture, storage, and use. Pest management approaches are also critical for efficient crop production in water limited environments. Notill based cropping systems improve precipitation use efficiency and allow for more intensive crop rotations with fewer fallow periods. The primary purpose of this long-term study was to determine if the stressful environment in the Briggsdale, CO area would support intensified cropping systems. We knew that some systems might fail but we wanted to "stretch" the system to its limit. The results were revealing and answered many questions that we had asked about intensive cropping systems in this climatic stressful environment.

The objectives of this research were to evaluate productivity and insect dynamics for different notill crop rotations in an environment with less than 15 inches of annual precipitation. Specifically, this research was designed to study integrated pest management tactics to control Russian wheat aphid (RWA) and to evaluate beneficial insect population abundance within more intensive cropping systems. Another objective of the study was to evaluate alternative crops for this environment. The research project was established in 1998, 1999 was the first crop year, and it was discontinued in 2005. The study compared four notill crop rotations ranging from one summer fallow every other year to continuous cropping with no summer fallow.

During the study period the Briggsdale area had annual precipitation several inches the long-term average of 13.7 inches. This in turn led to many crop failures and low crop grain yields. The dry conditions in the study environment did not sustain insect pest populations large enough to be of economic concern.

Reductions in wheat yields of 11-78% were observed in the most intense rotations as compared to the traditional 2-year system. Consequently, crops such as corn, sunflower, soybean, grain sorghum, Austrian winter pea, and forage soybean, all which were used at least once in the 6-year cropping system, had low yields and were found to be too risky for dryland production in this stressful environment.

These results indicate that the stressful environment coupled with intense cropping systems had a negative impact on the potential production for this location. The most suitable cropping systems found were those with fallow every other year or every third year (2-4 year systems). Well adapted annual forage crops may be a reasonable choice for rotation in winter wheat-based systems.

Introduction

The traditional dryland cropping system in Colorado is a winter wheat-summer fallow rotation. The purpose of the summer fallow period is to conserve limited water for the subsequent crop. Although summer fallow reduces the risk of crop failure, it is an inefficient use of precipitation. A research project was established in eastern Colorado in 1986 to explore the viability of more intense cropping systems in the semiarid climate of that region (Peterson et.al., 1986-2002). This research concluded that with adoption of notill practices, a crop rotation with fallow every third or fourth year provided a 25-40% increase in net annual income, compared to that of the traditional wheat fallow rotation (Peterson et al., 2002). These findings have resulted in a relatively large adoption of more intensive crop rotations in Eastern Colorado. Commonly, producers are implementing 3-year cropping systems with a winter wheat-summer crop-summer fallow rotation. Summer crops used in this rotation included corn, proso millet, sunflower, or sorghum. The dryland cropping system study (Peterson et al., 2002) also showed that more intensive crop rotations increased soil carbon content(Sherrod, et al., 2003) and improved soil physical properties (Shaver, et al., 2013). The original study did not, however, evaluate pest and beneficial insect populations.

Pest dynamics are an important consideration in the dryland cropping systems of the Great Plains. The Russian wheat aphid (RWA) can have a major economic impact in wheat based cropping systems. The RWA arrived in Colorado in 1986 and has become a major concern for small grain production throughout Eastern Colorado. In 2002, NASS reported that there were 1.7 million acres of dryland winter wheat in the state, which could potentially be infested by RWA. A potential solution for controlling RWA and other pests may be Integrated Pest Management tactics (Holtzer et.al., 1996). These management tactics include chemical, host plant resistance, cultural and biological control methods. Due to the cost of the chemical control, this option is usually not economically viable. Host plant resistance has shown some promise, however RWA can adapt to these plants if it is the only tactic used. Biological control through the release of predators has shown to be ineffective when predators are without prey for more than 2-3 weeks (Donahue, 1996). In the traditional winter wheat-fallow cropping system beneficial insect survival is minimal. However, if more intense cropping systems were used they may provide more suitable environment for insect presence and survival. The major objective of this study was to evaluate the dynamics of beneficial and pest insects in notill dryland crop rotations.

The specific objectives of this research were to:

1. To determine if intensive notill dryland cropping systems are adapted to this semi-arid environment.
2. Determine the importance of summer fallow and its needed frequency to sustain production.
3. Identify nontraditional crops that can be profitably grown in these dryland systems.
4. Determine the effectiveness of more diverse cropping systems at achieving an integrated approach to Pest Management.

Materials & Methods- Agronomic Studies

Briggsdale is located in Weld County in north-central Colorado. The field site is three miles south of Briggsdale on county road (CR) 84, between CR 77 and 79, at an elevation of 4850 ft with an average annual precipitation of 13.7 inches. A weather station was installed at the experimental site in 1999. The soil type is a Platner loam (fine, smectitic, mesic Aridic Paleustolls). Prior to experiment establishment in 1999, the cropping system used at this site was wheat/foxtail millet/fallow (WMF), proceeded by a traditional winter wheat/summer fallow crop rotation. The experimental cropping systems were initiated in 1998, with the first crop harvest in 1999 (Table 1). Each phase of each crop rotation was present every year and was replicated four times in a randomized complete block design.

Table 1. Experimental crop rotations by harvest year from 1999 to 2005 at Briggsdale, CO.

Year	Typical	Typical	New Systems Evaluated	Opportunity Cropping
1999	WF	WFt*F	WWCSbSfP*	Opp.
2000	WF	WFt*F	WWCSbSfP*	Opp.
2001	WF	WFt*F	WWCSbSfSb*	Opp.
2002	WF	WFt*F	WWCCSfF	Opp.
2003	WF	WFt*F	WWCCSfF	Opp.
2004	WF	WFt*F	WWCCSfF	Opp.
2005	WF	WFt*F	WCF/BT*Ft*	Opp.

* Harvested as forage

Key: Wheat (W), Corn (C), Soybean (Sb), Sunflower (Sf), Austrian Winter Peas (P), Barley (B), Triticale (T), Foxtail Millet (Ft), Fallow (F).

The WF and WFtF rotations were used as the control systems which compare nontraditional systems to common practices for the area; in addition allowing a comparison of two-year vs. three-year traditional practices. From Table 1, the experimental rotations were six-year systems evaluating various potential alternative crops. The opportunity rotation was used to take advantage of environmental conditions that might benefit a given crop in a particular year. The specific crop grown in this system varied and was chosen based on soil moisture conditions. Below normal rainfall conditions throughout the study period reduced opportunity crop choices more than anticipated.

Planting information for each crop including seeding and nitrogen (N) rates over the 7 study years, and the median planting date are reported in Table 2. Nitrogen fertilizer (32-0-0) was applied by dribbling in a band at the soil surface directly above the seed at planting. Soil sampling for residual profile-N was performed prior to planting of each crop by collecting soil cores to six feet (Table 3) and separating into one foot increments; N was applied based on crop requirements. Phosphorus (P) fertilizer (10-34-0) was band applied with the wheat seed at 30 lb P_2O_5/A on an annual basis. No P was applied to summer crops in any rotation.

Two winter wheat varieties were planted in each rotation. One was resistant to biotype RWA1, while the other was susceptible. Throughout the study period RWA aphid abundance was almost nonexistent and thus it was not possible to measure the benefit of using a resistant variety in these systems. Since little RWA activity was observed and because very few varietal yield differences were noted, wheat yields reported for each cropping system are means of the two varieties.

A suction trap was maintained at the Briggsdale site to monitor aphid flights from May to October, 2001-2005.

Crop residue samples were collected using a 1 meter quadrat (1m x 1m) from two positions in each plot prior to the planting of each crop. These measurements allowed us to monitor crop residue changes in these systems.

Table 2. Average seeding rate, nitrogen fertilizer application rate, and median planting date for all crops grown at Briggsdale from 1998 to 2005.

Crop	Seeding Rate	N Rate	Planting Date
Winter Wheat	58 lbs/acre	49 lbs/acre	September 22
Austrian Winter Peas/W.Wheat	90 lbs Peas + 30 lb Wheat/acre	0 lbs/acre	October 13
Spring Barley	50 lbs/acre	0 lbs/acre	February 24
Sorghum Sudan/Foxtail Millet	14 lbs/acre	30 lbs/acre	May 14
Corn	14K seeds/acre	76.9 lbs/acre	May 19
Soybean	91K seeds/acre	0 lbs/acre	May 21
Forage Soybeans	105 K seeds/acre	0 lbs/acre	May 24
Sunflower	14K seeds/acre	40.5 lbs/acre	June 1
Grain Sorghum	39K seeds/acre	50.5 lbs/acre	June 5
Foxtail Millet	14 lbs/acre	29 lbs/acre	June 15

Table 3. Soil profile (0-6') NO_3-N by crop and year at Briggsdale

Rotation	2000	2001	2002	2003	2004
Crop	--------------------- lbs NO_3-N/A -----------------------				
WF					
Wheat	67.6	90.7	108.4	119.3	130.5
WMF					
Wheat	80.2	63.8	72	93.2	131.3
Millet	8.8	49.6	31.5	57.8	80.9
$W^1W^2X^1X^2SfX^3$					
$Wheat^1$	13.6	44.4	83	123.1	112.1
$Wheat^2$	44.6	31.2	200	73.8	139.5
X^1 (Corn or Sorghum)	11.5	57.6	30.9	45.5	123.1
X^2 (Sb, Sf, or C)	0	0	44.5	42.1	0
Sunflowers	33.2	25.6	56.2	74.3	141.3
X^3 (Peas or Fallow)	0	0	0	0	0

X^1 – 1999-2003 = Corn, 2004 = Grain Sorghum
X^2 – 1999-2001 = Soybeans, 2002-2003 = Sunflower, 2004 = Corn
X^3 – 1999-2001 = Peas, 2002-2004 = Fallow

Results & Discussion - Agronomic Studies

Climatic Data

The 1998-1999 cropping season was the only favorable climate year for crop production in the seven-year period of the study (Table 4). Precipitation remained well below normal after the 1998-1999 season. With the exception of the 2000-2001 season, precipitation has only been 25-50% of normal. The normal precipitation pattern is such that the majority of the precipitation is received from April through September. This was true for the study period; however less frequent and more intense events were the primary sources of precipitation instead of the more frequent, less intense events. This type of rainfall pattern had a substantial impact on the moisture/temperature stress of summer crops. When rainfall is received in only a couple of events throughout the summer, desiccation of summer crops is likely to occur because of the course-textured nature of the soil and high temperatures that persist from June through August. The mean maximum air temperatures from 2003-2005 were 78°F in June, 94°F in July and 87°F in August. If the long-term precipitation pattern had occurred, summer crops would have been favored by the "spoon-feeding" of moisture received in more frequent events from June through August. Low moisture and high temperature conditions throughout each summer was the reason for the low crop yields.

The amount of precipitation received during the vegetative and reproductive growth stages for wheat, corn and foxtail millet crops is shown in Table 5. The data indicate that the vegetative growth stage for wheat and corn and the reproductive stage for wheat were the only stages in which moisture conditions favored crop production. Given the environmental conditions that have persisted at this location in the last seven years, finding crops and cropping systems that are more drought tolerant is critical for economic sustainability at this location.

Wheat

Winter wheat was the most productive crop grown at Briggsdale. It produced a harvestable amount of grain even in years of extreme drought when preceded by a fallow period (Table 6). Wheat yields in the WF system averaged 32 bu/acre, followed by WMF at 29 bu/acre. The first-year wheat crop in the six-year rotation yielded 12 bu/acre and the second-year wheat crop yielded 7 bu/acre; thus the six-year system did not produce sustainable wheat grain yields. These phases of the six-year rotation did not produce any wheat grain in 2001-2002, 2002-2003 and 2004-2005. Precipitation received in 2001-2002 was 5 inches below that of the expected normal, but the precipitation received in the other two non-yielding years was near the normal amount. This illustrates the impact of the exhaustive six-year system and suggests that this environment may not sustain six-year intense cropping systems even under "normal" precipitation conditions.

On the other hand, when comparing the two traditional two and three systems, there were no significant differences. These findings provide some promise that crop productivity can be increased with the use of a more intense system in this environment.

It should be noted that the 1999-2000 wheat crop had significant frost damage from a mid-May snow storm and the 2001-2002 and 2004-2005 wheat crops were severely stressed from drought. The 2001-2002 growing season was one of the driest years on record.

Table 4. Monthly precipitation received at Briggsdale since 1999.

	1999	2000	2001	2002	2003	2004	2005	Normal
	----------	----------	----------	----------	Inches	----------	----------	----------
September	2.63	0.91	1.01	0.21	0.51	1.35	0.32*	1.28
October	0.39	0.19	0.54	0.63	0.06	0.60	2.66*	0.66
November	0.18	0.10	0.00	0.04	0.24	0.54	0.66*	0.45
December	0.00	0.27	0.00	0.00	0.24	0.08	0.08	0.26
	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	
January	0.10	0.28	0.07	0.06	0.28	0.14	0.00	0.30
February	0.41	0.07	0.19	0.17	0.36	0.04	0.00	0.19
March	1.00	0.41	0.10	1.75	0.14	0.37	0.36	0.78
April	0.75	1.85	0.06	0.63	0.88	1.23	0.12	1.28
May	2.63	3.85	0.56	2.39	2.24	0.85	0.36	1.94
June	0.33	2.30	1.62	1.83	1.23	3.56	0.16	2.07
July	0.51	2.04	0.39	0.92	0.50	0.44*	2.16**	2.51
August	0.32	0.54	3.65	1.39	0.77	0.86*	0.86**	1.81
Yearly Total	**9.25**	**12.81**	**8.19**	**10.02**	**7.45**	**10.06**	**7.82**	**13.53**

*Data provided by the USDA-ARS Area-wide Pest Management of Russian Wheat Aphid and Greenbug Project.

**Data provided by the National Weather Service at Briggsdale, CO

Table 5. Precipitation by growing season segment for Briggsdale from 1998-2005.

	Wheat		Corn		Millet	
Year	Veg. Sept. - Mar	Reprod. Apr. - June	Veg. Apr. – June	Reprod. July - Sept.	Veg. June - July	Reprod. August
	----------	----------	----------	Inches	----------	----------
98-99	4.60	8.40	8.40	8.61	3.79	4.33
99-00	4.70	3.70	3.70	1.74	0.84	0.32
00-01	2.20	8.00	8.00	3.59	4.34	0.54
01-02	1.90	2.20	2.20	4.25	2.01	3.65
02-03	2.90	4.90	4.90	2.82	2.75	1.39
03-04	2.00	4.40	4.40	2.62	1.73	0.77
04-05	3.10	5.60	5.60	1.62	4.00	0.86
Average	**3.06**	**5.31**	**5.31**	**2.77**	**2.78**	**1.69**
Normal	3.90	5.30	5.30	5.60	*4.58*	1.81

Table 6. Wheat grain yields summarized from 2000 – 2005.				
	Rotation			
Year	WF	WMF	W'WXXXX	WW'XXXX
	------------------------- bu/ac -------------------------			
2000	19.4	15.6	12.0	11.6
2001	45.2	44.1	30.5	26.9
2002	19.4	18.2	0.0	4.9
2003	46.0	32.7	0.0	0.0
2004	42.2	30.9	30.5	0.0
2005	20.6	30.3	0.0	0.0
Mean	32.1a	28.6a	12.2b	7.2b

Corn

The 1999 corn crop was exceptional and was the highest yield achieved for corn throughout the experiment (Table 7). This was the only year corn was profitable based on information published by Kaan et.al. (2002) that indicated 53-55 bu/acre was the breakeven yield for dryland corn. Drought, rodent damage, and high plant populations affected corn yields for the next six years. In 2005, skip-row corn was planted to examine its potential in this arid climate. It looked promising early in the season, but fell short of expectations at harvest time with an average yield of 13.3 bu/acre. The overall site average for corn through seven years was 15.5 bu/acre; when 1999 is excluded, the average yield drops to 7.7 bu/acre. It is evident that dryland corn is not a feasible option for an alternative crop at this location.

Table 7. Summary of summer crop yields from 1999 – 2005.			
		Crop	
	Corn	Sunflower	Hay Millet
Year	bu/ac	lb/ac	lb/ac
1999	62.20	1290	4095
2000	0.00	0	n/a
2001	5.70	559	3500
2002	11.00	456	1500
2003	16.40	490	0
2004	0.00	0	475
2005	13.30	Not available	1000
Mean	15.51	466	1510

Sunflower

Sunflower was grown as an alternative crop in the fifth year of the six-year rotation. Sunflower is a good scavenger of soil water and seemed to be an appropriate fit as one of the crops in the six-year rotation. However, sunflower, like most summer crops, yielded poorly (Table 7). A sunflower crop was only harvested four of the six years they were planted and the average yield was only 466 lbs/acre. With the exclusion of the 1999 crop, the average dropped to 301 lbs/acre. Sunflower was discontinued in 2005, when the six-year rotation was discontinued and was split into two three-year rotations.

Foxtail Millet

Foxtail millet forage is one of the traditional options for the second year crop in a three-year system. In the seven year study period at this site foxtail millet averaged 1500 lbs/acre, including one year when the crop was not harvested due to drought and another year in which it was not planted due to drought. In 2005 and 2006 foxtail was planted as a mixture with a Sorghum-Sudan hybrid. The theory was that this mixture would reduce the risk of a complete crop failure due to early or late season drought and improved emergence. The larger seeded sorghum would help break surface soil crusting and improved emergence of the smaller seeded millet. The forage sorghum would rely on precipitation received later in the season, whereas the foxtail millet relied more on the early season precipitation. This would give the producer another month of time to receive rain to produce a crop. In June of 2005 over 3.5 inches of precipitation was received, but the month of July had an extended period of over 100^{o} F air temperatures and only 0.44 inches of precipitation. The combination of these climatic conditions caused the hay crop to mature early and yield less than a 0.5 ton/a.

Soybean and Forage Soybean

Soybean was planted in the 4^{th} year phase of the six-year rotation in 1999, 2000 and 2001. In 1999, the soybean crop was infested with Kochia, which eventually smothered the crop. From 2000-2001 the soybean crop was damaged by rodents and drought. Soybean never produced a harvestable seed crop and was dropped from the six-year rotation in 2002. Forage soybean was planted in the sixth year phase of the six-year rotation in 2001; it did not produce enough biomass and was not planted in subsequent years.

Austrian Winter Pea

Austrian winter pea was planted as a mixture with winter wheat in the late fall of 1998 and 1999. This forage mixture was the original sixth year phase of the six year rotation. This mixture did not produce enough biomass to be harvested in either year and was dropped as an alternative crop option.

Grain Sorghum

Grain sorghum was planted in the opportunity system in 2002, 2003, 2004, and in the six year rotation in 2006. These crops also failed to produce any grain and were not harvested. This crop was eliminated as an alternative crop option.

Triticale and Spring Barley

In 2005, the six-year system was split into two three-year systems based on its performance through six years. The two new rotations were Spring Barley/Triticale/Forage Sorghum and Foxtail Mixture and WCF. The triticale was not planted in 2005. Spring barley yielded 22 bu/acre, which was more than anticipated. This crop is now included in the new systems at this location and has shown some promise for future productivity.

Crop Residue Accumulation

The crop residue weights for all crops, rotations and years are reported in Table 8. The data indicate that crop residue levels were inconsistent, resulting in relatively large standard deviations. Comparison of the crop residue weights taken in 1999 to the average over the course of six years indicates that no rotation permitted an accumulation of crop residue.

Table 8. Crop residue weights by crop, rotation, and year at Briggsdale.

Crop Rotation	Wheat (WF)	Wheat (WMF)	Wheat 1 WWXXXX	Wheat 2 WWXXXX	Corn WWCXXX	Corn WWXCXX	Sunflower WWXXSfX	Foxtail WFtF
Crop Season	lbs/acre							
1999 - 2000	410	730	2550	3110				3580
2000 - 2001					1600		1000	2000
2001 - 2002	1690	0	310	1600	4630	4880	2340	4120
2002 - 2003	2480	460	1510	280	660	1250	1000	1040
2003 - 2004	200	620	380	730		1500	1900	1610
2004 - 2005								
Average	1195	453	1188	1430	2297	2543	1560	2470
Std. Deviation	1081	321	1062	1247	2075	2027	671	1319

Weed Counts:

Percent weed cover was determined after the harvest of each crop within each season. This was measured by using a 100 m beaded cable. Beads are spaced at 1 m and weed species present at each bead were noted. Table 9 provides the percent weed cover for each rotation and year after wheat harvest. Due to the inconsistency of stand establishment of the summer crops, percent weed cover for these crops will not be presented. Weed species not listed in the table were not consistent throughout the experiment. Kochia, Russian thistle, and puncture vine were the most prevalent broadleaf species. Among the grass species were volunteer wheat, stinkgrass, witchgrass and Texas tumblegrass. As mentioned previously, 2002 was the driest year on record, this is evident in the percent weed cover values, as Russian thistle populations reached >20% cover. In dry conditions, Russian thistle is extremely difficult to control, due to its ability to scavenge for moisture and to with stand extremely hot and dry conditions. There were no differences in percentage weed cover among the rotations or any consistent reduction in percent cover of any weed. One year with poor weed control allows for a significant increase in the seed bank for the following year. Timely herbicide applications are critical for weed control in this arid environment.

Table 9. Percent weed cover Post-Wheat harvest by rotation and year, Briggsdale, CO.									
	Weed Species								
Crop/Year	Kochia	Russian Thistle	Puncture Vine	Prostrate Pigweed	Common Purslane	Volunteer Wheat	Stinkgrass	Witchgrass	Texas Tumblegrass
---Percent---									
WF									
2000	0.2	0.5				1.2			
2001	1.0	0.8	1.0			0.2	1.0	0.5	
2002	0.2	23.78	1.8		2.8	0.0	0.0		
2003	1.0	1.0	1.5		0.2	0.0		0.2	0.2
2004	2.8	1.2	0.2		0.4		0.6		
Average	1.1	5.4	1.11		1.1	0.4	0.5	0.4	0.2
WMF									
2000						0.5			
2001	3.2	0.0	0.0	0.8			0.8	1.2	
2002	0.8	26.0	8.8		2.5	0.0	0.0		
2003	6.2	6.0	0.0		0.0	0.5		0.2	0.2
2004		3.2	3.2		0.5	0.0	1.0		1.8
2005			0.5			0.2			
Average	3.4	8.9	2.5	0.8	1.0	0.2	0.6	0.8	1.0
WWXXXX									
2000		0.2	0.2			0.5			
2001	5.2	3.2	0.0	0.2			3.0	0.2	
2002	0.2	3.2	9.2		0.0	0.0	0.2		
2003	0.2	0.8	6.2		0.2	0.2		0.0	0.0
2004	0.6	1.8	4.8		0.8		2.8		0.4
2005			0.8			0.2			
Average	1.6	1.9	3.6	0.2	0.4	0.2	2.0	0.1	0.2
W**W**XXXX									
2000	1.5	0.8				0.2			
2001	7.0	1.8	0.0	0.2			4.8	3.0	
2002	10.8	28.8	1.5			0.8	0.0		
2003	1.0	1.0	10.0			0.2		0.0	0.2
Average	5.1	8.1	3.8	0.2		0.4	2.4	1.5	0.2

Soil Moistures

Soil samples were collected at planting and harvest of each crop to determine soil water content in the six foot soil profile. The water contents and change in soil water from planting to harvest are reported from the spring of 2000 through the fall of 2004 in Table 10. There were no discernible soil moisture changes in the 6-year system plots relative to that of 2- or 3-year systems. The greatest changes in water content from planting to harvest occurred in 2000.

Table 10. Average water content in the 0-6 ft. soil profile by crop and year at Briggsdale.

Crop	2000			2001			2002			2003			2004		
	P	**H**	**Δ**	**P**	**H**	**Δ**	**P**	**H**	**Δ**	**P**	**H**	**Δ**	**P**	**H**	**Δ**
	--------							%							--------
WF	13.2	4.8	8.4	9.9	6.7	3.2	11.1	6.8	4.3	10.2	6.5	3.7	10.0	8.7	1.3
WMF	12.5	5.3	7.2	10.4	7.7	2.8	8.0	5.9	2.1	10.8	6.3	4.5	10.6	7.6	3.0
WWXXXX	11.6	7.0	4.6	6.3	7.2	-0.9	7.8	5.4	2.3	11.5	7.6	3.9	8.0	7.0	1.0
W**W**XXXX	9.7	5.6	4.1	7.1	7.1	-0.2	7.4	6.7	0.7	11.6	-	-	8.0	8.0	0.0
W**M**F	12.1	9.8	2.4	8.9	8.1	0.8	8.9	8.1	0.8	10.6	8.9	1.7	12.7	8.6	4.1
WW**C**XXX	12.7	9.9	2.9	6.8	8.4	-1.6	6.8	8.4	-1.6	11.5	8.1	3.4	7.7	9.9	-2.2
WWX**C**XX				8.7	7.8	0.9	8.9	7.8	1.1	11.6	8.0	3.7			
WWXX**Sf**X	12.7	8.1	4.6	8.4	7.9	0.4	8.4	8.0	0.4	13.6	8.6	5.0	9.0	9.0	0.0

Preplant (P); Post-Harvest (H); % Change (Δ)

Cropping System Conclusions

Our original goal was to determine what type of intensive cropping system might be sustainable in this stressful environment. As we had hypothesized, we had many crop failures due to our intent to "stretch" the system to its limit. The results were revealing and answered many questions that we had asked about intensive cropping systems in this stressful environment.

Through seven years of experimentation with alternative crops at Briggsdale, corn, soybean, sunflower, grain sorghum and forage soybean were eliminated as alternative options. The forage crops Foxtail millet and Austrian winter peas may succeed in this environment if proper management techniques are used. Mixing the foxtail with forage sorghum showed promise in recent years and mixing Austrian winter pea with fall seeded triticale has reportedly worked quite well in similar climatic situations. With the use of triticale in the place of winter wheat, an earlier forage harvest can be expected.

Examination of the rotations, based on wheat grain yield, indicates that the six-year system was too exhaustive of soil moisture and was not sustainable. There was no difference in wheat grain yield for the WF and WMF rotations, implying that the primary crop for the rotation (wheat) is not significantly affected by intensifying the rotation for a two- three-year system. However, the short coming is that most summer crops failed to yield consistently. However, with the changes that have been made to the type of summer crops planted, the three-year traditional rotation may be beneficial. Perhaps one of the easiest conclusions made from this research is that it is extremely difficult and risky to grow any crop in a moisture stressed environment like Briggsdale, CO. The millet tribe is one of the most drought tolerant groups of crops that can be grown in the high plains. Its repeated failure is a strong indicator of the severity of the drought experienced at this location. Although, intensifying cropping systems in this region to provide greater net annualized income has some legitimacy.

Results & Discussion - Entomological Studies

Wheat

Winter wheat was sampled at various growth stages throughout each year. Fifty random tillers were collected from each plot and phytophagous insect diversity and abundance were determined from these samples using Berlese funnels. Predators were assessed by observations during a 30 second interval. Tables 11-13 provide insect results by variety treatment, growth stage and year, and Tables A1-A5 provide weekly suction trap captures for alates of RWA and other cereal aphids. The number of samples varied each year. This is due to crop failures or very low insect populations at the initial sampling.

In 1999-2000, minimal RWA abundance was observed in the wheat. This is mostly attributed to the late spring frost that occurred on May 13th. Predatory insects comprised a few coccinellids. Again in 2000-2001, few RWA were observed. This was attributed to a snow storm. At no point during the season did RWA or other pest insect reach a level of economic concern. With the exception of brown wheat mites in 2002-2003, wheat pest and predator insects remained scarce; primarily due to late-spring freezes and severe summer drought.

Table 11. Wheat insect populations by variety and growth stage in 1999-2000, Briggsdale, CO.

	2000							
	Tillering		Regrowth		Jointing		Boot	
	S	R	S	R	S	R	S	R
WF								
Army Cutworm (#/ft.2)	0.4		0.7					
Pale Western Cutworm (#/ft.2)								
Russian Wheat Aphid (#/50 tillers)	28.0	25.0	0.0	1.0	1.5	2.0	33.5	16.5
Other Cereal Aphids (#/50 tillers)	0.6		2.3		0.2			
Brown Wheat Mite (#/1.75 ft.2)	287.0		54.0		3.0			
Banks Grass Mite (#/50 tillers)	0.0		0.3		0.1			
WMF								
Army Cutworm (#/ft.2)	0.4		0.7					
Pale Western Cutworm (#/ft.2)								
Russian Wheat Aphid (#/50 tillers)	23.0	45.0	0.0	1.5	3.2	1.2	34.8	31.8
Other Cereal Aphids (#/50 tillers)								
Brown Wheat Mite (#/1.75 ft.2)								
Banks Grass Mite (#/50 tillers)	1.0							
W'WXXXX								
Army Cutworm (#/ft.2)	0.4		0.7					
Pale Western Cutworm (#/ft.2)								
Russian Wheat Aphid (#/50 tillers)	0.0	0.0	0.0	1.0	0.2	2.2	10.2	5.8
Other Cereal Aphids (#/50 tillers)	11.0	23.0						
Brown Wheat Mite (#/1.75 ft.2)								
Banks Grass Mite (#/50 tillers)	2.0	5.0						
WW'XXXX								
Army Cutworm (#/ft.2)	0.4		0.7					
Pale Western Cutworm (#/ft.2)								
Russian Wheat Aphid (#/50 tillers)	0.0	0.0	0.0	1.0	2.5	4.8	33.2	11.8
Other Cereal Aphids (#/50 tillers)	5.0	2.0						
Brown Wheat Mite (#/1.75 ft.2)								
Banks Grass Mite (#/50 tillers)								

S= Susceptible to Russian Wheat Aphid (Lamar)

R=Resistant to Russian Wheat Aphid (Prowers)

Table 12. Wheat insect abundance by year, variety and growth stage, Briggsdale, CO for the 2000-2001, 2001-2002, and 2002-2003 growing seasons.

	2000-2001		2001-2002				2002-2003			
	Tillering		Tillering		Jointing		Tillering		Jointing	
	S	R	S	R	S	R	S	R	S	R
WF										
Army Cutworm (#/ft.2)	0.0	0.0	0.0		0.0		0.0		0.0	
Pale Western Cutworm (#/ft.2)	0.0~~0~~	0.0~~0~~	0.0~~0~~		0.0~~0~~		0.0~~0~~		0.0~~0~~	
Russian Wheat Aphid (#/50 tillers)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other Cereal Aphids (#/50 tillers)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brown Wheat Mite (#/1.75 ft.2)	7.3	16.0	1.5		256.0		1.5		256.0	
Banks Grass Mite (#/50 tillers)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WMF										
Army Cutworm (#/ft.2)	0.1	0.0	0.4		0.0		0.4		0.0	
Pale Western Cutworm (#/ft.2)	0.0~~0~~	0.0~~0~~	0.0~~0~~		0.0~~0~~		0.0		0.0	
Russian Wheat Aphid (#/50 tillers)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other Cereal Aphids (#/50 tillers)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	00	0.0
Brown Wheat Mite (#/1.75 ft.2)	17.8	9.3	1.2		86.0		1.2		86.0	
Banks Grass Mite (#/50 tillers)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
W'WXXXX										
Army Cutworm (#/ft.2)	0.1	0.0								
Pale Western Cutworm (#/ft.2)	0.1	0.0								
Russian Wheat Aphid (#/50 tillers)	0.0	0.0	Failed Wheat				Failed Wheat			
Other Cereal Aphids (#/50 tillers)	0.0	0.0								
Brown Wheat Mite (#/1.75 ft.2)	3.8	16.3								
Banks Grass Mite (#/50 tillers)	0.0	0.0								
WW'XXXX										
Army Cutworm (#/ft.2)	0.1	0.0								
Pale Western Cutworm (#/ft.2)	0.1	0.0								
Russian Wheat Aphid (#/50 tillers)	0.0	0.0	Failed Wheat				Failed Wheat			
Other Cereal Aphids (#/50 tillers)	0.0	0.0								
Brown Wheat Mite (#/1.75 ft.2)	3.8	16.3								
Banks Grass Mite (#/50 tillers)	0.0	0.0								

S=Susceptible to Russian Wheat Aphid (Yuma)
R=Resistant to Russian Wheat Aphid (Yumar)

Table 13. Wheat insect abundance by year, variety and growth stage, Briggsdale, CO for the 2003-2004 and 2004-2005 growing seasons.								
	2003-2004						2004-2005	
	Tillering		Jointing		Heading		Tillering	
	S	R	S	R	S	R	S	R
WF								
Army Cutworm (#/ft.2)	0.0		0.0		0.0			
Pale Western Cutworm (#/ft.2)	0.0		0.0		0.0			
Russian Wheat Aphid (#/50 tillers)	0.0	0.0	0.2	0.0	4.2	2.5	0.8	0.8
Other Cereal Aphids (#/50 tillers)	0.0	0.0	0.8	0.2	7.5	5.5	0.2	0.0
Brown Wheat Mite (#/1.75 ft.2)	2.5	4.2	5.2	3.0	--			
Banks Grass Mite (#/50 tillers)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WMF								
Army Cutworm (#/ft.2)	0.0		0.0		0.0			
Pale Western Cutworm (#/ft.2)	0.0		0.0		0.0			
Russian Wheat Aphid (#/50 tillers)	0.0	0.0	1.8	0.2	9.2	5.2	0.8	1.0
Other Cereal Aphids (#/50 tillers)	0.0	0.0	6.5	0.0	3.5	3.	0.0	0.2
Brown Wheat Mite (#/1.75 ft.2)	16.8	2.0	11.0	13.0	--			
Banks Grass Mite (#/50 tillers)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
W'WXXXX								
Army Cutworm (#/ft.2)	0.0		0.0		0.0			
Pale Western Cutworm (#/ft.2)	0.0		0.		0.0			
Russian Wheat Aphid (#/50 tillers)	0.0	0.0	0.0	0.2	6.5	5.0	0.2	0.8
Other Cereal Aphids (#/50 tillers)	0.0	0.5	2.8	0.5	6.0	7.5	0.8	0.5
Brown Wheat Mite (#/1.75 ft.2)					--			
Banks Grass Mite (#/50 tillers)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WW'XXXX								
Army Cutworm (#/ft.2)	Failed Wheat							
Pale Western Cutworm (#/ft.2)								
Russian Wheat Aphid (#/50 tillers)							0.5	0.5
Other Cereal Aphids (#/50 tillers)							0.2	0.0
Brown Wheat Mite (#/1.75 ft.2)								
Banks Grass Mite (#/50 tillers)							0.0	0.0

S=Susceptible to Russian Wheat Aphid (Akron)
R=Resistant to Russian Wheat Aphid (Ankor)

Corn

Field corn was scouted for pest and beneficial insects at five different growth stages each year (V-2, V-10, pollen shed, soft dough, and dry down). Table 14 provides the insect populations found by day and year. Similar to wheat, there were few corn pest or beneficial insects found except for coccinellids in 1999 and Banks grass mites in 2005. This is mostly attributed to drought conditions.

Table 14. Corn pest and predator insects by year and sample date, Briggsdale, CO.										
	1999			2000		2001	2002	2003	2005	
Pests (# per plant)	29-Jul	16-Aug	9-Jan	7-Jan	8-Aug	14-Aug	24-Jun	23-Aug	23-Aug	8-Sep
Western corn rootworm	0.6	1.2	0.0	0.0	0.7	0.6	0.1	0.2	4.0	0.0
Banks grass mite	0.0	0.0	0.0	0.0	0.	0.0	0.0	0.0	19.0	173.0
Twp-spotted Spider Mite	0.0	0.0	0.0	0.0	0.0	0.0	0.0.	0.0	0.0	19.0
Corn earworm	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Natural Enemies (total/sampling date)										
Coccinellids	10.0	0.0	0.0	1.9	0.1	0.1	0.0	0.0	2.0	0.0
Lacewings	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0
Mite destroyer	0.0	0.0	0.0	0.3	0.2	0.0	0.0	0.0	0.0	0.0
Pirate bugs	5.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	3.0	0.0
Predatory mites	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0
Spider	0.0	0.0	1.0	0.0	0.1	0.0	0.0	0.0	4.0	0.0

Years or insects counts not included when insects were not found or the corn crop had failed.

Sunflower

Sunflower was sampled at three growth stages throughout the season (2-3 leaf, R5 and R7). Table 15 provides the pest and beneficial insect populations found from 1999-2003. Stem and seed weevil were the only pest insects consistently observed. Neither reached a point of economic concern. The most stem weevils were found in fall of 2003; however lodging was observed. Minute pirate bugs were the most common beneficial insect, and they were most abundant in the initial 1999 sample. Persistent dry conditions contributed to the low insect populations.

Table 15. Sunflower pest and predator insects by day and year, Briggsdale, CO.								
	1999		2000			2001		2003
Pests (# per plant)	26-Jul	23 Aug.*	27-Jun	13 Sept.	9 Oct.	14 Aug.	15 Oct.	16 Oct.
Cutworms	0.0	0.0	3.1	0.0	0.0	0.0	0.0	0.0
Stem Weevil scars	0.1	0.0	0.0	0.0	4.1	0.0	4.2	22.5
Seed weevil	0.7	0.8	0.0	0.0	3.6	0.1	2.5	0.2
Sunflower moth	0.0	0.1	0.0	0.0	1.0	0.0	0.0	0.0
Banded SF moth	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aphids	8.2	3.0	0.0	0.0	0.0	0.0	0.0	0.0
Natural Enemies (total/sampling date)								
Coccinellids	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lacewings	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Nabid	1.0	2.0	0.0	0.1	0.0	0.0	0.0	0.0
Pirate bugs	30.0	1.0	0.0	0.7	0.0	0.2	0.0	0.0
Mummies	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Spiders	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Syrphids	0.00	0.0	0.0	0.0	0.0	0.1	00	0.0

*Date of sampling of larval growth stage

Foxtail Millet

Fifty random tillers were collected from each plot at 2-3 leaf, boot and heading (Table 16). Foxtail millet failed in 2003 and was not planted in 2000. Consistent with wheat, corn and sunflower, only small populations of insects were found in these samples. Thrips were the only consistent pest found. Thrips can be a significant pest for millet and should be closely monitored in the future. Coccinellids, minute pirate bugs and nabids were the only beneficial insects found.

Table 16. Foxtail Millet pest and predator insects by day and year, Briggsdale, CO.

	1999		2004			2005	
Pests (# per row foot)	26-Jul	23-Aug	12-Jul	27-Jul	6-Sep	Boot	Heading
Greenbug	0	0					4*
Other cereal aphids	0	0				6*	1*
Thrips (% damage)	2%		36*	9*	29*		
European corn borer		0					
W. Wheat stem maggot		0					
Natural Enemies (total/sampling date)							
Coccinellids	8	3					
Lacewings	0	1					
Pirate bugs	4	4					
Predatory mites	0	0					
Mummies	0	0					
Nabid	1	0					

* #/50 tillers

Soybean

Soybean was scouted on three occasions in 1999 (Table 17). Minimal damage by cutworms, flea beetles, and thrips was observed in the first sample, which declined as the season progressed. Grasshoppers and Mexican bean beetles damaged the crop later in the season. Few predatory insects were found.

Spring Barley, Triticale, Austrian Winter Pea, Grain Sorghum

None of these crops were sampled for insects.

Grasshoppers

Grasshoppers can damage all the crops grown in this area, however, economically significant grasshopper damage was not observed during this seven year period.

Table 17. Soybean insect damage, Briggsdale, CO, 1999.			
	Date		
Pests (% damage)	6-Jul	26-Jul	23 Aug.
Cutworms	2%		
Flea beetle	1%		
Thrips	5%		
Grasshoppers		2%	1%
Mexican bean beetle		0%	2%
Earworm			0
Aphids	0	0	0
Natural Enemies (total/sampling date)			
Coccinellids		0	0
Lacewings		0	0
Pirate bugs		0	0
Mummies		0	0
Nabid		0	1

Conclusion- Entomological Studies

Seven years of late spring freezes and/or severe summer drought provided an inhospitable environment for insects, and none reached levels of economic concern. Most insects were collected in the late spring and early summer, when plant vigor was at its highest. As the air temperatures rose and the soil moisture was depleted, insect abundance declined.

With new cropping systems in place and timely summer moisture, larger insect populations could be favored by the crops now grown. This would provide the opportunity to evaluate and implement appropriate IPM tactics for the cropping systems. Additional insect observations and herbicides used on the various cropping systems are presented in the Appendices.

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Appendix

Table A1. Suction Trap counts from Briggsdale, CO, 2001.

DATE	RWA	BCO	GB	CLA	RGA	EGA	YSA	NON
		--------------- Number trapped in one week ---------------						
1-May	0	0	1	0	0	0	0	0
17-May	0	0	0	0	0	0	0	2
7-Jun	0	0	13	1	0	0	0	16
14-Jun	0	46	7	2	0	0	0	10
22-Jun	0	24	9	0	0	0	0	10
11-Jul	0	2	0	0	0	0	0	1
18-Jul	0	1	3	0	0	0	0	1
24-Jul	0	1	10	0	0	6	0	4
2-Aug	0	43	36	0	0	1	0	1
7-Aug	0	30	5	0	0	7	0	0
13-Aug	0	29	5	0	0	5	0	4
21-Aug	1	21	24	1	0	6	0	12
27-Aug	0	19	4	0	0	25	0	6
4-Sep	1	12	0	1	0	5	0	5
11-Sep	0	3	0	1	0	2	0	0
18-Sep	0	20	0	1	0	1	0	14
9-Oct	3	186	3	7	0	8	0	67
TOTAL	5	437	120	14	0	66	0	153

Note all suction trap and pheromone data were provided by Terri Randolph. RWA = Russian wheat aphid, BCO = bird cherry-oat aphid, GB = greenbug, CLA = corn leaf aphid, RGA = rose grass aphid, EGA = English grain aphid, YSA = yellow sugarcane aphid, and NON = other, non-cereal aphids.

Table A2. Suction Trap counts from Briggsdale, CO 2002.

DATE	RWA	BCO	GB	CLA	RGA	EGA	YSA	NON
		--------------- Number trapped in one week ---------------						
3-May	0	0	0	0	0	0	0	0
9-May	0	0	0	0	0	0	0	1
16-May	0	0	0	0	0	0	0	0
14-Jun	2	3	1	0	0	2	0	246
20-Jun	0	0	0	0	0	0	0	0
27-Jun	0	0	0	0	0	0	0	0
3-Jul	0	0	0	0	0	0	0	0
11-Jul	0	0	0	0	0	0	0	0
25-Jul	0	0	0	0	0	0	0	0
1-Aug	0	0	0	0	0	0	0	0
7-Aug	0	0	0	0	0	0	0	0
15-Aug	0	0	0	0	0	0	0	0
21-Aug	0	0	0	0	0	0	0	0
29-Aug	0	0	0	0	0	0	0	0
5-Sep	0	6	0	0	0	3	0	8
13-Sep	0	8	1	3	0	1	0	10
19-Sep	0	3	0	7	0	0	0	33
27-Sep	0	11	0	0	0	2	0	50
4-Oct	0	4	0	0	0	0	0	11
11-Oct	0	0	0	0	0	1	0	1
18-Oct	0	2	0	3	0	0	0	26
24-Oct	0	1	0	0	0	2	0	15
TOTAL	2	38	2	13	0	11	0	401

RWA = Russian wheat aphid, BCO = bird cherry-oat aphid, GB = greenbug, CLA = corn leaf aphid, RGA = rose grass aphid, EGA = English grain aphid, YSA = yellow sugarcane aphid, and NON = other, non-cereal aphids.

Table A3. Suction Trap counts from Briggsdale, CO, 2003.							
DATE	RWA	GB	BCO	CLA	EGA	RGA	NON
		--------------- Number trapped in one week ---------------					
30-May	7	10	67	9	3	0	12
6-Jun	1	0	0	0	0	0	1
13-Jun	0	0	0	0	0	0	0
17-Jul	1	3	1	0	5	0	3
25-Jul	0	1	1	1	5	0	6
31-Jul	0	0	8	0	1	0	0
15-Aug	0	0	0	0	0	0	0
18-Aug	1	1	8	1	3	0	4
21-Aug	0	0	1	0	1	0	0
28-Aug	0	0	0	0	3	0	0
5-Sep	1	0	0	0	0	0	4
12-Sep	0	1	1	0	7	0	0
18-Sep	1	0	1	0	1	0	2
30-Sep	1	1	18	6	6	0	92
TOTAL	13	17	106	17	35	0	124

RWA = Russian wheat aphid, BCO = bird cherry-oat aphid, GB = greenbug, CLA = corn leaf aphid, RGA = rose grass aphid, EGA = English grain aphid, YSA = yellow sugarcane aphid, and NON = other, non-cereal aphids.

Table A4. Suction Trap counts from Briggsdale, CO, 2004.							
DATE	RWA	GB	BCO	CLA	EGA	RGA	NON
		--------------- Number trapped in one week ---------------					
3-Jun	25	18	12	1	1	1	19
11-Jun	20	1	9	0	1	2	4
25-Jun	4	2	1	0	0	0	0
7-Jul	376	3	10	0	4	10	23
13-Jul	3	0	3	0	0	0	2
22-Jul	0	0	0	0	0	0	1
6-Aug	0	0	9	0	0	0	1
12-Aug	0	1	13	0	1	0	0
3-Sep	0	0	12	2	5	1	4
8-Sep	0	0	0	0	3	0	4
10-Sep	0	0	0	0	1	0	0
16-Sep	0	0	1	0	0	0	3
23-Sep	0	0	10	0	1	9	12
7-Oct	0	0	9	3	3	3	20
15-Oct	0	0	19	0	0	5	6
22-Oct	3	0	7	0	0	0	2
TOTAL	428	25	105	6	20	31	101

RWA = Russian wheat aphid, BCO = bird cherry-oat aphid, GB = greenbug, CLA = corn leaf aphid, RGA = rose grass aphid, EGA = English grain aphid, YSA = yellow sugarcane aphid, and NON = other, non-cereal aphids.

Table A5. Suction Trap counts from Briggsdale, CO, 2005.

DATE	RWA	GB	BCO	CLA	EGA	RGA	NON
		--------------- Number trapped in one week ---------------					
30-May	44	0	3	0	0	0	16
6-Jun	14	0	3	1	0	0	6
13-Jun	135	5	2	0	0	0	4
20-Jun	585	2	11	7	2	0	5
27-Jun	41	0	8	1	1	0	5
4-Jul	13	2	3	0	0	0	1
11-Jul	0	0	0	0	0	0	0
18-Jul	0	0	11	0	0	0	0
25-Jul	2	0	1	1	0	0	0
2-Aug	0	0	0	0	0	0	0
27-Sep	0	0	17	0	2	2	11
14-Oct	0	0	2	0	0	1	2
TOTAL	834	9	61	10	5	3	50

Notes: Trap was not functional until the end of May.
Due to time constraints, trap catches were done monthly August-October.
Trap was not turned on for the August trap so nothing was collected.

RWA = Russian wheat aphid, BCO = bird cherry-oat aphid, GB = greenbug, CLA = corn leaf aphid, RGA = rose grass aphid, EGA = English grain aphid, YSA = yellow sugarcane aphid, and NON = other, non-cereal aphids.

Table A6. Pheromone trap catches for corn and sunflower insects, Briggsdale, CO, 2002.

Date	European Corn Borer	Western Bean Cutworm	Corn Earworm	Sunflower Moth	Banded Sunflower Moth
	----- # trapped since previous date (about 1 week) -----				
23-May	2				
30-May	2				
6-Jun	0				
13-Jun	2				
20-Jun	1				
27-Jun	1	0		0	0
3-Jul	1	0		0	0
11-Jul	0	2		0	0
18-Jul	0	7		0	0
25-Jul	0	5		0	0
1-Aug	0	0		0	0
7-Aug	0	0	3	0	0
15-Aug	0	0	15	0	0
21-Aug	0	0	2	0	0
29-Aug	0		2	1	0
5-Sep	1		50	1	0
13-Sep	0		106	0	0
20-Sep			11		
27-Sep			2		
TOTAL	8	14	189	1	0.0

Table A7. Pheromone trap catches for corn and sunflower insects, Briggsdale, CO,2003.

Date	European Corn Borer	Western Bean Cutworm	Corn Earworm	Sunflower Moth	Banded Sunflower Moth	Army Cutworm	Pale Western Cutworm
	----- # trapped since previous date (about 1 week) -----						
7-Jun	0	0	--	0	0	--	--
2-Jul	0	1	--	0	0	--	--
17-Jul	0	4	7	1	2	--	--
25-Jul	0	0	11	3	1	--	--
31-Jul	0	0	21	1	0	--	--
8-Aug	0	3	37	5	2	0	3
15-Aug	1	1	28	2	2	2	2
21-Aug	1	0	2	1	0	3	1
28-Aug	0	0	--	1	1	4	3
5-Sep	0	0	27	3	1	7	16
12-Sep	2	--	3	0	1	13	39
18-Sep	0	--	0	0	3	8	43
30-Sep	--	--	--	--	--	34	70
9-Oct	--	--	--	--	--	35	45
17-Oct	--	--	--	--	--	9	4
TOTAL	4	8	136	14	12	114	224

Table A8. Pheromone trap catches for corn and sunflower insects, Briggsdale, CO,2004.

Date	E.C. Borer	Corm Earworm	Sfl. Moth	B.S. Moth	Army Cutworm	P.W. Cutworm	F.A. Cutworm
	----- # trapped since previous date (about 1 week) -----						
21-Jun	0						
6-Jan	0						
2-Jul	0						
8-Jul	2	0					
22-Jul	0	9					
30-Jul	36						0
9-Aug	42	0					0
12-Aug	17	0	1	1	0	1	6
25-Aug			2	7	0	2	4
10-Sep	1				28	0	
16-Sep	0				2	0	
TOTAL	96	9	3	8	30	3	10

Table A9. Weed control, Briggsdale, CO, 1999.

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

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

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

Table A10. Weed control, Briggsdale, CO, 2000.

Crop	Herbicide/Tillage	Rate (English)	Rate (Metric)	Weed Pressure	Cost	Date Applied
Rotation: Wheat-Fallow						
Wheat:	Ally 2,4-D ester 4#	0.1 oz/A 8 oz/A	7.0 g/ha 0.58 l/ha	II II	$2.30/A $0.82/A	4 May 2000 4 May 2000
Fallow:	Fallowmaster* Fallowmaster*	44 oz/A 44 oz/A	3.2 l/ha 3.2 l/ha	I I	$6.49/A $6.49/A	13 May 2000 21 June 2000
Rotation: Wheat-Millet-Fallow						
Wheat:	Ally 2,4-D ester 4#	0.1 oz/A 8 oz/A	7.0 g/ha 0.58 l/ha	II II	$2.30/A $0.82/A	4 May 2000 4 May 2000
Millet:	Fallowmaster* Round-up Ultra*	44 oz/A 24 oz/A	3.21 l/ha 1.75 l/ha	I I	$6.49/A $7.23/A	13 May 2000 21 June 2000
Fallow:	Fallowmaster* Fallowmaster*	44 oz/A 44 oz/A	3.21 l/ha 3.21 l/ha	I I	$6.49/A $6.49/A	13 May 2000 21 June 2000
Rotation: Wheat-Wheat-Corn-Soybean-Sunflower-Pea:						
Wheat:	Ally 2,4-D ester 4# Fallomaster* 2,4D ester	0.1 oz/A 8 oz/A 32 oz/A 8 oz/A	7.0 g/ha 0.58 l/ha 2.33 l/ha 0.58 l/ha	II II I I	$2.30/A $0.82/A $4.72/A $0.82/A	4 May 2000 4 May 2000 2 Aug. 2000 2 Aug. 2000
Wheat:	Ally 2,4-D ester 4#	0.1 oz/A 8 oz/A	7.0 g/ha 0.58 l/ha	II II	$2.30/A $0.82/A	4 May 2000 4 May 2000
Corn:	Prowl Atrazine 4L Fallowmaster*	32 oz/A 32 oz/A(1#) 44 oz/A	2.33 l/ha 2.33 l/ha(454g) 3.21 l/ha	I I I	$5.11/A $2.80/A $6.49/A	13 May 2000 13 May 2000 13 May 2000
Soybeans:	Round-up Ultra* Round-up Ultra*	32 oz/A 24oz/A	2.33 l/ha 1.75 l/ha	I I	$9.64/A $7.23/A	13 May 2000 22 June 2000
Sunflowers:	Landmaster* Prowl	40 oz/A 48 oz/A	2.92 l/ha 3.50 l/ha	I I	$5.54/A $7.66/A	13 May 2000 13 May 2000
Peas	Fallowmaster* 2,4-D ester 4#	44 oz/A 8 oz/A	3.21 l/ha 0.58 l/ha	I I	$6.49/A $0.82/A	21 June 2000 21 June 2000
Rotation: Opportunity						
Soybeans:	Round-up Ultra* Round-up Ultra*	32 oz/A 24oz/A	2.33 l/ha 1.75 l/ha	I I	$9.64/A $7.23/A	13 May 2000 22 June 2000

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

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

Table A11. Weed control, Briggsdale, CO, 2001.

Crop	Herbicide/Tillage	Rate (English)	Rate (Metric)	Cost	Date Applied
Rotation: Wheat-Fallow					
Wheat:	Ally	0.1 oz/A	7.0 g/ha	$2.30/A	14 April 2001
	2,4-D ester 4#	8 oz/A	0.58 l/ha	$0.82/A	14 April 2001
(Stubble)	FallowMaster*	44 oz/A	3.2 l/ha	$6.49/A	27 July 2001
	Round-up*	24 oz/A	1.75 l/ha	$7.23/A	4 October 2001
Fallow:	Round-up*	20 oz/A	1.46 l/ha	$6.02/A	9 May 2001
	Clarity	6 oz/A	0.44 l/ha	$4.21/A	9 May 2001
	FallowMaster*	44 oz/A	3.2 l/ha	$6.49/A	13 June 2001
	FallowMaster*	44 oz/A	3.2 l/ha	$6.49/A	27 July 2001
(Wheat Planting)	Round-up	20 oz/A	1.46 l/ha	$6.02/A	7 September 2001
Rotation: Wheat-Millet-Fallow					
Wheat:	Ally	0.1 oz/A	7.0 g/ha	$2.30/A	14 April 2001
	2,4-D ester 4#	8 oz/A	0.58 l/ha	$0.82/A	14 April 2001
(Stubble)	FallowMaster*	44 oz/A	3.2 l/ha	$6.49/A	27July 2001
	Round-up*	24 oz/A	1.75 l/ha	$7.23/A	4 October 2001
Millet:	Round-up *	20 oz/A	1.46 l/ha	$6.02/A	9 May 2001
	Clarity	6 oz/A	0.44 l/ha	$4.21/A	9 May 2001
	Round-up*	24 oz/A	1.75 l/ha	$7.23/A	13 June 2001
Fallow:	Round-up*	20 oz/A	1.46 l/ha	$6.02/A	9 May 2001
	Clarity	6 oz/A	0.44 l/ha	$4.21/A	9 May 2001
	FallowMaster*	44 oz/A	3.2 l/ha	$6.49/A	13 June 2001
	FallowMaster*	44 oz/A	3.2 l/ha	$6.49/A	27 July 2001
(Wheat Planting)	Round-up*	20 oz/A	1.46 l/ha	$6.02/A	7 September 2001
Rotation: Wheat-Wheat-Corn-Soybean-Sunflower-Pea:					
Wheat:	Ally	0.1 oz/A	7.0 g/ha	$2.30/A	14 April 2001
	2,4-D ester 4#	8 oz/A	0.58 l/ha	$0.82/A	14 April 2001
(Stubble)	FallowMaster*	44 oz/A	3.2 l/ha	$6.49/A	27July 2001
	Round-up*	24 oz/A	1.75 l/ha	$7.23/A	4 October 2001
Wheat:	Ally	0.1 oz/A	7.0 g/ha	$2.30/A	14 April 2001
	2,4-D ester 4#	8 oz/A	0.58 l/ha	$0.82/A	14 April 2001
(Stubble)	FallowMaster*	44 oz/A	3.2 l/ha	$6.49/A	27July 2001
(Wheat Planting)	Round-up*	24 oz/A	1.75 l/ha	$7.23/A	4 October 2001
Corn:	Fallowmaster*	32 oz/A	2.33l/ha	$5.31/A	7 May 2001
	Prowl 3.3 EC	32 oz/A	2.33l/ha	$5.11/A	7 May 2001
	Atrazine 4L	32 oz/A	2.33l/ha	$2.80/A	7 May 2001
Soybeans:	Round-up*	16 oz/A	1.17 l/ha	$4.82/A	24 April 2001
	2,4-D Ester 4	8 oz/A	0.58 l/ha	$0.58/A	24 April 2001
	Authority	2.67 oz/A	187 g/ha	$9.91/A	9 May 2001
	Round-up*	24 oz/A	1.75 l/ha	$7.23/A	13 June 2001
Sunflowers:	Round-up*	16 oz/A	1.17 l/ha	$4.82/A	24 April 2001
	2,4-D Ester 4	8 oz/A	0.58 l/ha	$0.58/A	24 April 2001
	Spartan	2.67 oz/A	187 g/ha	$9.91/A	9 May 2001
Forage Soybeans:	Round-up*	16 oz/A	1.17 l/ha	$4.82/A	24 April 2001
	2,4-D Ester 4	8 oz/A	0.58 l/ha	$0.58/A	24 April 2001
	Authority	2.67 oz/A	187 g/ha	$9.91/A	9 May 2001
Rotation: Opportunity					
Wheat:	Ally	0.1 oz/A	7.0 g/ha	$2.30/A	14 April 2001
	2,4-D ester 4#	8 oz/A	0.58 l/ha	$0.82/A	14 April 2001
(Stubble)	FallowMaster*	44 oz/A	3.2 l/ha	$6.49/A	8 July 2001
	Round-up*	24 oz/A	1.75 l/ha	$7.23/A	4 October 2001

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

Table A12. Weed control, Briggsdale, CO, 2002.					
Crop	**Herbicide/Tillage**	**Rate (English)**	**Rate (Metric)**	**Cost**	**Date Applied**
Rotation: Wheat-Fallow					
Wheat:(Stubble)	RT Master*	16 oz/ac	1.17 l/ha	$2.99	20 Sept. 2002
Fallow:	RT Master*	32 oz/ac	2.33 l/ha	$5.98	15 June 2002
	Round-up Ultra*	16 oz/ac	1.17 l/ha	$4.06	10 July 2002
	2,4-D Lo Vol	8 oz/ac	0.58 l/ha	$1.17	10 July 2002
(Wheat Planting)	RT Master*	16 oz/ac	1.17 l/ha	$2.99	20 Sept. 2002
Rotation: Wheat-Millet-Fallow					
Wheat:(Stubble)	RT Master*	16 oz/ac	1.17 l/ha	$2.99	20 Sept. 2002
Millet:	RT Master*	32 oz/ac	2.33 l/ha	$5.98	15 June 2002
Fallow:	RT Master*	32 oz/ac	2.33 l/ha	$5.98	15 June 2002
	Round-up Ultra*	16 oz/ac	1.17 l/ha	$4.06	10 July 2002
	2,4-D Lo Vol	8 oz/ac	0.58 l/ha	$1.17	10 July 2002
(Wheat Planting)	RT Master*	16 oz/ac	1.17 l/ha	$2.99	20 Sept. 2002
Rotation: Wheat-Wheat-Corn-Corn-Sunflower-Fallow:					
Wheat:	Round-up Ultra*	16 oz/ac	1.17 l/ha	$4.06	10 July 2002
	2,4-D Lo Vol	8 oz/ac	0.58 l/ha	$1.17	10 July 2002
(Wheat Planting)	RT Master*	16 oz/ac	1.17 l/ha	$2.99	20 Sept. 2002
Wheat:(Stubble)	RT Master*	16 oz/ac	1.17 l/ha	$2.99	20 Sept. 2002
Corn1:	Prowl	32 oz/ac	2.33 l/ha	$5.16	6 June 2002
	Atrazine 4L	32 oz/ac	2.33 l/ha	$2.54	6 June 2002
	RT Master*	32 oz/ac	2.33 l/ha	$5.98	15 June 2002
Corn2:	RT Master*	32 oz/ac	2.33 l/ha	$5.98	15 June 2002
	Round-up UltraMAX*	20 oz/ac	1.46 l/ha	$7.56	5 July 2002
Sunflowers:	Spartan	2.0 oz/Ac	140 g/ha	$5.67	23 May 2002
	RT Master*	32 oz/ac	2.33 l/ha	$5.98	15 June 2002
Fallow:	RT Master*	32 oz/ac	2.33 l/ha	$5.98	15 June 2002
	Round-up Ultra*	16 oz/ac	1.17 l/ha	$4.06	10 July 2002
	2,4-D Lo Vol	8 oz/ac	0.58 l/ha	$1.17	10 July 2002
(Wheat planting)	RT Master*	16 oz/ac	1.17 l/ha	$2.99	20 Sept. 2002
Rotation: Opportunity					
Grain Sorghum:	RT Master*	32 oz/ac	2.33 l/ha	$5.98	5 July 2002
	Marksman	32 oz/Ac	2.33 l/ha	$7.13	4 June 2002
*Applied 1 qt/100 gal. of Choice ($0.25/ac) to all Round-up products and 2 qt/100 gal. of Activator 90 ($0.54/ac) with RT Master.					

Table A13. Weed control methods including herbicide rate, cost and date applied at Briggsdale in 2003 season.

Crop	Herbicide/Tillage	Rate (English)	Rate (Metric)	Cost	Date Applied
Rotation: Wheat-Fallow					
Wheat:	Ally XP	0.10 oz/A	7.02 g/ha	$2.33/A	21 April
	2,4-D LV6	5.3 oz/A	0.39 l/ha	$0.82/A	21 April
	Clarity	2.0 oz/A	0.15 l/ha	$1.46/A	21 April
(Stubble)	RT Master	20 oz/A	1.46 l/ha	$3.40/A	17 July
	2,4-D LV6	10 oz/A	0.73 l/ha	$1.54/A	17 July
	RT Master	24 oz/A	1.75 l/ha	$4.08/A	13 August
	2,4-D LV6	10 oz/A	0.73 l/ha	$1.54/A	13 August
	Atrazine 4L	24 oz/A	1.75 l/ha	$1.86/A	22 September
	RT Master	20 oz/A	1.46 l/ha	$3.40/A	22 September
Fallow:	RT Master	24 oz/A	1.75 l/ha	$4.08/A	29 April
	RT Master	32 oz/A	2.33 l/ha	$5.44/A	14 May
	RT Master	24 oz/A	1.75 l/ha	$4.08/A	17 June
	2,4-D LV6	10 oz/A	0.73 l/ha	$1.54/A	17 June
	RT Master	24 oz/A	1.75 l/ha	$4.08/A	13 August
	2,4-D LV6	10 oz/A	0.73 l/ha	$1.54/A	13 August
(Wheat Planting)	RT Master	20 oz/A	1.46 l/ha	$3.40/A	22 September
Rotation: Wheat-Millet-Fallow					
Wheat:	Ally XP	0.10 oz/A	7.02 g/ha	$2.33/A	21 April
	2,4-D LV6	5.3 oz/A	0.39 l/ha	$0.82/A	21 April
	Clarity	2.0 oz/A	0.15 l/ha	$1.46/A	21 April
(Stubble)	RT Master	20 oz/A	1.46 l/ha	$3.40/A	17 July
	2,4-D LV6	10 oz/A	0.73 l/ha	$1.54/A	17 July
	RT Master	24 oz/A	1.75 l/ha	$4.08/A	13 August
	2,4-D LV6	10 oz/A	0.73 l/ha	$1.54/A	13 August
	Atrazine 4L	24 oz/A	1.75 l/ha	$1.86/A	22 September
	RT Master	20 oz/A	1.46 l/ha	$3.40/A	22 September
Millet:	RT Master	24 oz/A	1.75 l/a	$4.08/A	29 April
	RT Master	32 oz/A	2.33 l/ha	$5.44/A	14 May
	Round-up Ultra MAX	26 oz/A	1.90 l/ha	$10.76/A	17 June
(to kill)	RT Master	24 oz/A	1.75 l/ha	$4.08/A	13 August
	2,4-D LV6	10 oz/A	0.73 l/ha	$1.54/A	13 August
Fallow:	RT Master	24 oz/A	1.75 l/ha	$4.08/A	29 April
	RT Master	32 oz/A	2.33 l/ha	$5.44/A	14 May
	RT Master	24 oz/A	1.75 l/ha	$4.08/A	17 June
	2,4-D LV6	10 oz/A	0.73 l/ha	$1.54/A	17 June
	RT Master	24 oz/A	1.75 l/ha	$4.08/A	13 August
	2,4-D LV6	10 oz/A	0.73 l/ha	$1.54/A	13 August
(Wheat Planting)	RT Master	20 oz/A	1.46 l/ha	$3.40/A	22 September
Rotation:Wheat-Wheat-Corn-Corn-Sunflower-Fallow:					

Wheat:	Harmony Extra	0.40 oz/A	28.1 g/ha	$5.67/A	14 May
	2,4-D LV6	5.3 oz/A	0.39 l/ha	$0.82/A	14 May
	RT Master	24 oz/A	1.75 l/ha	$4.08/A	13 August
	2,4-D LV6	10 oz/A	0.73 l/ha	$1.54/A	13 August
(Wheat Planting)	RT Master	20 oz/A	1.46 l/ha	$3.40/A	22 September
Wheat:	Harmony Extra	0.40 oz/A	28.1 g/ha	$5.67/A	14 May
	2,4-D LV6	5.3 oz/A	0.39 l/ha	$0.82/A	14 May
(Stubble)	RT Master	24 oz/A	1.75 l/ha	$4.08/A	13 August
	2,4-D LV6	10 oz/A	0.73 l/ha	$1.54/A	13 August
	Atrazine 4L	24 oz/A	1.75 l/ha	$1.86/A	22 September
	RT Master	20 oz/A	1.46 l/ha	$3.40/A	22 September
Corn1:	RT Master	24 oz/A	1.75 l/ha	$4.08/A	29 April
	RT Master	32 oz/A	2.33 l/ha	$5.44/A	14 May
	Prowl	32 oz/A	2.33 l/ha	$5.54/A	28 May
	Atrazine 4L	32 oz/A	2.33 l/ha	$2.46/A	28 May
Corn2:	RT Master	24 oz/A	1.75 l/ha	$4.08/A	29 April
	RT Master	32 oz/A	2.33 l/ha	$5.44/A	14 May
	Round-up Ultra MAX	26 oz/A	1.90 l/ha	$10.76/A	17 June
Sunflowers:	RT Master	24 oz/A	1.75 l/ha	$4.08/A	29 April
	RT Master	32 oz/A	2.33 l/ha	$5.44/A	14 May
	Spartan	2.0 oz/A	140 g/ha	$5.67/A	22 May
Fallow:	RT Master	24 oz/A	1.75 l/ha	$4.08/A	29 April
	RT Master	32 oz/A	2.33 l/ha	$5.44/A	14 May
	RT Master	24 oz/A	1.75 l/ha	$4.08/A	17 June
	2,4-D LV6	10 oz/A	0.73 l/ha	$1.54/A	17 June
	RT Master	24 oz/A	1.75 l/ha	$4.08/A	13 August
	2,4-D LV6	10 oz/A	0.73 l/ha	$1.54/A	13 August
(Wheat planting)	RT Master	20 oz/A	1.46 l/ha	$3.40/A	22 September
Rotation: Opportunity					
Millet:	RT Master	24 oz/A	1.75 l/a	$4.08/A	29 April
	RT Master	32 oz/A	2.33 l/ha	$5.44/A	14 May
	Round-up Ultra MAX	26 oz/A	1.90 l/ha	$10.76/A	17 June
(to kill)	RT Master	24 oz/A	1.75 l/ha	$4.08/A	13 August
	2,4-D LV6	10 oz/A	0.73 l/ha	$1.54/A	13 August
*Applied 1 qt/100 gal. of Choice ($0.25/ac) to all Round-up products and 2 qt/100 gal. of Activator 90 ($0.54/ac) with RT Master.					

Table A14. Weed control methods including herbicide rate, cost and date applied at Briggsdale in 2004 season.

Crop	Herbicide/Tillage	Rate (English)	Rate (Metric)	Cost	Date Applied
Rotation: Wheat-Fallow					
Wheat:	Ally XP	0.10 oz/ac	7.02 g/ha		4 May 2004
	2,4-D LV6	8 oz/ac	0.58 l/ha		4 May 2004
(Stubble)	RT Master	20 oz/ac	1.46 l/ha		19 July 2004
	2,4-D LV6	6 oz/ac	0.44 l/ha		19 July 2004
	Clarity	2 oz/a	0.15 l/ha		19 July 2004
Fallow:	RT Master	20 oz/ac	1.46 l/ha		1 June 2004
	2,4-D LV6	6 oz/ac	0.44 l/ha		1 June 2004
	Banvel	2 oz/ac	0.15 l/ha		1 June 2004
	RT Master	20 oz/ac	1.46 l/ha		2 July 2004
	2,4-D LV6	6 oz/ac	0.44 l/ha		2 July 2004
	Clarity	2 oz/ac	0.15 l/ha		2 July 2004
(Wheat Planting)	RT Master	32 oz/ac	2.33 l/ha		18 Sept. 2004
Rotation: Wheat-Millet-Fallow					
Wheat:	Ally XP	0.10 oz/ac	7.02 g/ha		4 May 2004
	2,4-D LV6	8 oz/ac	0.58 l/ha		4 May 2004
(Stubble)	RT Master	20 oz/ac	1.46 l/ha		19 July 2004
	2,4-D LV6	6 oz/ac	0.44 l/ha		19 July 2004
	Clarity	2 oz/a	0.15 l/ha		19 July 2004
Millet:	RT Master	16 oz/ac	1.17 l/ha		5 May 2004
	2,4-D LV6	16 oz/ac	1.17 l/ha		5 May 2004
	Round-up UltraMAX	26 oz/ac	1.90 l/ha		1 June 2004
Fallow:	RT Master	16 oz/ac	1.17 l/ha		5 May 2004
	2,4-D LV6	16 oz/ac	1.17 l/ha		5 May 2004
	RT Master	20 oz/ac	1.46 l/ha		1 June 2004
	2,4-D LV6	6 oz/ac	0.44 l/ha		1 June 2004
	Banvel	2 oz/ac	0.15 l/ha		1 June 2004
	RT Master	20 oz/ac	1.46 l/ha		2 July 2004
	2,4-D LV6	6 oz/ac	0.44 l/ha		2 July 2004
	Banvel	2 oz/ac	0.15 l/ha		2 July 2004
(Wheat Planting)	RT Master	32 oz/ac	2.33 l/ha		18 Sept. 2004
Rotation:Wheat-Wheat-Corn-Corn-Sunflower-Fallow:					
Wheat:	Ally XP	0.10 oz/ac	7.02 g/ha		4 May 2004
	2,4-D LV6	8 oz/ac	0.58 l/ha		4 May 2004
	RT Master	20 oz/ac	1.46 l/ha		19 July 2004
	2,4-D LV6	6 oz/ac	0.44 l/ha		19 July 2004
	Clarity	2 oz/a	0.15 l/ha		19 July 2004
(Wheat Planting)	RT Master	32 oz/ac	2.33 l/ha		18 Sept. 2004

Wheat:	RT Master	16 oz/ac	1.17 l/ha		5 May 2004
(Wheat desiccated)	2,4-D LV6	16 oz/ac	1.17 l/ha		5 May 2004
	RT Master	20 oz/ac	1.46 l/ha		1 June 2004
	2,4-D LV6	6 oz/ac	0.44 l/ha		1 June 2004
	Banvel	2 oz/ac	0.15 l/ha		1 June 2004
	RT Master	20 oz/ac	1.46 l/ha		2 July 2004
	2,4-D LV6	6 oz/ac	0.44 l/ha		2 July 2004
	Banvel	2 oz/ac	0.15 l/ha		2 July 2004
Grain Sorghum:	Bicep Lite II Magnum	35.2 oz/ac	2.57 l/ha		21 May 2004
	RT Master	16 oz/ac	1.17 l/ha		21 May 2004
	2,4-D LV6	16 oz/ac	1.17 l/ha		21 May 2004
	Clarity	8 oz/ac	0.58 l/ha		9 July 2004
Corn:	RT Master	16 oz/ac	1.17 l/ha		5 May 2004
	2,4-D LV6	16 oz/ac	1.17 l/ha		5 May 2004
	Atrazine 4F	32 oz/ac	2.33 l/ha		28 May 2004
	RT Master	20 oz/ac	1.46 l/ha		28 May 2004
	2,4-D LV6	6 oz/ac	0.44 l/ha		28 May 2004
	Banvel	2 oz/ac	0.15 l/ha		28 May 2004
	Round-up UltraMAX	26 oz/ac	1.901/ha		9 July 2004
Sunflowers:	RT Master	16 oz/ac	1.17 l/ha		5 May 2004
	2,4-D LV6	16 oz/ac	1.17 l/ha		5 may 2004
	Spartan	1.5 oz/ac	105 g/ha		11 May 2004
	Prowl H20	48 oz/ac	3.50 l/ha		28 May 2004
	Round-up UltraMAX	26 oz/ac	1.90 l/ha		28 May 2004
	Select 2EC	6 oz/ac	0.44 l/ha		2 July 2004
Fallow:	RT Master	16 oz/ac	1.17 l/ha		5 May 2004
	2,4-D LV6	16 oz/ac	1.17 l/ha		5 May 2004
	RT Master	20 oz/ac	1.46 l/ha		1 June 2004
	2,4-D LV6	6 oz/ac	0.44 l/ha		1 June 2004
	Banvel	2 oz/ac	0.15 l/ha		1 June 2004
	RT Master	20 oz/ac	1.46 l/ha		2 July 2004
	2,4-D LV6	6 oz/ac	0.44 l/ha		2 July 2004
	Banvel	2 oz/ac	0.15 l/ha		2 July 2004
(Wheat planting)	RT Master	32 oz/ac	2.33 l/ha		18 Sept. 2004
Rotation: Opportunity					
Proso:	RT Master	16 oz/ac	1.17 l/ha		5 May 2004
	2,4-D LV6	16 oz/ac	1.17 l/ha		5 may 2004
	RT Master	16 oz/ac	1.17 l/ha		21 May 2004
	2,4-D LV6	16 oz/ac	1.17 l/ha		21 May 2004
	2,4-D amine	12 oz/ac	0.87 l/ha		14 June 2004
	Clarity	4 oz/ac	0.29 l/ha		14 June 2004
The appropriate adjuvant was applied with herbicides according to label directions.					

Table A15. Weed control methods including herbicide rate, cost and date applied at Briggsdale in 2005 season.

Crop	Herbicide/Tillage	Rate (English)	Rate (Metric)	Cost	Date Applied
Rotation: Wheat-Fallow					
Wheat:	Ally Extra	0.4 oz/ac	28 g/ha	$3.96/ac	3 April 2005
	2,4-D LV6	5.3 oz/ac	0.39 l/ha	$0.80/ac	3 April 2005
(Stubble)	RT Master II	16 oz/ac	1.17 l/ha	$3.20/ac	7 July 2005
	Weedmaster	16 oz/ac	1.17 l/ha	$3.36/ac	7 July 2005
Fallow:	RT Master II	16 oz/ac	1.17 l/ha	$3.20/ac	3 April 2005
	2,4-D LV6	5.3 oz/ac	0.39 l/ha	$0.80/ac	3 April 2005
	Clarity	2 oz/ac	0.15 l/ha	$1.50/ac	3 April 2005
	RT Master II	16 oz/ac	1.17 l/ha	$3.20/ac	22 June 2005
	Weedmaster	16 oz/ac	1.17 l/ha	$3.36/ac	22 June 2005
	RT Master II	16 oz/ac	1.17 l/ha	$3.20/ac	28 July 2005
	Weedmaster	16 oz/ac	1.17 l/ha	$3.36/ac	28 July 2005
(Wheat Planting)	RT Master II	20 oz/ac	1.46 l/ha	$4.00/ac	4 Oct. 2005
Rotation: Wheat-Millet-Fallow					
Wheat:	Ally Extra	0.4 oz/ac	28 g/ha	$3.96/ac	3 April 2005
	2,4-D LV6	5.3 oz/ac	0.39 l/ha	$0.80/ac	3 April 2005
(Stubble)	RT Master II	16 oz/ac	1.17 l/ha	$3.20/ac	7 July 2005
	Weedmaster	16 oz/ac	1.17 l/ha	$3.36/ac	7 July 2005
Millet:	RT Master II	16 oz/ac	1.17 l/ha	$3.20/ac	3 April 2005
	2,4-D LV6	5.3 oz/ac	0.39 l/ha	$0.80/ac	3 April 2005
	Clarity	2 oz/ac	0.15 l/ha	$1.50/ac	3 April 2005
	RT Master II	22 oz/ac.	1.61 l/ha	$4.40/ac	22 June 2005
Fallow:	RT Master II	16 oz/ac	1.17 l/ha	$3.20/ac	3 April 2005
	2,4-D LV6	5.3 oz/ac	0.39 l/ha	$0.80/ac	3 April 2005
	Clarity	2 oz/ac	0.15 l/ha	$1.50/ac	3 April 2005
	RT Master II	16 oz/ac	1.17 l/ha	$3.20/ac	22 June 2005
	Weedmaster	16 oz/ac	1.17 l/ha	$3.36/ac	22 June 2005
	RT Master II	16 oz/ac	1.17 l/ha	$3.20/ac	28 July 2005
	Weedmaster	16 oz/ac	1.17 l/ha	$3.36/ac	28 July 2005
(Wheat Planting)	RT Master II	20 oz/ac	1.46 l/ha	$4.00/ac	4 Oct. 2005
Rotation: Wheat-Corn-Fallow:					
Wheat:	Ally Extra	0.4 oz/ac	28 g/ha	$3.96/ac	3 April 2005
	2,4-D LV6	5.3 oz/ac	0.39 l/ha	$0.80/ac	3 April 2005
(Stubble)	RT Master II	16 oz/ac	1.17 l/ha	$3.20/ac	7 July 2005
	Weedmaster	16 oz/ac	1.17 l/ha	$3.36/ac	7 July 2005
	RT Master II	20 oz/ac	1.46 l/ha	$4.00/ac	4 Oct. 2005
	Atrazine 4F	32 oz/ac	2.34 l/ha	$2.56/ac	4 Oct. 2005
Corn:	RT Master II	16 oz/ac	1.17 l/ha	$3.20/ac	3 April 2005
	2,4-D LV6	5.3 oz/ac	0.39 l/ha	$0.80/ac	3 April 2005
	Clarity	2 oz/ac	0.15 l/ha	$1.50/ac	3 April 2005
	Round-up Ultra Max II	22 oz/ac	1.61 l/ha	$7.92/ac	22 June 2005
	Atrazine 4F	24 oz/ac	1.75 l/ha	$1.92/ac	22 June 2005

Fallow:	RT Master II	16 oz/ac	1.17 l/ha	$3.20/ac	3 April 2005
	2,4-D LV6	5.3 oz/ac	0.39 l/ha	$0.80/ac	3 April 2005
	Clarity	2 oz/ac	0.15 l/ha	$1.50/ac	3 April 2005
	RT Master II	16 oz/ac	1.17 l/ha	$3.20/ac	22 June 2005
	Weedmaster	16 oz/ac	1.17 l/ha	$3.36/ac	22 June 2005
	RT Master II	16 oz/ac	1.17 l/ha	$3.20/ac	28 July 2005
	Weedmaster	16 oz/ac	1.17 l/ha	$3.36/ac	28 July 2005
(Wheat Planting)	RT Master II	20 oz/ac	1.46 l/ha	$4.00/ac	4 Oct. 2005
Rotation: Barley-Triticale-Millet:					
Barley:	Ally Extra	0.4 oz/ac	28.0 l/ha	$3.96/ac	3 April 2005
	2,4-D LV6	5.3 oz/ac	0.39 l/ha	$0.80/ac	3 April 2005
	RT Master II	20 oz/ac	1.46 l/ha	$4.00/ac	4 Oct. 2005
Triticale:	Ally Extra	0.4 oz/ac	28 g/ha	$3.96/ac	3 April 2005
(Wheat in 2005)	2,4-D LV6	5.3 oz/ac	0.39 l/ha	$0.80/ac	3 April 2005
	RT Master II	16 oz/ac	1.17 l/ha	$3.20/ac	7 July 2005
	Weedmaster	16 oz/ac	1.17 l/ha	$3.36/ac	7 July 2005
Millet:	RT Master II	16 oz/ac	1.17 l/ha	$3.20/ac	3 April 2005
	2,4-D LV6	5.3 oz/ac	0.39 l/ha	$0.80/ac	3 April 2005
	Clarity	2.0 oz/ac	0.15 l/ha	$1.50/ac	3 April 2005
	RT Master II	22 oz/ac.	1.61 l/ha	$4.40/ac	22 June 2005
Rotation: Opportunity					
Fallow:	RT Master II	16 oz/ac	1.17 l/ha	$3.20/ac	3 April 2005
	2,4-D LV6	5.3 oz/ac	0.39 l/ha	$0.80/ac	3 April 2005
	Clarity	2.0 oz/ac	0.15 l/ha	$1.50/ac	3 April 2005
	RT Master II	16 oz/ac	1.17 l/ha	$3.20/ac	22 June 2005
	Weedmaster	16 oz/ac	1.17 l/ha	$3.36/ac	22 June 2005
	RT Master II	16 oz/ac	1.17 l/ha	$3.20/ac	28 July 2005
	Weedmaster/Outlaw	16 oz/ac	1.17 l/ha	$3.36/ac	28 July 2005
(Wheat Planting)	RT Master II	20 oz/ac	1.46 l/ha	$4.00/ac	4 Oct. 2005
The appropriate adjuvant was applied with herbicides according to label directions.					