The 35th

ANNUAL RESEARCH REPORT

of the

WESTERN TRIANGLE AGRICULTURAL RESEARCH CENTER

Montana Agricultural Experiment Station

Conrad, Montana

2012 Crop Year

Submitted by

Dr. Gadi V.P. Reddy, Superintendent and Associate Professor of Entomology/Insect Ecology,

Dr. Olga Walsh, Soil Nutrient Management,

and

John H. Miller, Research Associate, Agronomy

Montana State University-Bozeman

MONTANA STATE UNIVERSITY

INTRODUCTION

The information and data reported are a compilation of ongoing or new research projects located at or near the Western Triangle Ag. Research Center (WTARC), Conrad, Montana. Many projects are conducted in cooperation with faculty members and research associates from the Depts. of Plant Science and Plant Pathology (PSPP) and Land Resources and Environmental Science (LRES) located on the campus of Montana State University (MSU), and Agricultural Research Centers: Central (CARC), Northern (NARC), Eastern (EARC) and Western (WARC) of the Dept. of Research Centers.

To simplify reading, trade or brand names of products, services, firms, or equipment are sometimes used. No endorsement of such names or firms is intended nor is criticism implied of those not mentioned.

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Dr. Luther Talbert and Susan Lanning – Spring Wheat Variety Breeding Program
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Dr. Tom Blake and Stan Bates – Barley Variety Breeding Program
Dr. Chengci Chen and Johnna Heser – Pulse Crop Variety Testing Program
Dr. Joyce Eckoff – Durum Variety Breeding and Testing Program
Brooke Bohannon - Canola Variety Testing Program
Dr. Greg Kushnak - Variety notes and comments
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WTARC Advisory Committee and cooperating producers: Boyd Standley, Dan Picard, Jeff Farkell, Jeff Habets, Jerry Jerome, Keven Bradley, Megan Mattson-Hedges, Phillip Hodgson, Rob Moog, Scott Inbody, and Terry Alme.

Summer Staff: Connie Miller, Megan Burchak, Christopher Banka, Jeff Jerome and Marliss Picard.

Summary of climatic data by month for the ‘11-‘12 crop year (September thru August) at the Western Triangle Agricultural Research Center, Conrad, MT.

Month	Precipitation (inches)		Mean Temperature (°F)	
	Current Year	Average (27-yr)	Current Year	Average (27-yr)
September, 2011	0.30	1.17	60.0	57.0
October, 2011	1.84	0.62	44.7	45.0
November, 2011	0.18	0.28	30.9	32.3
December, 2011	0.12	0.20	29.2	24.2
January, 2012	0.17	0.19	24.3	23.0
February, 2012	0.02	0.22	25.9	24.5
March, 2012	0.53	0.42	36.2	33.1
April, 2012	1.04	1.01	44.5	42.9
May, 2012	1.49	1.91	50.0	51.7
June, 2012	2.46	2.98	58.4	59.3
July, 2012	0.82	1.41	69.3	66.9
August, 2012	1.32	1.23	67.1	66.1
Total	10.29	--	--	--
Average	--	11.64	45.1	43.8

Last killing frost in Spring (32°F)
2012-------------------------------- April 29
Average 1986-2012-------------- May 18

First killing frost in Fall (32°F)
2012---------------------------------Oct 2
Average 1986-2012-------------- Sept 26

Frost free period (days)
2012------------------------------ 156
Average-------------------------- 130

Maximum summer temperature------- 93°F (August 28, 2012)

Minimum winter temperature------- -26°F (January 18, 2012)

MONTANA AGRICULTURAL EXPERIMENT STATION

Title: Developing Integrated Pest Management Programs for Insects in the Western Triangle Agricultural Area of Montana

Organizing Department: Department of Research Centers

Project Leader: Gadi V.P. Reddy, Associate Professor of Entomology/Insect Ecology and Superintendent, Western Triangle Ag Research Center (WTARC), Montana State University.

Cooperating Departments:
Miklós Tóth, Plant Protection Institute, MTA ATK, Budapest, Hungary, H-1525
Stefan T. Jaronski, Research Entomologist, USDA-ARS-NPARL, Sidney MT 59270
David K. Weaver, Associate Professor of Entomology, LRES-MSU
Robert K. D. Peterson, Professor of Entomology, LRES-MSU
Kevin Wanner, Assistant Professor, PSPP-MSU
Perry Miller, Professor of Sustainable Cropping Systems, LRES-MSU
Robert Stougaard, Northwestern Ag Research Center, NWARC-MSU
Chengci Chen, Agronomist, Central Ag Research Center, CARC-MSU
John H. Miller, Western Triangle Ag Research Center, WTARC-MSU

Location:
Montana State University (MSU),
Montana Agricultural Experiment Station (MAES),
Western Triangle Agricultural Research Center, Conrad, MT 59425

2. PROBLEM AND JUSTIFICATION

Montana's Golden Triangle. The Western Triangle is an area of unique value to Montana's agricultural sector. It is situated in the western part of the Montana's Golden Triangle region (Fig.1). The combination of extreme but favorable weather and some of the more productive soils in Montana provide an environment conducive to the successful production of high quality cereal grain crops. Montana weather conditions – an average annual precipitation of approximately 15 inches coupled with an average annual air temperature of about 43 degrees F° and a frost-free period of about 93 days – result in long, cold winters and relatively short, hot, arid summers. The Scobey soil series predominantly found in north-central Montana are very deep and well drained soils. Scobey soil's Ap horizon is characterized as grayish brown clay loam, dark brown when moist, with a Bt horizon of brown clay loam, dark brown when moist. The Btk, Bk, and C horizons are light brownish gray, grayish brown when moist, clay loams. The Scobey soils occur on more than 700,000 acres and are considered among the most fertile soils in the Golden Triangle region. Thus, the Western Triangle region is considered one of the more productive areas in the state of Montana.

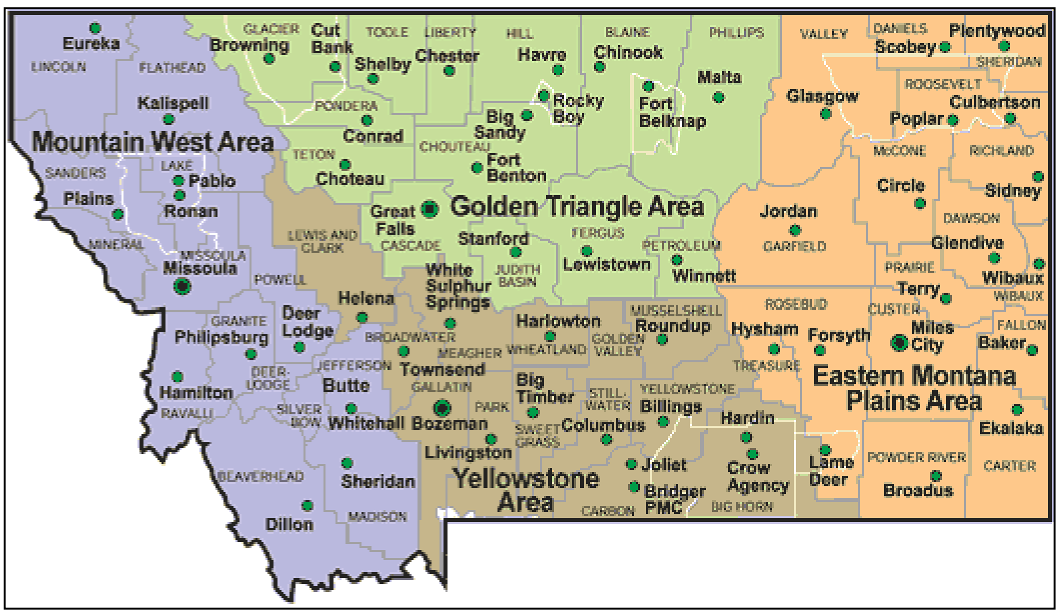

Fig. 1. Montana Geographic Area Map. Source: National Resource Conservation Service (NRCS), 2011.

Agriculture is Montana's most important industry, worth $3.5 billion in 2011 (USDA 2012). Montana's agricultural sector is between 40% livestock and 60% crop production, with the majority of livestock comprised of cattle, and small grains accounting for approximately half of the field crop industry. Alfalfa and cereal hay are also important crops in Montana, and the state let the nation's growers of dry peas and lentils (USDA 2012).

Wheat:

Wheat is the principal food grain produced in the United States (United States Department of Agriculture (USDA), 2009-a). Spring wheat (*Triticum aestivum* L.) and winter wheat (*Triticum aestivum* L.) are the major grain cereal crops grown in Montana. Wheat production employs approximately 15,000 individuals in the state and accounts for approximately 25% of Montana's total agricultural revenue (Montana Wheat and Barley Committee 2005). The planted and harvested acreage, yield, price, and production value for total wheat, spring wheat and winter wheat grown in Montana (2009-2011) are reported in Table 1.

Table 1. Acreage, production, and production value for wheat, Montana, 2009-2011.

Year	Acres		Production			Value	
	Planted (000)	Harvested (000)	Yield Per Acre Bu.	Total Bushels (000)	Price Per Bu. Dols.	Value of Production (000) Dols	Value Per Acre Dols.
	Total wheat production						
2011	5,100	4,980	36	178,920	n/a	n/a	n/a
2010	5,440	5,210	41	215,360	6.60	1,430,969	275
2009	5,520	5,305	33	176,625	5.18	917,570	173
	Spring wheat production						
2011	2,450	2,400	32	74,400	n/a	n/a	n/a
2010	2,850	2,730	38	103,740	7.05	731,367	268
2009	2,400	2,350	30	70,500	5.72	403,260	172
	Winter wheat production						
2011	2,250	2,150	41	89,790	n/a	n/a	n/a
2010	2,050	1,950	38	93,600	6.30	589,680	302
2009	2,550	2,420	37	89,540	4.79	428,897	177

Source: USDA, 2011-a. National Agricultural Statistics Service. Available at: http://www.nass.usda.gov/Data_and_Statistics/Quick_Stats/. Last updated: 09- 29-2011. Last accessed: 11-2-2011.

Spring wheat. Montana is traditionally recognized worldwide for production of high quality wheat. Spring wheat continues to be the key cereal crop for the state of Montana. In 2012, Montana was second in the U.S. in spring wheat production (with 2.4 million acres), which represented a value of more than $605 million. Montana ranked third among the spring wheat producing states in the nation in 2010 (USDA 2011-a) with almost 2.9 million acres, and more than $730 million value (Table 1). Montana's spring wheat acreage varied from 44 to 55% of the total wheat acreage planted during the past 5 years. In 2010, spring wheat accounted for approximately 52% of all wheat grown in the state.

Winter wheat. More than 2.3 million acres of winter wheat were planted in Montana in 2011, increasing from 2.05 million acres planted in 2010 (Table 1). Hard red winter wheat is mainly produced in the Great Plains states, from the Mississippi River west to the Rocky Mountains and from Canada to Mexico. It is characterized as having a wide range of protein content (usually about 10%), and good milling and baking qualities. Hard red winter wheat is used to make bread, rolls, sweet goods and all-purpose flour. Montana is ranked 3rd for winter wheat planted acreage in the United States (USDA 2011b). Genou, Yellowstone, CDC Falcon, and Rampart are the top four varieties grown in Montana and account for approximately 60% of the total winter wheat planted in the state for 2011.

The wheat stem sawfly, *Cephus cinctus* (Hymenoptera: Cephidae), is infesting wheat and barley (Morrill and Kushnak 1996). The sawfly larva bores down inside the stem and makes a discolored tunnel from about the top joint to the root. Larval wireworms *Limonius californicus* (Mannerheim) and *Hypnoidus bicolor* (Eschscholtz) (Coleoptera: Elateridae) are causing damage to wheat and barley and other crops in the Golden Triangle areas of Montana. According to unpublished data from Dr. Kevin Wanner and his team at the Montana State University, there seems to be two dominant species of *L. californicus* and *H. bicolor* injuring wheat and barley in the Golden Triangle.

Canola:

Canola (*Brassica napus* L.) is another attractive oilseed crop to Montana producers due to its high seed yield, prospective benefit in a crop rotation, and the relative ease with which it can be integrated into small grain cropping systems. With the release of improved cultivars incorporating herbicide resistant technologies that simplify weed management, producer interest in canola production in Montana is increasing. Canola is well adapted to the northwestern region of Montana, due to its high rainfall and cooler daytime temperatures (Jackson 1999). In recent years, northwestern Montana has 2.7% of US total harvested canola acreage and ranks third in the nation (USDA 2012). However, lack of adequate agronomic information about the crop is a perceived barrier among area farmers. In field experiments conducted across Montana, the response of canola to nitrogen (N) and sulfur (S) fertilizer varied according to location and variety. More multi-year, multi-site research is required to solidify fertilizer recommendations for this crop.

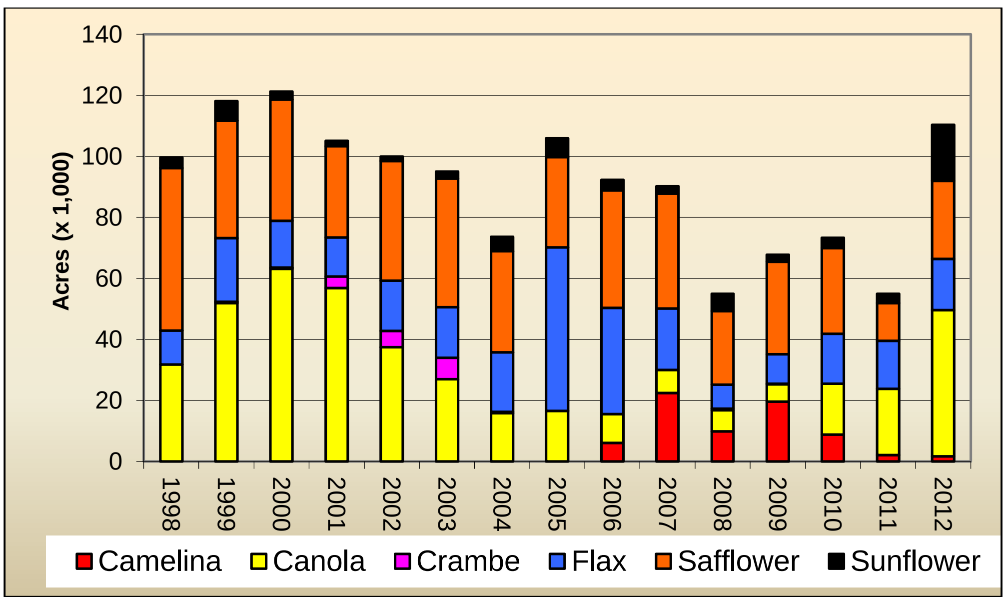

Fig. 2. Montana oilseed area planted, 2012 (Source: Perry Miller, MSU LRES)

Canola is well suited for, and has been widely grown in, the Northern Great Plains (Boyles et al. 2007). Presently, the United States imports the equivalent of 3 million acres of production each year, so a domestic market for the oil and meal exists. Both spring and winter types of canola are developed and grown in the US. However, its production has declined significantly in recent years primarily due to insect pest problems. The canola pest complexes are responsible for several insecticide applications on canola. Many growers in Montana rely on seed treatments and a calendar-based spraying schedule for insecticide applications. Oilseed *Brassica* crops grow best in cool, short-season climates (Thomas 2002). This makes them very suitable for production on the Montana prairies. Insecticides are the main means of control of flea beetles, *Phyllotreta* spp., and diamondback moth, *P. xylostella* in canola crops, with more than 90% of the 5 million ha seeded to canola in North America treated with insecticides (Waite et al. 2001). Integrated methods of management of these agricultural pests are urgently needed, including tools based on pheromones and host plant volatiles.

Although there are numerous outreach based reports on the canola pests from North Dakota and Canadian Prairie Provinces, no concrete research based sampling, thresholds, and curative control tactics on canola are available for implementation. Although canola acreage has recently increased to approximately 50,000 acres in Montana alone (Fig. 2), very little applied, production-oriented research has addressed IPM practices for canola production in Montana. Therefore, better research of the current IPM programs for canola is needed. Flea beetles cause numerous feeding holes and 25% defoliation is reported to be the nominal economic threshold for seedling canola (Canola Council of Canada 2010; Knodel and Olson 2002). Adult feeding on young seedlings results in reduced crop stands and plant growth, delayed maturity, and lower seed yield (Cárcamo et al. 2008). When flea beetle populations are large, and warm and sunny situations favor feeding, fields can be infested quickly and canola seedlings can be destroyed. Currently, neonicotinoid seed treatment and post-emergence chemical pesticides (bifenthrin, deltamethrin, gamma-cyhalothrin and lambda-cyhalothrin) are being used regularly by growers to control *Phyllotreta* spp., *Phyllotreta cruciferae* Goeze and *P. striolata* (F.) (Coleoptera: Chrysomelidae), and diamondback moth *Plutella xylostella* L. (Lepidoptera: Plutellidae). These chemicals are not only expensive, but also affect the natural enemies and development of resistance and can lead to secondary pest outbreaks in general (Madder and Stemeroff 1988). Also, control of pest insects with pesticides potentially generates several other problems, including safety risks for humans and domestic animals, contamination of water resources, decrease in biodiversity, and other ecological problems. Although there are no reports yet in Montana on all these aspects, there is potential cause of these problems in future. Therefore, research on economic thresholds that are appropriate for canola production in the Triangle areas.

The diamondback moth, *P. xylostella,* and flea beetle, *Phyllotreta* spp. can cause serious damage to canola. In the Northern Great Plains, *P. xylostella* is now recorded everywhere that canola is grown. For the early flowering stage, insecticide applications may be justified at *P. xylostella* larval densities of 10 to 15 larvae per square foot as nominal threshold level. The economic threshold for canola at the pod stage increases to 20 to 30 larvae per square foot (Knodel and Ganehiarachchi 2008). Although, there is no any record of using these thresholds by growers in Golden Triangle, the plant and insect phenology is different due to hot and dry conditions, the existing thresholds may not work. Moreover, these thresholds are not developed based on any field research but generally agreed to use the threshold level for time being by different researchers from Canada and US.

The flea beetles *P. cruciferae* and *P. striolata* are severe, yet sporadic pests, especially during the early stages of the crop growth. Even small numbers of *P. cruciferae* and *P. striolata* can cause severe damage during the particularly early growing stages. On the other hand, *P. xylsotella* has been causing some damage to canola during the latter stage of the crop (from 40 – 50 days after sowing) in Havre. In the recent past, several growers have noted huge yield losses particularly due to *P. cruciferae* in Sunburst and other nearby areas. Consequently, several growers in the Western Triangle area are compelled to apply several insecticidal applications. However, some growers are not aware of the threshold levels while some are not using an IPM program. Based on feedback from local growers in the region and extension agents of Montana State University, the studies in this document have been proposed. Although some control methods exist, such calendar based spraying and/or seed treatments, they are not providing adequate control. Without taking appropriate action to gain effective control, these insect pests are likely to cause huge or complete loss of canola production in Montana.

3. LITERATURE REVIEW

Wheat stem sawfly *Cephus cinctus* (Hymenoptera: Cephidae)

The wheat stem sawfly *C. cinctus* is the major pest of wheat grown in Montana and is a key pest in Golden Triangle (Morrill and Kushnak 1996). There are nonconforming views from the common assumption that *C. cinctus* is indigenous to North America (Beres et al. 2011b). According to these authors, cumulative grain-yield losses and annual economic losses associated with this pest can exceed 30% and $350 million, respectively. Stem mining injury by *C. cinctus* also reduces yield per infested stems by up to 35% (Delaney et al. 2010).

The larva feeds within the stem until the plant is nearly mature; the duration of this period varies with host plant phenology (Beres et al. 2011b). The larvae overwinter in diapause in hibernaculum within the sawfly-cut stem, which is called a “stub”. The pupation occurs over no more than 21 days (Criddle 1923). The prepupal period begins in early- to mid-May and the first pupae develop in late May (Holmes 1979). After pupation, each newly-eclosed adult cut stubs at or below the soil surface (Beres et al. 2011b). The life cycle of the wheat stem sawfly explains the difficulty ion controlling its population because all immature stages are protected within wheat stems (Beres et al. 2011b). The most diagnostic evidence of sawfly feeding is the presence of sawdust-like frass inside the wheat stem. The greatest losses occur around the margins of fields. Adults emerge from obligate, overwinter diapause in the wheat stubble which remains in the field following harvest (Fig-3). Adult males generally emerge first and remain near field edges where most mating and oviposition occurs (Weaver et al. 2005). The normal lifespan of the adults is 5–8 days depending on climatic conditions and available moisture (Criddle 1923). Wheat stem sawflies spend up to 10 months of the year as larvae within host plants; thus, early control tactics targeted the larva through destruction of the stub (Beres et al. 2011b).

Fig. 3: Adult female wheat stem saw fly (Photo credit: Dr. Robert K. Peterson, Montana State University).

The control of *C. cinctus* has been challenging. The chemical insecticides do not kill the larvae which is cryptic in nature. Additionally, several unpublished studies in Montana reported that systemic seed treatments of imidacloprid applied at varying rates and foliar-applied chlorpyrifos, carbofuran, and cyhalothrin-lambda had no significant effects on sawfly survivorship (Goosey 1999). The recommended cultural practices to manage wheat stem sawfly had potential for reducing infestation levels, but the rate of adoption of cultural control methods during that time is not fully known. Tillage was another early recommendation for wheat stem sawfly control. Criddle (1922) recommended ploughing infested stubble to a depth of at least 15 cm and completely burying all stubs can give some sort of control. Although tillage was thought to provide effective control during this period, the method did not destroy all sawflies (Beres et al. 2011a; Goosey 1999).

The use of solid-stemmed cultivars helps mitigate crop losses but can also affect the survivorship of *C. cinctus*. Solid-stemmed spring wheat cultivars available in Montana include 'Fortuna', 'Lew', and 'Choteau'. Similarly, solid-stemmed winter wheat cultivars available to Montana producers include 'Vanguard' (Carlson et al. 1997), 'Rampart', and 'Genou' (Bruckner et al. 1997, 2006). However, solid-stemmed cultivars are historically reported to have lower grain yield and quality than hollow-stemmed cultivar (Beres et al. 2011b).

Although, nine species of Hymenoptera are known to parasitize *C. cinctus*, two parasitoids (*Bracon cephi* and *Brocon lissogaster*) have been recorded in *C. cinctus* populations in wheat (Morrill et al. 1998). Criddle (1923) suggested that *B. cephi* had great potential for wheat stem sawfly control because it was largely responsible for larval parasitism rates as high as 85% in grasses in Canada. This parasitoid ultimately adjusted to parasitizing sawfly larvae in wheat and has become the most important parasitoid of *C. cinctus*. On the other hand *B. lissogaster* is known to more dominant parasitoid in the Golden Triangle area. (Weaver et al. 2004, 2005, Peterson et al. 2011). However, successful parasitism by the second generation is dependent on crop maturity and the timing of host larva overwintering preparations (Holmes et al. 1963). Also, *B. lissogaster*, the second major parasitoid of *C. cinctus* in wheat, also was slow to shift to sawfly populations in wheat but is now active in Montana and North Dakota (Meers

2005). Its life cycle is similar to that of *B. cephi* but it can more readily complete a second generation in late fall, which is attributed to immediate oviposition by adult females after they emerge (Somsen and Luginbill 1956). First-generation females of both species will often oviposit in stems covering multiple *C. cinctus* eggs. This can result in a significant reduction in parasitism rates because of cannibalism of parasitized larvae by other *C. cinctus* larvae (Weaver et al. 2005). The use of solid-stemmed cultivars in zero tillage cropping systems conserved parasitoids and reduced sawfly populations (Runyon et al. 2002; Weaver et al. 2004).

Pathogens, including nematodes, can also be used as biocontrol agents to manage insect pests (Lacey et al. 2001) and studies of pathogens and their efficacy for the control of *C. cinctus* have reported some success (Piesik et al. 2009; Wenda-Piesik et al. 2006, 2009). However, not much research work has been done on the evaluation of various available commercial formulations of pathogens and nematodes for the control of *C. cinctus.*

Semiochemical-based pest management could influence oviposition behavior of *C. cinctus* if a bait and trap can be established that would attract and capture females prior to oviposition (Beres et al. 2011b). Cossé et al. (2002) used coupled gas chromatographic–electroantennographic detection (GC-EAD) to study the effects of pheromone components on the behavior of adult *C. cinctus*. They also conducted field assays to determine if 9-acetyloxynonanal could be used as a female attractant in traps. They also reported that trap baited with the pheromone compound of 9-acetyloxynonanal catch was dose-dependent and there was no significant difference in the sex ratio of trapped individuals. Dr. David Weaver and his team at the Montana State University have been working on the optimization of trapping technique for *C. cinctus*. Trap characteristic such as trap type, size and color are known to influence the adult catches in many insects (Reddy et al. 2011), and are likely to be important in trap success for wheat stem sawfly.

In this direction, the present studies will be undertaken to investigate whether trap characteristics can influence catches of *C. cinctus.* Therefore it became essential to characterize factors that affect trap-capture efficiency to improve trap performance and render traps more reliable for IPM strategies. Similarly, the lab and field work will be initiated to screen the efficacy of nematode and pathogens formulations against *C. cinctus*.

Wireworms – Click beetles (Coeloptera: Elateridae)

Wireworms, the soil-living larvae of click beetles (Coleoptera: Elateridae), are known to cause serious damage to wheat and barley in the Golden Triangle areas of Montana. Widely distributed throughout the Northern Great Plains (Montana, North and South Dakota, and Minnesota), these click beetle larvae move below the soil surface where they feed on wheat and barley seed and seedlings (Hermann et al. 2012). In recent years, wireworm damage has become an increasing problem for growers, so the demand for a meaningful risk assessment and useful methods to restrict damage is increasing. However, due to the cryptic habitat of the wireworms, pest control is very difficult and leads to unsatisfying results (Blackshaw and Vernon 2006).

Vickie Ophus & Leanne Curry digging a hole in the field to place a wireworm trap.

Wireworms can attack both spring and fall-seeded crops (Kevin Wanner, Personal Communication). In the spring, when soil temperatures warm to 50°F, wireworm larvae begin to migrate upward, almost to the soil surface, where they feed on newly planted seed and seedlings (Fig 4). When soil temperatures rise to 80°F, the larvae seeks lower temperature additional a foot or two below the surface. Although seed treated with Gaucho (imidacloprid) gave some level of control, the monitoring of the pests has been very challenging and difficult. Pheromone-baited traps are useful in monitoring and control of insect pests (Reddy and Guerrero 2004). The pheromone compounds have not yet been identified for North American species of wireworms. Nevertheless, the compounds have been identified for European based wireworm species (Tóth et al. 2008, 2011). Therefore, the proposed study will begin spring 2013 to screen pheromones of the European *Agriots* spp., plus valeric acid and hexanoic acid (the two formerly described pheromone compounds for *Limonius* spp) using theYatlor trap (Fig. 5).

Fig. 4: Larvae of the wireworms (Photo credit: Dr. Kevin Wanner, Montana State University).

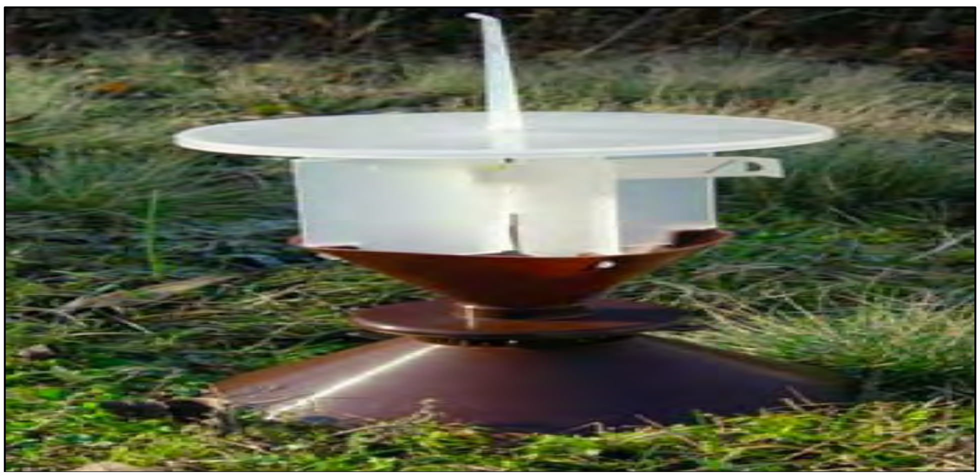

Fig. 5: YATLOR FUNNEL trap design specifically developed for pheromone trapping of click beetles (Photo credit: L. Furlan, Italy; *Inform. Fitopat*. 10: 49, 2004).

Flea beetles - *Phyllotreta* spp. (Coleoptera: Chrysomelidae).

The crucifer flea beetle was introduced from Eurasia into North America in the 1920s and is now distributed across southern Canada and the northern Great Plains of the United States, including North Dakota, South Dakota, Montana, northwestern Minnesota, Manitoba, Saskatchewan, Alberta, British Columbia, Ontario, Quebec, and New Brunswick (Bain and LeSage 1998). The crucifer flea beetle is the most common and destructive flea beetle injuring canola (Knodel and Olson 2002). According to these authors, flea beetle damage to oilseed *Brassica* crops exceeds $300 million annually in North America.

The crucifer flea beetle, *P. cruciferae*, and the striped flea beetle, *P. striolata*, are the most serious insect pests of canola (Fig. 3) (Gavloski et al. 2011). Tansey et al. (2008) reported that *P. cruciferae* is likely a more effective competitor than *P. striolata* under most field conditions.
Both species were introduced from Eurasia. *Phyllotreta cruciferae* has become the dominant flea beetle pest of oilseed *Brassica* (canola) in Golden Triangle area. Adult flea beetles emerge in the spring and feed on the cotyledons and true leaves. Of the species of flea beetles that feed on oilseed *Brassica* crops, only *P. cruciferae* and *P. striolata* (Fig. 6) are economic pests. Adult flea beetles emerge in the spring and feed on the cotyledons and true leaves. When they emerge in large numbers, they can quickly devastate a seedling canola field; therefore, timely detection and management of this pest is important.

Both of the economically important species of flea beetles overwinter as adults, usually beneath hedges or groves of trees, but *P. cruciferae* can overwinter in the soil in fields if green food plants are available until cool fall weather sets in (Burgess 1977). These species become active with the arrival of warm, sunny weather in the spring (Burgess 1977; Lamb 1983; Ulmer and Dosdall 2006). They feed most actively when the weather is sunny, warm, and dry; cool, damp weather reduces the injury and aids plant growth (Burgess 1977). Adults feed on the cotyledons and slender stems of seedling cruciferous plants and continue to feed on the leaves as the plant develops (Feeny et al. 1970). Feeding by flea beetles typically consists of small holes or pits in the epidermis of leaves. Although the initial feeding does not penetrate the leaf completely, tissues below the injury eventually dry up and break or fall out, giving a shot-hole appearance (Westdal and Romanow 1972; Brandt and Lamb 1993).

The flea beetle has the widespread host range and feeds on members of the Brassicaceae, Polygonaceae, Chenopodiaceae, Boraginaceae, and Asteraceae (Burgess 1977). The two *Phyllotreta* species, *P. cruciferae* and *P. striolata,)* are considered Brassicaceae specialists, but will also feed on plants in the Capparidaceae and Tropaeolaceae that contain glucosinolates (Feeny et al. 1970). Crop hosts of the three beetle species include Argentine canola (*Brassica napus* L.), Polish canola (*B. rapa* L.), brown and oriental mustard (*B. juncea* (L.) Czern.), and yellow mustard (*Sinapis alba* L.). Numerous species of flea beetles are associated with oilseed *Brassica* crops in the grasslands, including the crucifer flea beetle, *Phyllotreta cruciferae* (Goeze); the striped flea beetle, *P. striolata* (Fabricius); the cabbage flea beetle, *P. albionica* (LeConte); the western black flea beetle, *P. pusilla* Horn; the horseradish flea beetle, *P. armoraciae* (Koch); *P. bipustulata* (F.); *P. robusta* LeConte; *P. oregonensis* (Crotch); *Chaetocnema protensa* LeConte; the threespotted flea beetle, *Disonycha triangularis* (Say); and the hop flea beetle, *Psylliodes punctulata* Melsheimer (Burgess 1977, 1980*a*; Bok Cho et al. 1994). Among these species, *P. cruciferae* and *P. striolata* are most abundant and damaging to crops of canola and brown mustard (*B. juncea*) (Burgess 1982; Lamb 1989), although white mustard (*S. alba*) is resistant to flea beetle infestation (Bodnaryk and Lamb 1991). *Phyllotreta striolata* feeds on a wider range of host plants than does *P. cruciferae* (Hicks and Tahvanainen 1974), and larvae of both species feed on root hairs of canola (Westdal and Romanow 1972).

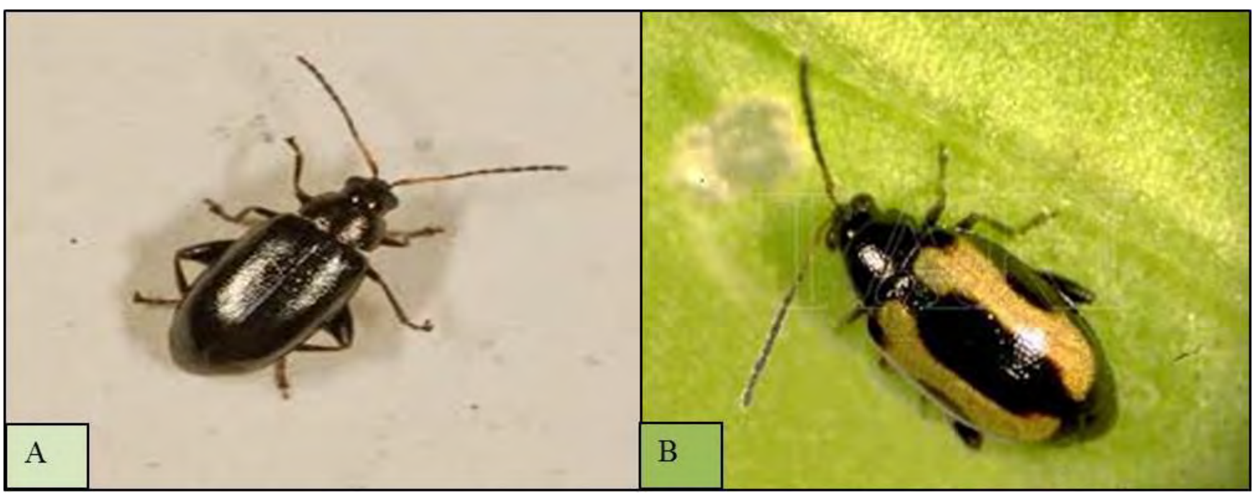

Fig. 6. Adult crucifer flea beetle, *Phyllotreta cruciferae* (A) and striped flea beetle, *Phyllotreta striolata* (B) (Photo credit: Digital Insect of Taiwan Agricultural Research Institute).

Canola plants are most vulnerable to injury at the cotyledon and early true leaf stages (Lamb 1984), with injury past the fourth leaf stage having little impact on subsequent crop performance (Foster 1983). Feeding at the early seedling stage can cause seedling mortality, reduced plant growth, delayed and uneven maturity, and lower seed yield or grade (Lamb 1984). Damage is often most severe at field edges as flea beetles emigrate from overwintering sites. Canola seedlings can compensate for defoliation levels around 20% (Gavloski and Lamb 2000). Flea beetle numbers can be very high in ripening canola in the fall (Soroka and Elliott 2011). If crops are very late in maturity, extensive feeding on pods can lower yields and increase green seed content (Lamb 1980). However, seed yields are usually not affected when crop maturity is more advanced than growth stage 5.2, when the seeds in lower pods are turning green (Soroka 2009). Both larval and adult stages have chewing mouthparts, which they use efficiently below ground (larvae) and above ground (adults). Below- and above-ground feeding injury can kill seedlings and small transplants (Parker et al. 2012).

Crucifer flea beetles have a single generation in the northern Great Plains. Both species are usually univoltine in North America (Westdal and Romanow 1972). They overwinter as adults in the leaf litter of shelterbelts or grassy areas and are rarely found in canola stubble. Beetles emerge when temperatures warm up to 57 °F (14 °C) in early spring. They feed on volunteer canola and weeds, such as wild mustard, and move to newly planted canola as it emerges. Depending on the temperature, it may take as many as three weeks for the adults to leave their overwintering sites (Westdal and Romanow 1972). The striped flea beetle adults usually emerge before the crucifer flea beetle. Warm, dry, and calm weather promotes flea beetle flight and feeding throughout the field, while simultaneously slowing canola growth (Turnock et al. 1987). In contrast, cool, rainy, and windy conditions reduce flight activity, and flea beetles walk or hop, leading to concentrations in the field margins (Lamb 1989).

The crucifer flea beetle has a narrow host range restricted to plants primarily in the mustard family (Cruciferae). Other plant families attacked are the caper family (Capparidaceae), the nasturtium family (Tropaeolaceae), and the marshflower family (Limnanthaceae) (Feeny et al. 1970). Remarkably, all of the flea beetles prefer plant families that produce mustard oil (or allyl isothiocyanate), which is a known aggregation pheromone of the crucifer flea beetle (Soroka et al. 2005). The most-preferred hosts are in the genus *Brassica* (Cruciferae), which include the major agricultural host attacked by flea beetle, oil rapeseed or Argentine canola *(B. napus)* and Polish canola *(B. rapa/campestris*) (Pivnick and Jarvis 1991) . Mustard (*Brassica* spp.) and crambe *(Crambe abyssinica)* are also susceptible to flea beetle attack, but not preferred over canola (Pivnick et al. 1992). Other hosts that flea beetles will attack in the garden setting are cabbage, turnip, cauliflower, kale, Brussel sprouts, horseradish, and radish. Some weeds attacked in the cruciferous group are flixweed, field pennycress, peppergrass, and wild mustard (Knodel and Olson 2002).

The occurrence of high flea beetle numbers in fall may signal the potential for high numbers the following spring. Various methods have been used to monitor flea beetle populations in the spring. These include sweep nets, emergence traps, yellow sticky cards, and traps baited with the attractant allyl isothiocyanate (Soroka and Elliott 2011). Aggregation pheromones of male *P. cruciferae* and *P. striolata* have been field tested (Soroka et al. 2005; Geber Osgood 1975), but are not available commercially. To date, none of these methods has provided accurate forecasting of potential flea beetle injury. Feeding injury is greatest when it is warm, dry, and calm. Under these conditions, seedling canola fields should be inspected daily for evidence of flea beetle activity and injury (Soroka and Elliott 2011).

Diamondback moth - *Plutella xylostella* L. (Lepidoptera: Plutellidae).

The diamondback moth, *Plutella xylostella* (L.) (Lepidoptera: Plutellidae), is one of the more destructive cosmopolitan insect pests of brassicaceous crops (Talekar and Shelton 1993). This insect is a cosmopolitan species that probably originated in the Mediterranean region. It is found over much of North America, the southern portion of South America, southern Africa, Europe, India, Southeast Asia, New Zealand, and parts of Australia (Hardy 1938). Accidentally introduced from Europe, it was first reported in North America in Illinois in 1854 and from western Canada in 1885 (Harcourt 1962). It is now present throughout the US and in every province of Canada. It was first reported on Hawaii in 1892, and is now present on all Hawaiian Islands. It is an important, occasional pest of canola in Montana. The immature, or larva stage, injures the leaves, buds, flowers, and seed pods of canola (Knodel and Ganehiarachchi 2008). In North Dakota, most outbreaks that occurred in 2001 and 2007 were primarily in the north central and northeastern growing regions. However, it has been reported to be serious problem in canola in the Golden Triangle areas of Montana.

Larvae of diamondback moth (Fig. 7) feed only on Brassicaceae in North America (Talekar and Shelton 1993), although a localized population developed on sugar snap pea (*Pisum sativum* L.) in Kenya (Löhr 2001). Newly hatched larvae crawl to the lower surface of the leaf and bore through the epidermis (Harcourt 1957) to tunnel within or “mine” the leaf tissue. Typical mines are shallow and appear as numerous white markings on the leaf. Late first instars emerge from the mines, spin a few protective threads, and molt beneath them, selecting a sheltered site such as a depression on the leaf or near an edge that is slightly curled. Older larvae feed on the lower leaf surface and usually consume all tissue except the wax layer on the upper surface to create a “window” in the leaf (Talekar and

Shelton 1993). Late in the season when the leaves become senescent, larvae may feed on pods. There are four larval instars. Adults feed on water drops or dew and are short lived (Talekar and Shelton 1993).

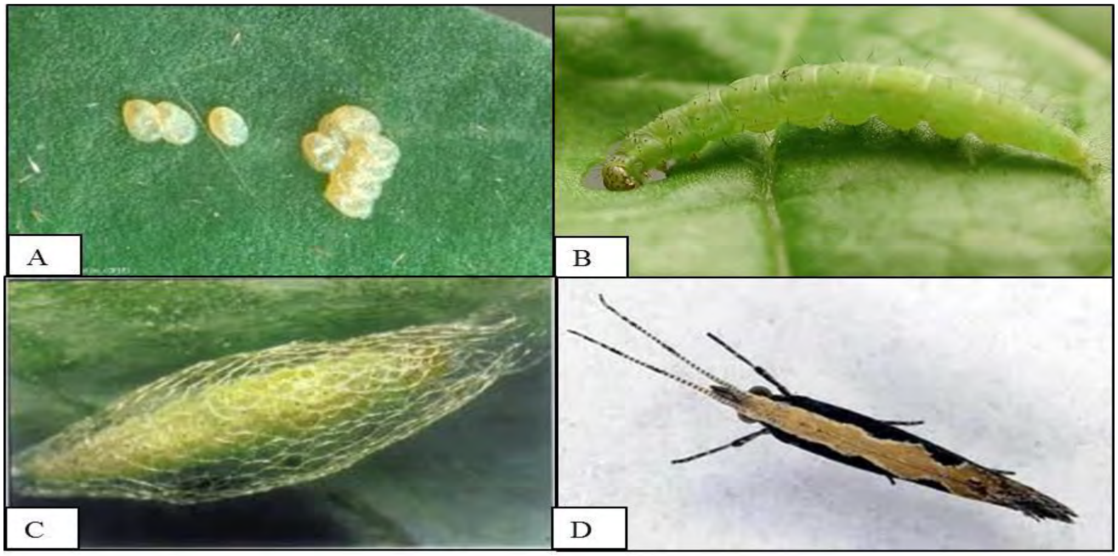

Fig. 7. Eggs (A), larva (B), pupa (C) and adult (D) of diamondback moth, *Plutella xylostella.* (Photo credit: http://www.conferences.unimelb.edu.au/moth/) and http://lepidoptera.butterflyhouse.com.au)

The *P. xylostella* is multivoltine with four to 20 generations per year in temperate and tropical regions, respectively (Harcourt 1986). Each female can lay more than 200 eggs mainly on the upper leaf surface (Talekar et al. 1994). This pest occurs throughout the year wherever its host plants are grown. The larvae feed on all plants in the crucifer family (canola, *Brassica campestris* L. and *Brassica napus* L. mustard, *Brassica juncea* L.), cole crops (cabbage, *Brassica oleracea* L. subsp. *capitata*, cauliflower *B. oleracea* L. subsp. *Botrytis*, and kohlrabi *B. oleracea* L. subsp. *gongylodes*) and on several green house plants (Reddy et al. 2004). Because of the widespread use of insecticides to control *P. xylostella*, it has developed resistance to numerous insecticides, including several *Bacillus thuringiensis* (Bt) products (Tabashnik et al. 1992) and also to several insecticides, particularly pyrethroids, which are the primary registered insecticides for use in canola. This has led to a renewed interest in developing alternatives to the use of insecticides, such as biological control and development of resistant plants (Thomas and Waage 1996).

Larvae of *P. xylostella* feed on all plant parts, but favor the undersides of older leaves, crevices between loose leaves, and young buds (Talekar and Shelton 1993). They create small holes in leaves and buds, or feed superficially leaving slight perforations instead of distinct holes completely through the leaf (Talekar et al. 1994). The newly hatched larvae crawl to the under surface of the leaf and may shallowly bore into the leaf and feed on tissue beneath the leaf surface. The remaining three larval stages feed on the surface, consuming all the leaf tissue except the veins and sometimes the upper epidermis. Larvae wriggle backwards rapidly when disturbed and may drop from the leaf suspended by a silken thread to remain suspended temporarily or drop to a lower leaf (Talekar and Shelton 1993). When populations remain small, these early instars cause little damage; however, in large numbers, they may be injurious to young plants. Larvae are susceptible to drowning; the first instars are the most vulnerable. An average mortality of 56% caused by rainfall was reported by Harcourt (1957). Mortality due to rainfall is affected by temperature (colder temperatures cause higher mortality) and the intensity of rainfall (the harder the rain the higher the mortality). Heavy feeding on buds may cause the marketable portion of the plant to fail to grow (Talekar and Shelton 1993).

Various parasitoid wasps – [*Diadegma semiclausum* (Hellen), *D. insulare* (Cress.), *Cotesia plutellae* (Kurdj.), and *Diadromus subtilicornis* (Gravenhorst)] – and predaceous arthropods, such as ground beetles, true bugs, syrphid fly larvae, lacewing larvae and spiders, can be important in controlling *P. xylostella* populations (Sarfraz et al. 2005). In addition, *Entomophthorales* fungi such as *Zoopthora radicans* Brefeld and *Beauveria bassiana* (Balsamo) Vuillemin, play an important role in controlling moth populations (Reddy et al. 1998; Shelton et al. 1998). Disease outbreaks typically occur later in the growing season when *P. xylostella* populations are larger and weather conditions are more favorable for the fungi to develop.

Sex pheromone traps are useful tools for detecting and managing the *P. xylostella* on cabbage (Reddy and Guerrrero 2000). The recommended trap design is the sticky wing trap suspended near the crop at the field's edge. Traps can also provide an early indication of a possible infestation. Several commercial formulations of the three-component pheromone blend have been shown to be operative in maintaining populations of *P. xylsotella* at economically tolerable levels in vegetables. Although, there has been some success in managing *P. xylostella* on cabbage using pheromone traps, Schroeder et al. (2000) indicated that mating disruption of *P. xylostella* with the present technology does not seem to work even under very controlled situations to eliminate insect movement between plots.

The outreach publications based in North Dakota indicate that, economic thresholds for canola are 10-15 larvae per square foot during early flowering or 20-30 per foot (or two to three larvae per plant) during pod stage (Knodel and Ganehiarachchi 2008). However, there has been no research based information available on the economic threshold for *P. xylostella* to optimize the timing of insecticide sprays on canola. However, Srinivasan and Veeresh (1986) reported that visual injury of up to 1.0 hole per leaf could be effectively controlled by using weekly or bi-weekly insecticide treatments on cabbage. Similarly, Reddy and Guerrero (2001) reported that applications of cartap hydrochloride as an insecticide during a 12-24 h period after pheromone traps caught on average 8, 12, and 16 males per trap per night in cabbage, cauliflower and knol khol, respectively, were significantly more effective than regular insecticide sprays at 7, 9, 12, or 15 days after transplantation.

4. GOALS/OBJECTIVES/EXPECTED OUTPUTS

ii) Objectives:
John Miller, Vickie Ophus and Khanobporn Tangtrakulwanich are involved in the projects.

Objective 1: Evaluate the efficacy of biological control agents for wheat stem sawfly *C. cinctus* (multistate Project) at production scales using on-farm research in the Western Triangle.
This is a collaborative project between MSU-WTARC and David Weaver, Montana State University and Western Triangle Agricultural Research Center, Conrad.

A sub-objective: Evaluating nematodes and entomopathogens as biological control agents.

- The studies will be aimed in developing microbial pesticides as practical tools for *C. cinctus*. The possible use of entomopathogens nematodes (*Steinernema carpocapsae, S. kraussei*, *S. feltiae and* and *Heterorhabditis bacteriophora*) and fungi (*Beauveria bassiana* and *Metarhizium anisopliae*) for *C. cinctus* management will be investigated.

Objective 2: Optimization of trapping technique for *C. cinctus.*

A sub-objective: Influence of trap type, size and color on the trap catches of *C. cinctus*

- Field studies will be carried on the evaluation of various pheromone baited traps with different sizes and eight different colors to determine whether any visual cues affect trap catches. This color preference with trap type and size may help in mass trapping the wheat stem sawfly from various fields.

Objective-3: Role of nutrients in *C. cinctus* management
A sub-objective: Impact of nutrient availability as a function of *C. cinctus* infestation

- Evaluate the effects of supplemental N across two spring wheat varieties at two sites planted on cereal residue.

Objective 4: Trapping wireworms with pheromone traps
This is a collaborative project between Montana State University Western Triangle Agricultural Research Center and Kevin Wanner, MSU-PSPP, David Weaver, MSU-LRES and Miklós Tóth, Plant Protection Institute MTA ATK, Budapest, Hungary, H-1525.

A sub-objective-1: Evaluating pheromone lures for *L. californicus* and *H. bicolor*.

- Screen European based pheromone lures (Hungary) in the Golden Triangle areas using Yatlor Funnel trap (Italy) which is specifically designed for catching click beetles.
- Isolating pheromone compounds from the dominant species found in Western Triangle.

A sub-objective-2: Use of entomopathogens for the control wireworms (Coleoptera: Elateridae)
This is a collaborative project between Montana State University Western Triangle Agricultural Research Center and Stefan T. Jaronski, USDA-ARS, Sidney, Kevin Wanner, MSU-PSPP.

Objective 5: Threshold levels for flea beetles and diamondback moth on canola.
This is a collaborative project between Montana State University Western Triangle Agricultural Research Center and Robert K. D. Peterson, MSU-LRES, Perry Miller, MSU-LRES, Robert Stougaard, MSU-NWARC, Chengci Chen, MSU-CARC.

A sub-objective-1: Evaluating the appropriate threshold levels for flea beetles *Phyllotreta cruciferae* and *P. striolata*.

- Generate different action threshold levels by applying chemical spray (Warrior-II®/lambda-cyhalothrin, 1 ml/liter) within 12 h after reaching the threshold levels as well as regular recommended sprays and non-sprayed control.

A sub-objective-2: Evaluating the appropriate threshold levels for *P. xylostella*.

- Generate different action threshold levels by applying chemical spray (Warrior-II/lambda-cyhalothrin, 1 ml/liter) within 12 h after reaching the different threshold levels as well as regular recommended sprays and non-sprayed control.

Objective 6: Developing integrated control tactics for insect pests on canola.

A sub-objective-1: Comparative effect of alternative control tactics versus conventional insecticidal treatments on canola.

- Develop the best sustainable management practices, using neem, petroleum spray oils, trap crop, and biological control agents (*Steinernema carpocapsae, S. kraussei* , *S. feltiae* and *Heterorhabditis bacteriophora*, *Beauveria bassiana, and Metarhizium anisopliae*).
- Elucidate information on the relative effect of integrated pest management practices versus regular pesticides (bifenthrin, deltamethrin, gamma-cyhalothrin and lambda-cyhalothrin).

It is anticipated that the overall project will provide us with biological control and pheromone-based trapping programs for wheat stem sawfly and wireworms on wheat and barley. On the other hand, canola growers also benefit by economic thresholds for two major pests on canola. Moreover, the IPM program will be developed using low-risk insecticides. It is expected that we will develop IPM programs based on economic thresholds for canola, and contribute to existing scientific knowledge about reducing on-farm use of regular insecticides and insect infestation levels in canola.

Montana wheat and canola growers will benefit from appropriate modifications of pest management and trapping methods resulting from the IPM approaches developed from these studies. Increased production as a result of strong and healthy canola and wheat crops will result in enhanced agricultural industry that would in turn lead to economic prosperity of the region. Thus, this project will help to reduce operating costs of growers and will also help them maintain healthy and strong crop production.

5. METHODS

Objective 1: Evaluate the efficacy of biological control agents for wheat stem sawfly *C. cinctus* (multistate Project) at production scales using on-farm research in the Western Triangle.
A sub-objective: Evaluating nematodes and entomopathogens as biological control agents.

Since the *C. cinctus*, overwinter diapause in the wheat stubble which remains in the field following harvest, this study will be aimed to target these immature stages. All the entomopathogenic formulations are commercially available and can be obtained from the local markets (Table 2), and the dosages will be used as recommended by the manufacturer.

Laboratory Studies:
This experiment will be conducted during the summer months of 2013 and 14 after the harvest is over. The laboratory assays will indicate the hypothesis that the pathogens we test, when topically applied to wheat stubble, would exhibit toxicity and cause mortality of the immature stages. Wheat stubbles will be easily uprooted from the fields after the harvest. For each replicate, one wheat stubble were transferred to a disk of clear plastic box (25×45cm) lined with moist filter paper. Four replicate boxes of 4 wheat stubbles will be sprayed (Household Sprayer) with 2.0 mL of each of the formulations. Two control treatments will be maintained; in one, the boxes will be sprayed with 2.0 mL of tap water, and in the other, no treatment was applied. Following this application, boxes will be maintained ambient temperature and adult mortality will be assessed 14 days after the treatment.

Table-2: Details of the commercially available entomopathogens available and will be evaluated against immature stages of the *Cephus cinctus* in the laboratory and field conditions.

Treatment	Active Ingredient	Dose	Source
Control (no treatment)	No treatment	—	—
Control (water spray)	—	—	—
Mycotrol® 22WP	*Beauveria bassiana* Strain	2.4 grams/L of water	Laverlam International Corporation, Butte, Montana
Met 52 G	*Metarhizium anisopliae* Strain F52	5 grams/liter	Novozymes, Davis, CA
Millenium®	*Steinernema carpocapsae*	1 mil/13 liters	Becker Underwood, Ames, Iowa 50010
Nemasys®L	*Steinernema kraussei*	1 mil/13 liters	Becker Underwood, Ames, Iowa 50010
Nemasys®	*Steinernema feltiae*	1 mil/13 liters	Becker Underwood, Ames, Iowa 50010
Nemasys®G	*Heterorhabditis bacteriophora*	1 mil/13 liters	Becker Underwood, Ames, Iowa 50010

Field Experiments:
Field trials will be established in 2013 and again in the summer of 2014 at two locations in Montana: Western Triangle Agricultural Research Center, Conrad, MT, and at a grower's field near Devon, MT. The size of treatment plots will be 4 m × 4 m and separated from other plots at a 1.5 m distance to avoid treatment effects. The experiment consists of 8 treatments with three replications will be carried out in a Complete Randomized Block Design.

When applying nematodes, enough water needs to be used to penetrate the plant canopy and deposit the nematodes on the soil surface so they can enter the soil. Beneficial nematodes and entomopathogens are sold in packets which can be kept viable in refrigerated storage. When they are ready to be applied, the content of the packets can be simply mixed with water (one million nematodes for an area of 2000 square feet, it will take around 24 million to cover an acre of land) and spread them on the soil using a sprayer.

Observations:
The stubbs will be cut with a fine knife and observed for mortality of the immature stages after 14 days after the treatment. The immobile immature stages failed to move when probed with a dissecting needle were recorded as dead and removed from the boxes. For the treatments with entomopathgen formulations, dead immature stages will be removed and incubated separately in in Petri dishes lined with damp filter paper. The Petri dishes will be placed in a desiccator and inspected for the presence of mycelium on cadavers (mycosis) starting on day 7.

Objective 2: Optimization of trapping technique for *C. cinctus.*
A sub-objective: Influence of trap type, size and color on the trap catches of *C. cinctus*.

The experiments will be undertaken during spring 2014 and 2015 at four locations, Western Triangle Ag Research Center (WTARC), grower's field near Devon, Sunburst and Conrad, MT.

Effect of trap design:
The four trap types (Delta, prototype trap developed by the wheat stem saw fly laboratory, sticky and funnel), with the *C. cinctus* pheromone lures, will be placed at randomly chosen locations about 10 m apart in wheat fields at the four test locations. Tests will be replicated three times at each site to yield 12 replications. Traps without pheromone lures will be used as controls. Overall, 96 traps were used: 8 treatments (4 trap designs, each with and without lures) × 3 replications × 4 sites. Each week, the trapped adults will be removed and counted and their numbers recorded. The traps will be washed and rinsed, and new detergent water can be added. We will rotate the trap positions weekly at each location to diminish positional effect on trap catch.

Effect of trap size:
The effectiveness's of four sizes of the effective trap known from the above studies (sizes will be decided later depending upon the trap) will be compared. At each site, three traps of each size will be set up and their positions rotated weekly to preclude location effects. Tests will be replicated three times at each site to yield 12 replications. The study will use 48 traps (4 trap sizes × 3 replications × 4 sites).

Effects of color:
Traps will be entirely covered with brown, black, gray, yellow, red, white, green, or blue vinyl tape and tested independently (8 trap colors × 3 replications × 4 sites) at the above sites. The experiments will be carried out during summer 2013 and 2014. Color characteristics of the tape will be determined with a Konica Minolta CR-410 Chromometer (Minolta Instrument Systems). Once the particular attractive color to wheat stem sawfly is known from the initial trials, additional experiments will be carried out independently on the evaluation of different shades of the attractive trap color.

Objective-3: Role of nutrients in *C. cinctus* management
A sub-objective: Impact of nutrient availability as a function of *C. cinctus* infestation

- Evaluate the effects of supplemental N across two spring wheat varieties, Choteau and Reeder.

The experiment will be conducted at two sites. One site will be near Devon, MT and planted and maintained by WTARC near Conrad. The second site will be on-station at NARC near Havre, MT. The experimental design will be RCBD with two spring wheat varieties and four fertilizer treatments.

The varieties Choteau and Reeder will be planted into chemical fallow using a 5 row, 12 inch spaced, plot planter equipped with Conserv-a-Pac® openers. Nitrogen fertilizer at the rates of 0, 40, 80, and 120 lbs/acre will be applied while. Nitrogen treatments will be surface broadcast with N as urea and with 25 lbs K, as potash. Phosphorus, as 0-45-0 will be placed with the seed while planting. Plot size will be 5 by 25 feet with 4 replicates.

At both sites, 3 one foot samples of row will be collected 1 week before harvest for stem dissection to determine *C. cinctus* infestation, parasitism of *C. cinctus* larvae, and stem cutting by *C. cinctus* larvae. Samples will be typically removed with a shovel due to dry overall environmental conditions and the numbered of severed stems that challenge sample integrity. After the stem samples are collected from the research plots, the plots will be harvested for yield, protein and test weight information. Yield, test weight, and protein data will be adjusted to 12% moisture content. All statistical analyses will be carried out using SPSS. Analysis of variance (ANOVA) will be performed to examine treatment differences and any interactions. Treatment differences can be explored using Gabriel's multiple comparison procedure. Variety and N will be fixed effects. The percentage of stems infested and cut by *C. cinctus*, and the percentage of WSS larvae parasitized will be arcsine square root transformed.

Objective 4: Trapping wireworms with pheromone traps.
A sub-objective-1: Evaluating pheromone lures for *L. californicus* and *H. bicolor*.

The Yatlor Funnel traps (Fig 5) with the lures will be installed at the Western Triangle Ag Research center and in the grower's field at Valier and Cut Bank.

Pheromones	Geranyl butanoate	E,E-farnesyl acetate	Geranyl hexanoate	Geranyl octanoate	Geranyl isovalerate	E,E-farnesyl butanoate	valeric acid	hexanoic acid
Agriots sputator	+	-	-	-	-	-	-	-
Agriots brevis	+	+	-	-	-	-	-	-
Agriots ustulatus	+	-	-	+	-	-	-	-
Agriots lineatus	+	-	+	-	-	-	-	-
Agriots obscurus	-	-	+	+	-	-	-	-
Agriots litigiosus	-	-	-	-	+	-	-	-
Agriots sordidus	-	-	+	-	-	-	-	-
Limonius californicus	-	-	-	-	-	-	+	-
L. californicus diff. dispenser	-	-	-	-	-	-	+	-
Limonius canus	-	-	-	-	-	-	-	+
L. canus pher., diff. dispenser	-	-	-	-	-	-	-	+

Table-2: List of pheromones lures of different European based wireworms species

Traps with different lures and control (without lures) tested independently (12 pheromone lures × 3 replications × 3 sites) at the above mentioned locations. The experiments will be carried out during summer 2013 and 2014. The trap catches will be recorded fortnightly.

A sub-objective-2: Use of entomopathogens for the control wireworms (Coleoptera: Elateridae)

In an attempt to cause fatal infection of wireworm species on spring wheat, the commercialized *M. anisopliae* Strain Met52 and *B. bassiana* Strain GHA will be applied at the recommended rates in the field as factorial combinations of conidia formulated as granules, or as water-based sprays of conidia, both applied in furrow, and as conidia-coated wheat seed. Fungus materials will be provided by USDA ARS Sidney MT.
T1: Conidia of *M. anisopliae* formulated as granules applied in furrow at planting.
T2: Conidia of *M. anisopliae* applied as a drench in furrow (just ahead of drilling the wheat and allow the openers to mix the conidia with the soil as the seed is sowed).
T3: Conidia of *M. anisopliae*-coated wheat seed (as seed treatment)
T4: Conidia of *B. bassiana* formulated as granules, applied in furrow at planting.
T5: Conidia of *B. bassiana* applied as a drench in furrow (just ahead of drilling the wheat and allow the openers to mix the conidia with the soil as the seed is sowed).
T6: Conidia of *B. bassiana*-coated wheat seed (as seed treatment)
T7: Untreated control

To treat wheat seed with conidia (+seed), canola oil (24 ml) will be used to adhere conidia to the surface of the seed by placing 3 kg of wheat seeds in the container and coated with conidial powders (Kabaluk et al. 2007). These seeds and granules will be prepared for these tests by Dr. Stefan Jaronski, USDA ARS in Sidney MT, based on his work with controlling sugarbeet root maggot with these fungi. For the drenches, technical grade conidial powders will be suspended in 0.1% Silwet L77 (a wetting agent) for application.

Laboratory Experiments:
The laboratory assays will indicate the hypothesis that the pathogens we test, would exhibit toxicity and cause mortality of the wireworms. Plastic containers will be used for evaluation of different pathogens and formulations. Wireworms will be easily collected from the field using stocking traps. Conidial suspensions or granules will be

mixed into dried, sieved, field soil at rates similar to field applications. The control will be merely wetted with the appropriate amount of water. The soil will then be moistened to 20% field capacity and divided into four replicates. For each of the replicates, 20 wireworm larvae will be added to the treated or control soils. The containers will be subsequently maintained at ambient temperature; larval mortality and mycosis will be assessed weekly for three weeks.

Field Experiments:
Field trials will be established during the spring in 2013 at two locations in Montana: a grower's fields in Valier and Ledger. The size of treatment plots will be 4 m × 4 m and separated from other plots at a 1.5 m distance to avoid treatment effects. The experiment consists of 7 treatments, as described above, with three replications in a Complete Randomized Block Design. Rates of fungus will be partially determined by the results of the laboratory bioassays, and partly by practicality and economics.

Observations:
The larvae from each plot will be collected at different intervals after the treatment, incubated in the laboratory for up to two weeks and observed for mortality. Any larvae failing to move when probed with a dissecting needle will be recorded as dead and removed from the boxes. These dead larvae will be surface sterilized then incubated separately in Petri dishes lined with damp filter paper and the cadavers will be inspected for the presence of mycelium (mycosis) starting on day 7.

Objective 5: Threshold levels for flea beetles and diamondback moth on canola.
A sub-objective-1: Evaluating the appropriateness of threshold levels for flea beetles *Phyllotreta cruciferae* and *P. striolata*.

Field trials will be established in 2013 and again in the spring of 2014 at two locations in Montana: Western Triangle Agricultural Research Center, Conrad, MT, and at a grower's field near Cut Bank, MT. This experiment will be conducted on the Dekalb 30-42 or Nexera 1012 canola varieties that are extensively grown in the Golden Triangle area of Montana. The size of treatment plots will be 8 m × 8 m and separated from other plots at a 1.5 m distance to avoid spray drift or treatment effects. In each plot, there will be 35 rows with row spacing of 23 cm. All recommended agronomic practices will be followed. Seeds will be drilled into plots measuring 15 ft by 3.5 ft (7 rows with 6 inch spacing). For treatment applications T1 to T5 based on *P. cruciferae* or *P. striolata* threshold levels, an application of Warrior-II (lambda-cyhalothrin, Syngenta) at the rate of 1.0 ml/liter was sprayed within 12 h after reaching mean threshold levels of 5, 15, 25, 35, and 45% of the surface area of cotyledons and first true leaves injury by *P. cruciferae* or *P. striolata* is noticed. Lambda-cyhalothrin was chosen for the present study as it is one of the chemicals being popularly used by the canola growers in the Golden Triangle area. For the calendar-based chemical treatments, the same chemical will be applied as shown in treatments T6 to T8. This spraying schedule is usually performed by growers. The plot (T9) with the standard seed treatment without any further spray will serve as customary control. No chemical treatment is applied in T10 (control). The experiment consists of 10 treatments with three replications will be carried out in a Complete Randomized Block Design at two locations. The observations will be recorded on the larval populations and damage by *P. cruciferae* or *P. striolata* and finally yield levels. To evaluate feeding injury, 10 plants per plot (or 30 per treatment) will be randomly selected and assessed for the number of holes at weekly intervals. Appropriate statistical analyses will be performed on the recorded data.

Thresholds used to determine when to spray canola for *P. cruciferae* and *P. striolata* control are shown below:

T1: Initiate insecticide spray when 5% of the surface area of cotyledons and first true leaves are injured by *P. cruciferae* or *P. striolata*;

T2: Initiate insecticide spray when 25 % of the surface area of cotyledons and first true leaves are injured by *P. cruciferae* or *P. striolata*;

T3: Initiate insecticide spray when 45 % of the surface area of cotyledons and first true leaves are injured by *P. cruciferae* or *P. striolata* is detected;

T4: Calendar-based spray schedule (CSS) (15 days after sowing (DAS)): 15, 30, 45, 60, 75, 90, 105 and 120;

T5. CCS: (30 DAS): 30, 60, 90, and 120;

T6. CCS: (45 DAS): 45, 90, and 135;

T7: Standard seed treatment (no spray);

T8: Untreated control (no spray).

A sub-objective-2: Evaluating the appropriateness of threshold levels for *P. xylostella*.

The treatment plots and all other cropping details are the same as in the case of experiments with action threshold levels for flea beetles. Field trials will be established in 2013 and again in the spring of 2014 at two locations in Montana: Western Triangle Agricultural Research Center, Conrad, MT, and at an growers field in Joplin, MT. Thresholds used to determine when to spray canola for *P. xylostella* control are shown below. The observations will be recorded on the larval populations and damage by *P. xylostella* and to end yield levels. To evaluate feeding injury, 10 plants per plot (or 30 per treatment) will be randomly selected and assessed for the number of holes at weekly intervals. Appropriate statistical analyses will be performed on the recorded data.

T1: First spray timed when 10 larvae of *P. xylostella* are observed on 10 plants, followed by additional sprays every 7 days until swathing or a direct cut harvest;

T2: First spray timed when 15 larvae of *P. xylostella* are observed on 10 plants, followed by additional sprays every 7 days until swathing or a driect cut harvest;

T3: First spray timed when 10 larvae of *P. xylostella* are observed on 10 plant samples, followed by an additional spray only if 10 larvae /10 plants are observed;

T4: First spray timed when 15 larvae of *P. xylostella* are observed on 10 plant samples, followed by an additional spray only if 15 larvae /10 plants are observed;

T5: First spray timed when 15 larvae of *P. xylostella* are observed on 10 plant samples, followed by an additional spray only if 20 larvae /10 plants are observed;

T6: First spray timed when 15 larvae of *P. xylostella* are observed on 10 plant samples, followed by an additional spray only if 30 larvae /10 plants are observed;

T7: Calendar-based spray schedule (CSS) (15 days after sowing (DAS)): 15, 30, 45, 60, 75, 90, 105 and 120;

T8. CCS: (30 DAS): 30, 60, 90 and 120;

T9: Standard seed treatment (no spray);

T10: Untreated control (no spray).

Objective 6: Developing integrated control tactics for insect pests on canola.

A sub-objective-1: Comparative effect of alternative control tactics versus conventional insecticidal treatments on canola.

The aim of this objective study is to reduce high-risk agricultural insecticide use with integrated pest management using beneficial nematodes, entomopathogens, petroleum spray oil, and neem to control flea beetles (*P. cruciferae* or *P. striolata*) and *P. xylostella* on canola. Field trials will be established in 2015 and again in the spring of 2016 at two locations in Montana: Western Triangle Agricultural Research Center, Conrad, MT, and at a grower’s field near Joplin, MT.

Research Procedures:
This field study will be carried out with 10 treatments to be replicated three times in a randomized complete block design. This experiment will be conducted on the Dekalb 30-42 or Nexera 1012 canola varieties that are widely grown in the Golden Triangle area of Montana. The following are the planned treatments: The treatment combinations will be the *S. carpocapsae* (Becker Underwood, at the rate of (1 mil/13 liters); *B. bassiana* 22WP (Laverlam International, at the rate of 2.4 grams/liter) and Met 52 Granular containing *M. anisopliae* Strain F52 (Novozyme, at the rate of 5 grams/liter), Volck oil spray/PSO, (Ortho, at the rate of 20 ml/liter), Aza-Direct/neem containing 1.2% azadirachtin (Gowan Company, at the rate of 10 ml/liter), bifenthrin at the rate of 2.5 ml/liter and deltamethrin at the rate of 1.5 ml/liter. The size of treatment plots will be 8 m × 8 m and separated from other plots at a 1.5 m distance to avoid spray drift or treatment effects. In each plot, there will be 35 rows with row spacing of 23 cm. All recommended agronomic practices will be followed.

When applying nematodes, enough water needs to be used to penetrate the plant canopy and deposit the nematodes on the soil surface so they can enter the soil. Beneficial nematodes and entomopathogens are sold in packets which can be kept viable in refrigerated storage. When they are ready to be applied, the content of the packets can be simply mixed with water (one million nematodes for an area of 2000 square feet, it will take around 24 million to cover an acre of land) and spread them on the soil using a sprayer. Where plots will be treated with insecticide, the insecticide will be applied as a foliar spray using a propane Solo brand backpack sprayer equipped with a boom containing three hollow cone nozzles; the center nozzle oriented over the top of the row and two drip nozzles directed to either side of the same row. Sprays will be made on a weekly basis, with the specific number of spray applications and dates according to treatment structure. The pre-treatment counts will be made or damage levels assessed.

In this proposal we intend to study:
T1: Release of nematodes (*Steinernema carpocapsae*) at 15 and 30 days after sowing (DAS);
T2: Release of nematodes (*Steinernema carpocapsae*) at 15, 30, 45 and 65 DAS;
T3: An application of petroleum spray oil (PSO) at 15 DAS + an application of neem at 30 DAS;
T4: Two applications of PSO at 15, 30 DAS and + two applications of neem at 45, 60 DAS;
T5: An application of *B. bassiana* at 15 DAS + an application of *M. anisopliae* at 30 DAS;
T6: Two applications of *B. bassiana* at 15, 30 DAS and + two applications of *M. anisopliae* at 45, 60 DAS;
T7: Five applications of bifenthrin at 10, 20 30, 40 and DAS (the growers' practice);
T8: Five applications of deltamethrin at 10, 20 30, 40 and 50 DAS (the growers' practice);
T9: Standard seed treatment (no spray);
T10: Untreated control (no spray).

6. NON-TECHNICAL PROJECT SUMMARY

Wheat is the major food grain produced in the United. Spring wheat and winter wheat are the major grain cereal crops grown in Montana. The wheat stem sawfly, *Cephus cinctus* is major pest and infesting both winter and spring wheat in the Golden Triangle Area. In contrast, two species of wireworms *Limonius californicus* and *Hypnoidus bicolor* are recently found to be serious pests infesting wheat and barley. All these species are causing millions of dollars annually ever since the management has been very difficult and challenging. The biological control program with entomopathogens, pheromone-based trapping technique to improve the capture efficiency of wheat stem sawfly and role of nutrients in *C. cinctus* management will be investigated. Since the pheromone compounds are not identified for the wireworm species found in Golden Triangle; the pheromone compounds of European based wireworm species will be evaluated. These works are as a part of the development of pheromone trapping techniques for monitoring and management for the wireworms and wheat stem sawfly.

Canola is an important oilseed crop in the northern Great Plains of the United States and Canada. Flea beetles, *Phyllotreta cruciferae* and *P. striolata,* and diamondback moth, *Plutella xylostella*, are the most serious insect pests of canola. The damage to oilseed *Brassica* crops from these beetles alone can exceed $300 million annually in North America. Producers are frustrated by the high incidence of flea beetles and diamondback moth on canola. Even small numbers of adults on plants can cause severe damage to the cotyledons and true leaves. While some control methods do exist, chemical application is both undesirable and expensive. Without appropriate effective controls, these insect pests are likely to cause significant reduction or complete loss of canola production in Montana. Canola growers in the Golden Triangle areas of Montana are applying various chemical pesticides and often seem to be expensive and not environmentally safe. The action threshold levels are used in pest management programs and are known to reduce insecticide usage. There are reports of flea beetle and diamondback moth infesting canola in several locations in the Golden Triangle areas of Montana. These insect populations can build rapidly, and cause problems in canola when plants start to bloom. We do not currently have any research-based economic thresholds from Montana for managing insect pests on canola, so the study will be undertaken to develop nominal threshold levels for *P. cruciferae* and *P. striolata*, and *P. xylostella* in spring canola. Once these threshold levels are developed, a sustainable pest management program will be developed based the action threshold levels.

Research results from all projects will be disseminated to producers and extension personnel at community meetings and through extension publications. Contributions to the scientific community will be made through conference presentations and the publication of scholarly papers.

7. KEYWORDS

Pest management, pheromones, visual cues, traps, Golden Triangle, wheat, barley, canola, *Limonius californicus*, *Hypnoidus bicolor, Cephus cinctus*, nutrients, action thresholds, *Phyllotreta striolata*, *P. cruciferae, Plutella xylostella,* entomopathogens, nematodes, fungi, *Metarhizium anisopliae*, *Steinernema carpocapsae*, *Beauveria bassiana*, spray oils, insecticides, Volck oil, Azadirachtin, Aza-Direct, bifenthrin, deltamethrin, deltamethrin, bifenthrin, gamma-cyhalothrin, lambda-cyhalothrin.

8. PROJECT EVALUATION

Progress will be reviewed annually by the MAES dean and by a mentoring committee each year during the annual MAES planning conference. Research results will be reported in the WTARC and MAES annual reports each year. Findings will be disseminated to producers and other industry stakeholders at annual field days and the annual MAES advisory committee meeting, as well at any relevant community meetings. Research results will be presented to the scientific and academic communities via professional presentations, conference proceedings, and referred journal articles, as well as through extension and popular press publications, where appropriate.

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2012 Winter Wheat Variety Evaluations in the Western Triangle Area.

Location: Western Triangle Agricultural Research Center (WTARC), Conrad, MT.

Personnel: John H. Miller and Gadi V.P. Reddy, WTARC, Conrad, MT, Dave Wichman, CARC, Moccasin, MT, and Phil Bruckner and Jim Berg, MSU Plant Science Dept., Bozeman, MT.

The uniform, winter wheat intrastate and advanced variety nurseries, along with four off station locations were grown 2012. Off station trials were grown north of Cut Bank, MT, north of Devon, MT, near the 'Knees' east of Brady, MT, and northeast of Choteau, MT in Teton county.

Results: Winter wheat variety data are shown in Tables 1 thru 9. Soil test results may be viewed in Table 33 at the end of the barley section.

Winter wheat intrastate and advanced data are shown in Tables 1 thru 4. Off station plots were harvested at Choteau, Devon, and the 'Knees'. The Cut Bank location was lost due to a hailstorm. The data is presented in Tables 5 thru 9.

The 2012 growing season at WTARC began with a bit warmer temperatures than normal and a little less rain, followed by a dry and slightly warmer than the long term average summer. Yields in the intrastate nursery were about 12 bu/a higher than the long term average, with test weight, protein, and plant height about the same as the long term mean, Tables 1 and 3.

Grain yields, test weights, and protein at the 'Knees' were very close to the four year average (Table 4 and 5). Grain yields and test weights at the Devon location were also close to the three year average, whereas the protein was slightly higher than average (Tables 2 and 3).

Top yielding varieties at the Choteau location were Pryor, MTS0819, and Yellowstone. MT0871, MTS0819, and MT08172 were the high yielding varieties at Devon. Top yielders at the 'Knees' include Overland, MTS0826, and MTS0832

Off station cooperators: Bradley Farms, north of Cut Bank, MT
Brian Aklestad, north of Devon, MT
Aaron Killion, east of Brady, MT
Inbody Farms, northeast of Choteau

Detailed descriptions of most of the varieties tested are included in Extension Bulletin 1098 "Performance Summary of Winter Wheat Varieties in Montana", available at County Agent Offices.

MWBC FY2014 Grant Submission Plans: A similar project will be proposed for FY 2014.

Winter Wheat Variety Notes & Comments

Western Triangle Agricultural Research Center, Conrad, MT

Winterhardiness ratings: 5 = very good; 1 = poor.
Coleoptile length: Long = 3.4" or more; Short = 3" or less.
Stem solidness scores of 19 or higher are generally required for reliable sawfly resistance.

Accipiter (Sask. DH0018196): First tested in 2008. High yield in 2008. 4” taller than Falcon. Similar to Falcon for test weight, head date and protein. Parentage = Raptor x Falcon.

Bauermeister (WA7939, 2005): Winterhardiness = 2. Medium height, med-strong straw. Medium coleoptile. Very late maturity. Very low test weight.

Bearpaw (MSU, 2011): Awned, white-glumed, solid-stem (stem solidness score = 21.8), semi-dwarf hard red winter wheat. Maturiety similar to CDC Falcon, and a day earlier than Genou and Rampart. About 3.5 inches shorter than Genou and Rampart, with yields similar to CDC Falcon and higher than Genou and Rampart. Susceptible to strip and leaf rust. Resistant to prevalent races of stem rust and UG99.

Big Sky (MT9432, 2001): Nuwest/Tiber cross, hard red kernels, white chaff. Good winterhardiness (4). Strong, stiff straw, very good lodging resistance, height equal to Tiber. Medium coleoptile. Medium maturity, heading 1-2 days later than Rocky, but 2 days earlier than Tiber and Morgan. Yield about equal to Rocky, and 2-3 bu higher than Tiber. High test weight and protein. Post-harvest seed dormancy is high, like Tiber. Septoria and tan spot resistance is good. A good alternative to Tiber.

Bond (CO 2004): Winterhardiness = 2. Clearfield system IMI resistant. Stiff straw, medium height & coleoptile, early maturity. Above average yield. Average test weight. Resistant to biotype 1 Russian wheat aphid. Low protein and poor quality.

Buteo (CDC, WPB, Sask., 2006): Winterhardiness = 4. Standard height, medium coleoptile. Medium-late maturity. Below average yield. Above average test wt. Average protein.

Bynum (MSU & WPB, 2005): Clearfield system single-gene resistance to imazamox or ‘Beyond’ herbicide. Winterhardiness = 2. Medium strong straw, medium height, long coleoptile. Stem solidness = 20 (compared to 22 for Rampart), which typically provides a reliable level of sawfly tolerance. Similar in yield and other characteristics to Rampart. Sawfly resistant, low yield, high protein, and excellent baking quality.

Carter (WestBred, 2007): Winterhardiness = 3. Semidwarf height, stiff straw, short coleoptile. Stem solidness score = 15. Medium early heading. Average yield. Above average test weight. Average protein. Moderate resistance to stripe rust.

Darrell (S. Dak., 2006): Medium height and coleoptile. Medium-early heading. High yield. Average test weight and protein.

Decade (MSU/NDSU, 2009): White chaffed, hard red winter wheat, with winter hardiness almost equal to Jerry. High yield potential, medium to high test weight, early maturity, and medium to high grain protein.

Falcon (CDC, WPB, Sask. 1999): Good winter-hardiness (4). Semi-dwarf, stiff straw, 4” shorter than Rocky. Short coleoptile. The first true winter hardy semi-dwarf available for irrigated conditions in Montana. Heading 1 day later than Rocky, 2 days earlier than Neeley & Tiber. Above average yield and test weight on dryland, good performance for irrigated or high rainfall conditions. Protein similar to Rocky. Not for stripe rust areas.

Genou (MSU, 2004): Sawfly resistant. Stem solidness not quite as solid as Rampart; and may be more sensitive to environmental factors than that of Rampart. Solid stem comparison: (max rating = 25): Rampart = 22, Genou = 19. Winterhardiness higher than Vanguard and Rampart, equal to Rocky. Medium stiff straw. Height similar to Vanguard, and 2" shorter than Rocky. Medium coleoptile. Maturity 1-2 days later than Rocky. Yield 7% higher than Vanguard & Rampart, 5% less than Rocky. Average test weight and protein.

Hawken (AgriPro, 2007): Semidwarf height, short coleoptile. Early maturity. Yield is below average. Above average test weight and protein.

Hatcher (CO 2004): Winterhardiness = 2. Strong straw, semidwarf height, medium coleoptile. Early maturity. Low protein. Resistant to biotype 1 Russian wheat aphid and Great Plains biotype Hessian fly. Very low quality.
Jagalene (AgriPro, 2002): Winterhardiness = 2. Semidwarf, stiff straw, medium coleoptile. Early maturity, 1 day earlier than Rocky. Shatter resistant. Average yield. Very high test weight. Avg protein, but higher than Rocky. Good milling quality. Good disease resistance package (stem & stripe rust, tan spot and Septoria).

Jerry (ND, 2001): Winterhardiness high (5). Medium-stiff, med-tall straw, medium coleoptile. Medium-late maturity. Yield is below average, except in winterkill areas where it's above average. Below-average test weight. Average protein. Has one of the worst sawfly stem-cutting ratings. Shatter susceptible.

Judee (MSU, 2011): Awned, white-glumed, solid-stem (stem solidness score = 20.1), semi-dwarf hard red winter wheat with good straw strength. Maturiety similar to CDC Falcon, and a half day earlier than Genou and Rampart. About 2.5 inches shorter than Genou and Rampart, with yields similar to CDC Falcon and higher than Genou and Rampart. Winter hardiness is medium to low. Susceptible to prevalent races stem and leaf rust, but is resistant to stripe rust.

Ledger (WestBred, 2005): Winterhardiness = 2. Semidwarf height & stiff straw, 4" less than Rocky. Medium coleoptile. Stem solidness = 10, variable & sensitive to cloudy conditions; not a reliable level of sawfly tolerance. Early heading. Above avg yield & test wt. Avg protein and acceptable quality. Moderate stripe rust resistance.

Morgan (Sask & WPB, 1996): High winterhardiness (5). Standard height. Medium stiff straw. Very short coleoptile. Three days later to head and slightly later maturity than Rocky; heading similar to Neeley. Below average yield. Test wt 1-lb less than Rocky or Tiber. Protein slightly higher than Rocky, similar to Neeley. Milling and baking acceptable. Recommended for areas needing high levels of winterhardiness.

MT08172 (MSU): Awned, white-glumed, high-yielding hard red winter wheat. Similar to Yellowstone for most agronomic traits with the exception of test weight, MT08172 is about 0.5 lb/bu higher. Better stem rust resistant than Yellowstone, moderately resistant to prevalent races of stem rust including UG99. Also, moderately resistant to stripe rust, but susceptible to leaf rust. Medium to late maturity, 2.5 days later than CDC Falcon and 4 days later than Jagalene. Similar in height to Yellowstone.

MTS0808 (MSU): Awned, white-glumed, solid-stem, semi-dwarf hard red winter wheat. With medium maturiety, similar to Genou and Rampart. Medium-short, similar to Judee and Bearpaw. Resistant to prevalent races of stem rust including UG99 and stripe rust. Suseptable to leaf rust. Solid-stem score averages 21.4, similar to Rampart and Bearpaw.

Neeley (Idaho, 1980): Winterhardiness medium (3). Medium short straw. Medium coleoptile. Medium-late maturity. Susceptible to stem rust. High yielder in good years, but does poor if stressed for moisture. Below average test weight. Good shatter resistance. Protein & quality are erratic, ranging from low to high. Not for stripe rust areas.

Norris (MSU & WPB, 2005): Clearfield system single-gene resistance to imazamox or 'Beyond' herbicide (which controls cheatgrass, goatgrass and wild oats). Winterhardiness = 3. Stiff straw, medium height, medium coleoptile. Early maturity. Above average yield and test weight. Average protein, good quality. Replaces MT1159CL.

Promontory (Utah, 1990): Red head. Winter hardiness poor (2 or less). Medium-short, medium-strong straw. Short coleoptile. Medium maturity. Excellent stripe rust & dwarf smut resistance; Stem rust susceptible. Average yield and above average test weight. Protein medium low. Has severe sawfly stem cutting ratings.

Pryor (WPB, 2002): Winterhardiness 3 = Neeley. Short stiff straw, 4" shorter than Neeley. Short coleoptile. Medium late maturity similar to Neeley & Tiber, 2 days later than Rocky. Above average yield. Average test weight and protein, good quality. Intended mainly for Central Montana as a replacement for Neeley. Not for stripe rust areas.

Rampart (MSU, 1996): Sawfly resistant (sister line to Vanguard). Solid stem rating = 22. Red chaff, upright head. Winterhardiness is marginal (2-). Should not be grown in areas where high levels of winterhardiness are needed, unless protected by stubble. Height 1 inch shorter than Neeley, med-stiff straw. Very long coleoptile. Matures 1 day later than Rocky, 2 days earlier than Neeley. Some resistance to stem rust, and some tolerance to wheat streak mv. Medium shatter resistance. Yield is below average, but is above average under heavy sawfly conditions. Does not seem as prone to shatter as Vanguard. Good test weight, protein and quality. See Genou.

Ripper (Colorado, 2006): Semidwarf height, medium coleoptile. Early maturity. Above average yield and test weight. Average protein.

Rocky (Agripro, 1978): A selection from Centurk for soil borne mosaic resistance. Winterhardiness = 2. Medium weak straw, medium height. Medium coleoptile. Early maturity. High yield. Very susceptible to yellow berry expression under low nitrogen conditions. Medium protein. See Jagalene and Ledger for shorter-straw alternatives.

Tiber (MSU, 1988): Dark Red head, (blackish-red in years of favorable moisture). Winterhardiness = 3. Medium height with good lodging resistance. Stiff straw, which may cause it to thresh a little harder than weaker-strawed varieties. Med-long coleoptile. Very resistant to sprouting, causing some dormancy. Medium maturity. Susceptible to stem rust. Very resistant to shatter. Below average yield. Protein above average. Good milling and baking quality. Fdn seed being discontinued. See Big Sky for alternative.

Vanguard (MSU, 1995): Sawfly resistant. Good stem solidness. White chaff, nodding head. Winterhardiness marginal (2-). Straw slightly stiffer and 1 inch shorter than Rocky, but moderately susceptible to lodging under high-yield conditions. Long coleoptile. Medium head date, 1 day later than Rocky, 3 days earlier than Neeley. Good wheat streak mv tolerance. Susceptible to stem & stripe rust. Below average yield; but under heavy sawfly infestation, yield is above average. Medium shatter resistance. Good test weight. Protein high; quality adequate. Not a satisfactory variety for non-sawfly areas, and should not be grown where high levels of winterhardiness are needed unless protected by stubble. See Genou.

Wahoo (Nebr & Wyo, 2000): Winterhardiness = 3. Semidwarf, 2” shorter than Rocky, stiff straw. Short coleoptile. Very early maturity. High yield. Average test weight & protein, marginally poor quality.

Willow Creek (MSU 2005): Beardless forage winter wheat for hay. HRW class. Winterhardiness = 5. Very tall straw, lodging susceptible. Long coleoptile. Very late maturity. High forage yield. Tends to be safer than barley for nitrates, because earlier seasonal development escapes heat stress better. Low grain yield and test weight. High protein.

Yellowstone (MSU, 2005): Winterhardiness = 4. Medium height similar to Neeley, and taller than Falcon, and Pryor. Straw strength is excellent. Medium-short coleoptile length. Medium maturity. Broadly adapted state-wide, but is stem-rust susceptible (thus, not for District 6, eastern Montana). Moderate resistance to stripe rust. Very high-yielding, and 3% higher than Falcon. Below average test weight. Protein is medium. Excellent baking quality and good Asian noodle quality.

Hard White Winter Wheat

Protein of hard white wheat for bread baking needs to be higher than required for noodle markets. Some varieties are dual-purpose and can be used for both bread and noodles. Although not a concern for bread baking quality, varieties with low levels of polyphenol oxidase (PPO) are desirable for Chinese noodles, since high PPO levels are associated with noodle discoloration. Low PPO provides good noodle brightness and color stability. Some hard white varieties sprout more readily than hard reds, especially those developed from Australian germ-plasm. The pure white trait is difficult to maintain, as pollen from red wheats may pollinate a white variety, causing a mixture of red kernels. It is very important to clean the combine, storage bins and other grain handling equipment prior to harvest to avoid mixing hard white wheat with other wheat. Seeding equipment and seedbed must also be free of red wheat. It is important to have a market strategy in place before growing a hard white variety.

Alice (S. Dak., 2006): Hard white. Short straw, short coleoptile. Early heading. Above average yield, test weight and protein.

Golden Spike (UT, Gen Mills, 1998): Hard white, low PPO. Winterhardiness 3. Height similar to Rocky, med-stiff straw. Medium coleoptile. Medium maturity. Below average yield. Low test weight & protein.

Hyalite (MSU & WPB, 2005): Hard White, low PPO with good noodle brightness and color stability. Clearfield system single-gene resistance to imazamox or 'Beyond' herbicide. Winterhardiness = 3. Standard height, but stiff straw. Short coleoptile. Early maturity. Average yield and test weight. Red kernel occurrence is 0.7% (high, but still acceptable). Dual-purpose quality similar to NuWest & NuSky. Above average protein, good milling & baking quality. Stem rust resistant. Stripe rust susceptible.

MDM WA7936 (Wash., 2006): Hard white. Winterhardiness = 2. Medium stiff straw. Medium coleoptile. Very late maturity. Yield similar to NuWest. Low test weight.

NuDakota (AgriPro, 2005): Hard white. Winterhardiness = 2. Semidwarf height, stiff straw. Early heading. Average yield, test weight and protein. Medium PPO.

Nuwest (MSU, 1994): Hard white, low PPO. Dual purpose, noodle and bread. Winterhardiness = 4. One inch shorter than Rocky. Stiff straw. Very short coleoptile. Two days later than Rocky. Resistant to stem rust but susceptible to stripe rust, dwarf bunt, and WSMV. Susceptible to sawfly, RWA, and Hessian fly. Average yield and well adapted to Montana. Medium test weight and protein. Good resistance to preharvest sprouting – (In 1993, everything sprouted - red or white). Contains 1 red kernal/1000. Protein medium to high. Good quality.

NuSky (MSU, 2001): Hard white, low PPO. (Sister line to the hard red var BigSky). Good dual purpose quality for noodles & bread. Winterhardiness 4. Height and straw strength similar to Nuwest & Rocky, med-stiff. Short coleoptile. Heading similar to Nuwest, Tiber & Neeley; and 3 days later than Rocky. Shatter resistant. Average yield. Test weight similar to Nuwest. Medium to high protein. Quality similar to Nuwest. High level of post-harvest dormancy (similar to Tiber), and thus does not have the sprouting problems common to some of the other hard white wheats. NuSky is a public release.

Wendy (SD, 2004): Hard white. Winterhardiness = 3. Semidwarf height, Short coleoptile. Early heading. Average yield. Above-average test weight and protein. Medium PPO.

Table 1. 2012 Intrastate Winter Wheat Variety Nursery, Western Triangle Ag. Research Center, Conrad, MT.

Variety and Class	Source	Solid Stem score*	Yield bu/ac	Test weight lb/bu	Heading date Julian	Plant height in	Protein %
MT1090	-	-	101.1	61.0	167.8	34.6	11.3
MT0978	-	-	97.0	60.7	170.6	32.3	11.6
Accipiter	Saskatchewan, 2008	-	96.9	62.1	168.2	33.4	10.6
Yellowstone	Montana, 2005	-	96.2	60.6	168.6	32.4	11.1
MT1078	-	-	95.8	59.6	168.8	31.3	11.3
Judee	Montana, 2011	22.7	95.4	63.0	168.3	32.3	11.8
MT08172	-	-	95.3	61.1	168.9	33.5	11.6
MT10116	-	-	95.2	60.8	169.3	32.9	12.1
Robidoux	Nebraska, 2010	-	94.2	62.4	165.8	31.6	11.2
MTS1024	-	22.4	93.9	60.3	169.0	30.7	11.2
CDC Falcon	Sask/WestBred, 1999	7.1	92.9	61.8	166.8	30.1	11.3
Jagalene	AgriPro, 2002	-	92.9	62.9	167.0	32.9	12.3
MT1091	-	-	92.6	60.2	167.9	33.2	11.3
Pryor	WestBred, 2002	-	92.5	60.6	169.2	31.5	11.4
MTS0819-98 (HWW)	-	20.2	91.7	62.4	168.3	30.2	11.6
MT1105	-	-	90.7	60.4	168.5	30.6	11.7
MT1092	-	-	89.7	60.5	169.5	33.8	11.8
MT0871	-	-	89.3	60.2	171.2	32.2	11.8
MTW08168	-	-	88.8	61.3	173.3	33.6	12.1
MT1088	-	-	88.7	60.2	168.3	33.5	11.8
MTS0819	-	19.4	88.6	60.4	169.0	31.5	11.9
SY Wolf	Syngenta (Agripro), 2010	-	88.3	61.9	166.0	29.2	11.5
MT10113	-	-	88.1	62.0	165.9	31.7	12.3
Broadview	Alberta, 2009	-	87.7	61.2	167.8	31.5	11.4
WB-Quake	WestBred, 2011	22.9	87.7	61.5	169.2	32.0	11.7
MTS0826	-	-	87.7	62.3	167.5	32.8	11.4
MT1156	-	-	87.3	60.9	169.4	32.6	11.3
MT1155	-	-	87.1	59.1	168.7	33.2	11.4
Overland	Nebraska, 2007	-	87.0	62.1	166.0	31.9	12.2
MTCL1077	-	-	86.8	60.2	169.2	33.1	11.9
MTS0832	-	-	86.6	61.8	167.5	32.1	11.8
Art	AgriPro, 2007	-	85.4	61.9	164.0	30.4	12.2
Carter	WestBred, 2006	14.5	85.1	61.4	167.1	29.8	11.8
Norris (CL)	Montana/WestBred, 2005	-	85.0	62.4	166.0	33.1	11.7
McGill	Nebraska, 2010	-	84.6	60.9	164.4	33.3	12.0

Table 1 continued on next page

Table 1 continued

Variety and Class	Source	Solid Stem score*	Yield bu/ac	Test weight lb/bu	Heading Date Julian	Plant height In	Protein %
MTS0808	-	23.9	84.5	61.0	168.2	31.9	11.6
MTCL1067	-	-	84.0	60.9	168.4	34.1	11.9
Curlew	Utah, 2009	-	83.7	60.9	167.0	35.2	11.9
Decade	Montana/North Dakota, 2010	-	81.5	62.4	166.3	32.2	12.7
Radiant	Alberta, 2002	-	81.2	60.0	168.0	35.0	12.1
Promontory	Utah, 1990	-	79.8	62.9	167.0	32.2	11.2
Peregrine	Saskatchewan, 2008	-	79.5	60.6	167.1	37.7	10.9
Jerry	North Dakota, 2001	-	78.6	60.5	168.2	36.5	11.6
Ledger	WestBred, 2004	9.5	78.2	62.3	167.5	31.4	11.2
Bearpaw	Montana, 2011	22.5	78.1	61.4	167.3	30.8	12.0
Genou	Montana, 2004	23.0	77.3	61.6	167.7	34.4	12.0
Rampart	Montana, 1996	24.5	73.4	60.3	168.6	33.3	12.8
AP 503 CL2	AgriPro, 2007	-	70.5	63.1	166.6	27.9	12.2
Bynum (CL)	Montana/WestBred, 2005	22.4	66.6	60.8	165.9	32.4	13.0
Mean		19.6	87.2	61.2	167.9	32.4	11.7
LSD (0.05)		2.2	15.4	1.3	1.4	2.4	
C. V. (%)		6.8	10.1	1.2	0.5	4.4	
P-value (Varieties)		<0.0001	0.0069	<0.0001	<0.0001	<0.0001	

Planted: 9/22/2011 on conventional fallow and harvested on 8/9/2012.
Fertilizer, actual pounds/a of N-P-K: 11-22-0 applied with seed and 30-0-20 broadcast at planting. 115 lbs/a N as urea was broadcast on 3/14/2012.
Herbicide, Bronate at 1.5 pt/a and Axial XL at 16.4 oz/a applied on 5/8/2012.
* Solid stem score of 19 or higher is generally required for reliable sawfly resistance.
HWW = Hard White Wheat
CL = Clearfield System

Table 2. 2012 Intrastate Winter Wheat Variety Test Condensed list, Western Triangle Ag. Research Center, Conrad, MT.

Variety	Source	Solid stem score*	Yield bu/ac	Test weight lb/bu	Heading date Julian	Plant height in	Protein %
Accipiter	Saskatchewan, 2008	-	96.9	62.1	168.2	33.4	10.6
Yellowstone	Montana, 2005	-	96.2	60.6	168.6	32.4	11.1
Judee	Montana, 2011	22.7	95.4	63.0	168.3	32.3	11.8
Robidoux	Nebraska, 2010	-	94.2	62.4	165.8	31.6	11.2
CDC Falcon	Sask/WestBred, 1999	7.1	92.9	61.8	166.8	30.1	11.3
Jagalene	AgriPro, 2002	-	92.9	62.9	167.0	32.9	12.3
Pryor	WestBred, 2002	-	92.5	60.6	169.2	31.5	11.4
SY Wolf	Syngenta (Agripro), 2010	-	88.3	61.9	166.0	29.2	11.5
Broadview	Alberta, 2009	-	87.7	61.2	167.8	31.5	11.4
WB-Quake	WestBred, 2011	22.9	87.7	61.5	169.2	32.0	11.7
Overland	Nebraska, 2007	-	87.0	62.1	166.0	31.9	12.2
MTS0832	-	-	86.6	61.8	167.5	32.1	11.8
Art	AgriPro, 2007	-	85.4	61.9	164.0	30.4	12.2
Carter	WestBred, 2006	14.5	85.1	61.4	167.1	29.8	11.8
Norris (CL)	Montana/WestBred, 2005	-	85.0	62.4	166.0	33.1	11.7
McGill	Nebraska, 2010	-	84.6	60.9	164.4	33.3	12.0
MTS0808	-	23.9	84.5	61.0	168.2	31.9	11.6
MTCL1067	-	-	84.0	60.9	168.4	34.1	11.9
Curlew	Utah, 2009	-	83.7	60.9	167.0	35.2	11.9
Decade	Montana/North Dakota, 2010	-	81.5	62.4	166.3	32.2	12.7
Radiant	Alberta, 2002	-	81.2	60.0	168.0	35.0	12.1
Promontory	Utah, 1990	-	79.8	62.9	167.0	32.2	11.2
Peregrine	Saskatchewan, 2008	-	79.5	60.6	167.1	37.7	10.9
Jerry	North Dakota, 2001	-	78.6	60.5	168.2	36.5	11.6
Ledger	WestBred, 2004	9.5	78.2	62.3	167.5	31.4	11.2

Table 2 continued on next page

Table 2 continued

Variety	Source	Solid stem score*	Yield bu/ac	Test weight lb/bu	Heading date Julian	Plant height in	Protein %
Bearpaw	Montana, 2011	22.5	78.1	61.4	167.3	30.8	12.0
Genou	Montana, 2004	23.0	77.3	61.6	167.7	34.4	12.0
Rampart	Montana, 1996	24.5	73.4	60.3	168.6	33.3	12.8
AP 503 CL2	AgriPro, 2007	-	70.5	63.1	166.6	27.9	12.2
Bynum (CL)	Montana/WestBred, 2005	22.4	66.6	60.8	165.9	32.4	13.0
Mean		19.6	87.2	61.2	167.9	32.4	11.7
LSD (0.05)		2.2	15.4	1.3	1.4	2.4	
C. V. (%)		6.8	10.1	1.2	0.5	4.4	
P-value (Varieties)		<0.0001	0.0069	<0.0001	<0.0001	<0.0001	

Planted: 9/22/2011 on conventional fallow and harvested on 8/9/2012
Fertilizer, actual pounds/a of N-P-K: 11-22-0 applied with seed and 30-0-20 broadcast at planting. 115 lbs/a N as urea was broadcast on 3/14/2012.
Herbicide, Bronate at 1.5 pt/a and Axial XL at 16.4 oz/a applied on 5/8/2012.
* Solid stem score of 19 or higher is generally required for reliable sawfly resistance.
HWW = Hard White Wheat
CL = Clearfield System

Table 3. Six-year averages, Winter Wheat varieties, Western Triangle Ag. Research Center, Conrad, MT. 2007 - 12.

Variety	Source	Class	Solid stem* score	6-Year Average Yield bu/a	Test wt	Height in.	Head date	Protein %	Winter survival class
Pryor	WestBred	-	-	80.8	60.6	31.5	171.4	11.4	3
Judee	MSU	-	22.7	80.5	63.0	32.3	169.9	11.8	-
MTS0808		-	23.9	79.8	61.6	33.8	171.0	11.6	-
Yellowstone	MSU	-	-	78.7	60.6	32.4	171.9	11.1	4
Decade	MSU/ND	-	-	78.2	62.4	32.2	168.9	12.7	-
Jagalene	AgriPro	-	-	77.6	62.9	32.9	168.7	12.3	2
WB-Quake	WestBred	-	22.9	76.6	61.5	32.0	171.1	11.7	-
Norris	WestBred	CL	-	75.8	62.4	33.1	168.2	11.7	3
Falcon	CDC/WestBred	-	7.1	75.7	61.8	30.1	170.3	11.3	4
Carter	WestBred	-	14.5	75.2	61.4	29.8	169.2	11.8	3
Bearpaw	MSU	-	22.5	75.2	61.4	30.8	170.4	12.0	-
Ledger	WestBred	-	9.5	74.1	62.3	31.4	170.1	11.2	2
Genou	MSU	-	23.0	73.8	61.6	34.4	170.6	12.0	2
Jerry	N. Dakota	-	-	70.7	60.5	36.5	171.0	11.6	5
Promontory	Utah	-	-	70.7	62.9	32.2	170.8	11.2	2
AP 503 CL2	AgriPro	CL2	-	69.9	63.1	27.9	170.0	12.2	-
Rampart	MSU	-	24.5	66.8	60.3	33.3	171.1	12.8	2
Bynum	WestBred	CL	22.4	64.1	60.8	32.4	169.3	13.0	2
Mean				75.1	61.9	32.5	170.1	11.6	

HW = Hard White; CL = Clearfield herbicide system.
* Solid stem score of 19 or higher is generally required for reliable sawfly resistance.
Winterhardiness: 5 = high, 1 = low.

Table 4. 2012 Advanced Yield Nursery, Western Triangle Ag. Research Center, Conrad, MT.

ID or Variety	Yield bu/ac	Test weight lb/bu	Heading Date Julian	Plant height In	Protein %
MT1102	116.2	61.2	169.2	32.7	11.1
MT1103	111.6	60.9	168.1	34.5	11.4
MT1113	111.2	61.0	168.3	35.4	11.8
MTCL1133	110.6	60.4	169.3	34.7	11.2
MT1108	110.5	61.7	168.3	34.4	10.8
MT1117	110.3	61.9	168.9	35.2	11.3
MT1106	109.6	60.2	168.7	33.8	11.4
MT1143	109.3	61.5	166.2	32.3	11.4
Yellowstone	108.4	61.2	168.8	35.3	11.2
MT1138	108.0	61.3	168.9	36.1	11.8
MTCL1131	106.4	61.6	168.6	37.1	11.3
MTW1154	106.2	61.3	168.0	32.7	12.0
Decade	105.3	62.9	166.7	33.8	11.6
MT1112	105.2	61.1	169.4	33.8	10.9
MT1137	104.9	62.9	168.3	34.1	10.9
MT0871E	104.8	60.2	167.9	35.4	11.0
MT1149	103.6	62.1	167.5	32.4	10.9
MT1110	103.1	59.7	169.4	30.6	11.2
MT1157	102.5	60.4	168.3	32.2	11.8
MTCL1130	102.1	62.6	168.2	32.8	11.9
MT1140	102.1	61.4	167.0	31.8	11.5
MTW1152	101.7	62.2	169.2	31.5	
Jagalene	101.5	63.2	165.8	31.7	11.7
MTCL1132	101.3	60.9	168.9	34.0	11.8
MT1142	101.0	62.0	166.6	35.0	11.6
MTS0826-70	99.6	61.8	172.2	37.7	12.5
MT1119	97.9	61.7	169.8	32.0	12.2
MTS0826-63	97.4	60.7	172.1	35.9	12.1
MTS1170	96.6	60.3	168.5	34.8	11.1
MTCL1127	95.7	60.8	165.1	29.5	12.2

Table 4. Continued on next page

Table 4. Continued

ID or Variety	Yield bu/ac	Test weight lb/bu	Heading Date Julian	Plant height In	Protein %
MTS0532L	95.3	61.9	167.2	31.7	11.8
MTS713-70	95.0	63.1	168.1	31.5	12.0
MTS0819-2	94.5	61.8	170.1	30.9	11.5
MTS1166	93.9	60.5	169.1	34.5	11.9
Genou	92.9	60.6	167.1	35.9	12.0
MTS0827-30	91.9	59.1	171.4	32.8	12.2
Mean	103.0	61.3	168.5	33.6	11.6
LSD (0.05)	8.2	0.9	1.1	1.9	
C.V. (%)	4.5	0.9	0.4	3.2	
P-value (Varieties)	<0.0001	<0.0001	<0.0001	<0.0001	

Planted: 9/23/2011 on conventional fallow and harvested on 8/9/2012.
Fertilizer, actual pounds/a of N-P-K: 11-22-0 applied with seed and 30-0-20 broadcast at planting. 115 lbs/a N as urea was broadcast on 3/14/2012. Herbicide, Bronate at 1.5 pt/a and Axial XL at 16.4 oz/a.

Table 5. Off-station Winter Wheat variety trial (Exp. 3866) located east of Choteau, MT. Teton county. Western Triangle Ag. Research Center. 2012.

Variety Or ID	Stem Solidness Score*		Yield bu/ac	Test weight lb/bu	Plant height in	Protein %
Pryor	-		48.8	58.9	26.0	14.5
MTS0819	-	+	47.9	59.5	23.3	14.3
Yellowstone	-		47.1	58.5	28.3	14.3
Ledger	9.5		45.8	59.6	23.7	14.0
MT0871	-		45.8	58.8	25.7	14.2
MT08172	-	+	45.4	58.2	28.7	13.9
Accipiter	-		44.6	58.2	25.7	14.6
MTS0832	-		43.6	60.8	29.0	13.5
MTS0826	-	+	43.6	60.7	28.7	14.7
WB-Quake	22.9		43.5	58.3	26.7	14.2
Judee	22.7		42.8	59.9	25.0	13.9
CDC Falcon	7.1		42.6	58.2	25.3	14.4
MTS0808	23.9		42.0	58.8	24.3	14.5
MTCL1077	-	+	41.7	58.3	29.0	13.8
Decade	-		40.9	59.6	26.7	14.3
Genou	23.0		40.7	58.9	26.3	14.2
Bearpaw	22.5		39.4	59.0	24.0	14.2
Jerry	-		38.0	59.0	28.0	15.0
MTCL 1067	-		37.6	58.6	27.3	14.1
Rampart	24.5		37.5	58.9	28.0	14.5
Overland	-	+	36.8	60.3	25.3	15.0
Jagalene	-		33.0	61.0	24.3	14.5
AP 503 CL2	-		32.6	60.4	24.0	13.9
Norris (CL)	-		32.2	60.6	26.0	12.9
Mean			41.4	59.3	26.2	14.2
LSD (0.05)			5.4	0.8	2.2	
C.V. (%)			7.9	0.9	5.2	
P-value (Varieties)			<0.0001	<0.0001	<0.0001	

Cooperator and Location: Inbody Farms, Teton county.
Planted: October 4, 2011 on chem-fallow Harvested: August 22, 2012
Fertilizer, actual lbs/a: 11-22-0 applied with seed and 30-0-20 urea blended with potash were broadcast at seeding. Spring topdressing took place on 5/15/2012 with 91-0-0.
Herbicide: None Precipitation: No data.
* = Solid stem sawfly-resistant (solid stem score of 19 or higher) and were determined at the on station intrastate winter wheat nursery. + = New to off station trial for 2012.
Conducted by MSU Western Triangle Ag. Research Center.

Table 6. Off-station winter wheat variety trial (Exp. 3865) located north of Devon, MT. Toole county. Western Triangle Ag. Research Center. 2012.

Variety Or ID	Stem Solidness Score*		Yield bu/ac	Test weight lb/bu	Plant height in	Protein %	Lodging %
MT0871	-		36.0	57.2	24.7	14.2	1.0
MTS0819	-	+	34.5	59.2	23.3	13.8	0.3
MT08172	-	+	33.5	57.1	25.7	14.9	1.7
WB-Quake	22.9		32.9	57.0	24.0	14.2	0.3
Decade	-		32.5	59.0	24.7	14.5	2.0
CDC Falcon	7.1		32.1	56.0	23.7	14.5	0.0
MTCL1077	-	+	31.9	56.9	26.7	14.1	3.7
MT S0826	-	+	31.2	58.9	27.3	14.1	1.7
Genou	23.0		31.0	57.5	27.0	14.9	2.7
MTS0808	23.9		30.8	58.3	24.0	13.9	0.7
Accipiter	-		30.7	55.8	25.0	14.5	2.7
Bearpaw	22.5		30.7	56.2	22.7	15.0	0.7
Pryor	-		30.4	58.9	24.0	13.7	2.7
MTCL1067	-		30.1	56.7	27.0	14.6	2.0
MT S0832	-		29.6	59.8	26.0	14.2	1.3
Rampart	24.5		29.2	58.0	26.3	15.1	0.0
Yellowstone	-		29.1	56.9	26.3	14.4	1.0
Jagalene	-		29.0	59.3	24.7	14.3	7.3
Overland	-	+	28.9	59.5	23.7	13.0	2.3
Ledger	9.5		26.2	58.9	25.3	13.7	0.0
Norris (CL)	-		25.1	56.9	25.0	14.7	1.0
Jerry	-		24.6	57.1	24.7	14.8	7.7
AP 503 CL2	-		24.4	57.1	24.0	15.6	1.3
Judee	22.7		24.1	57.8	23.0	15.3	1.3
Mean			29.9	57.8	24.9	14.4	1.9
LSD (0.05)			ns	1.6	1.8		3.8
C.V. (%)			14	1.6	4.3		123
P-value (Varieties)			0.0602	<0.0001	<0.0001		0.0126

Cooperator and Location: Brian Aklstad Farm, Toole county.
Planted: September 17, 2011 on chem-fallow. Harvested: August 7, 2012
Fertilizer, actual lbs/a: 56-22-20; 11-22-0 applied with seed and urea blended with potash were topdressed on 5/9/2012.
Sprayed with Huskie at 11 oz/a and Axial XL at 16.4 oz/a on 5/16/2012.
Precipitation: 5.5 inches, then gauge disappeared.
* = Solid stem sawfly-resistant (solid stem score of 19 or higher) and were determined at the on station intrastate winter wheat nursery. + = New to off station trial for 2011.
Conducted by MSU Western Triangle Ag. Research Center.

Table 7. Three-year Means, Winter Wheat varieties, Devon area, Eastern Toole County. 2010-2012.

Variety	Class	3-Year Means Yield bu/a	Test weight	Height in.	Protein %
Accipiter	-	35.1	57.2	24.7	13.2
Bearpaw	22.5	28.4	57.6	23.7	13.6
CDC Falcon	7.1	33.1	57.2	23.6	13.2
Decade	-	37.2	59.3	25.9	13.3
Genou	23.0	32.2	58.0	26.8	13.6
Jagalene	-	30.0	58.7	25.6	13.2
Jerry	-	32.9	57.5	25.1	13.3
Judee	22.7	29.5	58.8	24.4	13.7
Ledger	9.5	27.1	59.5	25.0	12.6
MTS0826	-	37.9	59.3	26.2	13.2
MTS0832	-	31.1	57.7	25.8	12.9
Norris CL	-	25.7	57.6	26.1	13.2
Pryor	-	25.7	57.3	24.7	12.6
Rampart	24.5	24.7	57.3	25.3	14.2
Yellowstone	-	32.7	57.1	25.3	13.0
Mean		30.9	58.0	25.2	13.3

** = Solid stem sawfly-resistant (solid stem score of 19 or higher).
* = Less preferred by sawfly (behavioral preference) in small plots.
Cooperator and Location: Brian Aklestad, Eastern Toole County.
Conducted by MSU Western Triangle Ag. Research Center.

Table 8. Off-station winter wheat variety trial (Exp. 3862) located at the Knees, Chouteau county. Western Triangle Ag. Research Center. 2012.

Variety Or ID	Stem Solidness Score*		Yield bu/ac	Test weight lb/bu	Plant height in	Protein %	Lodging %
Overland	-	+	72.0	62.5	33.3	11.8	6.7
MTS0826	-	+	68.9	60.6	34.3	12.8	5.7
MT S0832	-		68.2	60.4	33.7	13.0	7.0
Decade	-		67.8	60.6	31.0	12.8	9.0
MT S0808	23.9		66.8	60.0	30.3	12.2	0.7
CDC Falcon	7.1		66.6	60.6	29.3	12.6	3.3
MTCL1067	-		66.5	59.3	35.7	12.6	35.0
MTCL1077	-	+	65.2	57.6	33.0	13.0	28.3
MTS0819	-	+	64.8	58.9	29.7	12.6	2.7
MT08172	-	+	63.1	58.9	31.7	12.4	30.0
WB-Quake	22.9		63.0	59.9	31.0	12.4	6.0
MT0871	-		61.5	57.4	32.3	13.6	18.3
Ledger	9.5		60.3	60.5	28.7	12.0	10.0
Yellowstone	-		60.1	57.7	33.0	13.3	23.3
Pryor	-		59.8	59.1	30.7	11.7	10.0
Accipiter	-		59.4	59.4	31.0	12.8	3.3
Jagalene	-		58.3	62.4	30.3	12.2	15.0
Judee	22.7		57.0	60.0	30.0	13.5	3.5
AP 503 CL2	-		54.9	60.1	28.7	13.8	13.3
Norris (CL)	-		54.9	59.9	33.3	13.1	18.3
Bearpaw	22.5		54.0	58.1	31.3	13.3	6.7
Jerry	-		53.2	58.0	34.7	13.5	28.3
Rampart	24.5		50.5	59.7	33.7	13.1	6.7
Genou	23.0		50.2	59.1	35.0	13.2	21.0
Mean			61.1	59.6	31.9	12.8	13.0
LSD (0.05)			10.5	1.3	1.8		13.2
C.V. (%)			10.5	1.4	3.4		62
P-value (Varieties)			0.0018	<0.0001	<0.0001		<0.0001

Cooperator and Location: Aaron Killion, eastern Chouteau county.
Planted: September 19, 2011 on chem-fallow Harvested August 1, 2012.
Fertilizer, actual lbs/a: 125-22-20; 11-52-0 applied with seed and urea blended with potash were broadcast while seeding. The balance of the N was applied topdress on 5/15/2012.
Sprayed with Powerflex at 3.5 ox/a on 4/24/2012. Precipitation, rain gauge cracked.
* = Solid stem sawfly-resistant (solid stem score of 19 or higher) and were determined at the on station intrastate winter wheat nursery. + = New to off station trial for 2011.
Conducted by MSU Western Triangle Ag. Research Center.

Table 9. Four-year Means, Winter Wheat varieties, Knees area, western Chouteau County. 2009-2012.

Variety Or ID	Class	4-Year Means Yield bu/a	Test weight	Height in.	Protein %
Yellowstone	-	65.4	58.3	33.6	13.2
MTS0826	-	63.6	60.2	34.4	13.3
MTS0832	-	62.5	58.9	34.9	12.6
CDC Falcon	7.1	60.1	59.3	29.3	13.4
Decade	-	59.8	59.6	32.2	13.1
Jagalene	-	58.6	61.0	31.7	12.6
Ledger	9.5	58.3	59.8	29.7	12.4
Pryor	-	58.1	58.5	30.5	12.8
Judee	22.7	58.1	60.1	30.2	13.5
Accipiter	-	57.7	59.0	31.9	13.2
Bearpaw	22.5	57.0	58.7	31.6	13.3
Norris CL	-	55.0	59.7	35.5	12.9
Genou	23.0	53.7	59.2	40.7	13.2
Rampart	24.5	52.6	59.7	33.8	13.5
Jerry	-	51.0	58.3	33.6	13.2
Mean		58.1	59.3	32.9	13.1

** = Solid stem sawfly-resistant (solid stem score of 19 or higher).
* = Less preferred by sawfly (behavioral preference) in small plots.
Cooperator and Location: Aaron Killion, western Chouteau County.
Conducted by MSU Western Triangle Ag. Research Center.

2012 Spring Wheat Evaluations in the Western Triangle Area

Personnel: John Miller and Gadi V.P. Reddy, Western Triangle Ag. Research Center, Conrad, MT. Dave Wichman, Central Ag. Research Center, Moccasin, MT, and Luther Talbert and Susan Lanning, PSPP, Bozeman.

The advanced spring wheat and durum nurseries were planted on fallow and grown under dryland conditions in 2012. Off-station spring wheat variety nurseries were planted on chemical fallow. Off station trials were grown north of Cut Bank, MT, north of Devon, MT, near the 'Knees' east of Brady, MT, and northeast of Choteau, MT in Teton county. For the 2013 growing season, all nurseries will be grown on to-till chemical fallow.

Results: Results are tabulated in Tables 10 thru 21. Results for the Advance nursery are presented in Tables 10 thru 12. Results are tabulated in Table 13 for the irrigated off-station spring wheat nursery and Table 14 is six year averages for selected varieties in the irrigated off-station spring wheat nursery. Table 15 is for the Choteau location. Tables 16 and 17 are for the Devon location, with Table 18 and 19 representing the 'Knees' location. The durum nursery data are shown in Tables 20 and 21. The Cut Bank location was lost due to a hailstorm. Soil test results may be viewed in Table 33 at the end of the barley section.

The 2012 growing season at WTARC began with temperatures a bit warmer than normal, there was a less precipitation than the 27 year average, this trend continued throughout the growing season.

Top yielding varieties at Choteau were WB Gunnison, McNeal, and Jedd with protein averaging 15.4% across all varieties. Vida, WB Gunnison and Duclair were the high yielding varieties at Devon while averaging 15.1% protein across all varieties. The 'Knees' high yielders were WB Gunnison, IMICHT79, and Duclair with 13.7% protein across all varieties. The top yielders in the irrigated trial were SY Tyra, Duclair, and IMICHT79, with protein averaging 13.3 percent. The top yielding varieties in the advanced nursery were experimental varieties.

Yields in the advanced nursery ranged from 57.9 to 87.2 bu/acre. Yields and test weight for the advanced nursery were higher, with lower grain protein when compared to the six year average (Tables 10 and 11).

Yields in the irrigated off-station spring wheat trial ranged from 63.6 to 113.8 bu/acre. When compared to the six year averages, the irrigated off-station spring wheat nursery had much higher yields, with slightly higher test weight, and slightly lower grain protein (Tables 13 and 14). Yields ranged from 32.5 to 43.9 bu/acre at Choteau, 24.9 to 34.2 bu/acre north of Devon, and 43.1 to 56.7 bu/acre at the 'Knees'. The multiyear means for Devon and the 'Knees' contain data from the last four years. At Devon the 2012 yield was down from the four year average; with higher grain protein and about equal test weight (Tables 16 and 17). The 'Knees' location had higher yields, lower grain protein and about equal test weight when compared to the four year mean (Tables 18 and 19).

Durum yields ranged from 61.3 to 84.5 bu/acre (Table 20). With Strongfield, Aldabo, and MT05183 being the top three yielding varieties. The 2012 yields were about 10 bu/acre higher than the six year average (Table 21). Test weights were equal to the long term average.

Off station cooperators: Bradley Farms, north of Cut Bank, MT
Brian Aklestad, north of Devon, MT
Aaron Killion, east of Brady, MT
Inbody Farms, northeast of Choteau

These data should be used for comparative purposes rather than using absolute numbers. Statistics are used to indicate that treatment or variety differences are really different and are not different due to chance or error. The least significant difference (LSD) and coefficient of variability (CV) values are useful in comparing treatment or variety differences. The LSD value represents the smallest difference between two treatments at a given probably level. The LSD at p=0.05 or 5 % probability level is usually the statistic reported, and it means that the odds are 19 to 1 that treatment differences by the amount of the LSD are truly different. The CV value measures the variability of the experiment or variety trial, and a CV greater than 15 % indicates a high degree of variability and less accuracy.

Funding Summary: Office of Special Projects will provide expenditure information. No other grants support this project.

MWBC FY2014 Grant Submission Plans: A similar project will be proposed for FY 2014. The continuation of on and off-station variety trials help to elucidate researchers and farmers which varieties are better suited for that particular region in Montana.

Spring Wheat Variety Notes & Comments

Western Triangle Agricultural Research Center, Conrad MT

Sawfly Tolerant & Semi-tolerant Hard Red Spring Wheat Varieties:

Resistance (stem-solidness) among varieties ranges from low to high and varies with yearly climate differences; none have total resistance. Stem-solidness scores range from 5 (hollow) to 25 (completely solid). Solidness should be at least 19 to provide a reliable level of sawfly tolerance. However, some partially-solid stem varieties, such as Conan and Corbin, are less attractive to sawflies and show higher tolerance than expected for their level of stem solidness.

Agawam: See Hard White Spring Wheat. (Solid stem score = 23).

Choteau (MSU, 2004): Semidwarf with good straw strength. Height is 2" shorter than McNeal and 4" shorter than Fortuna. Stems very solid with good sawfly resistance (more solid than Fortuna). Sawfly resistance comparisons (max rating = 25): Choteau = 21, Fortuna = 19, Ernest = 16. Medium-early, 2 days later than Hank, 0.5 day later than Ernest & Fortuna, 2 days earlier than McNeal. High yield, similar to McNeal on both dryland and irrigated. Yields substantially higher than Ernest and Fortuna. Above average test wt (similar to Fortuna, and higher than McNeal). Moderate resistance to Septoria, and good resistance to most stem rust races. Protein above average. Normal gluten strength and good milling and baking quality. Fair Hessian fly tolerance. Some tolerance to root-lesion nematode.

Conan (WPB, 1998): Semidwarf. Solid stem score is low (10), but has low levels of sawfly-attractant cis-3-hexenylacetate, which increases sawfly resistance to medium. Medium maturity. Average yield and test weight. Some tolerance to Wheat Streak M V. Protein 0.5-0.9% higher than Rambo, and better protein quality than Rambo.

Corbin (WPB, 2006). Semidwarf height, 1" taller than Conan. Stem-solidness score = 10, medium sawfly resistance. Medium maturity, 1 day earlier than Conan. Average yield. Above-average test weight. Higher yield and test weight than Conan. Moderate resistance to stripe rust. Average protein.

Duclair (MSU, 2011): Solid stemmed hard red spring wheat, with stem solidness score of 20, slightly less than Choteau and slightly more than Fortuna. Yields were comparable to Choteau, Reeder, and Vida. Maturiety is day earlier than Choteau. Plant heights average about 31 inches. Yields (66 bu/a) tend to be similar to Choteau (65 bu/a), Reeder (66 bu/a) and Vida (68 bu/a). The average test weight is 60 lbs/bu, with grain protein averaging 13.7%. Duclair showed good resistance to stripe rust at Kalispell in 2010.

Ernest (ND, 1995): Tall, weak straw. Medium sawfly resistance (solid stem score = 16). High level of sawfly-attractant cis-3-hexenylacetate. Moderately late maturing, slightly earlier than McNeal. Poor threshability. Tolerant to Far-go. Resistant to prevalent races of leaf & stem rust. Below average yield. High protein and test weight. Good quality.

Lillian (Sask.): Tall weak straw. Late heading. Partial stem solidness. Sawfly cutting for Lillian was 30% at Conrad 2008, compared to 65% for susceptible varieties. Below average test weight. Above average protein.

Fortuna (ND): Beardless, tall straw. Too tall for irrigated conditions, vulnerable to lodging. Good sawfly resistance (solid stem score = 19). Early maturity. Tolerant to Fargo. Very susceptible to Septoria. Medium to low yield except under severe sawfly conditions, where Fortuna often ranks high for yield. Susceptible to shattering, especially in conditions favoring development of large kernels. Average test weight and protein. Fair Hessian fly tolerance.

Triangle II (WestBred, bz9m1024, 2008): Clearfield version of Conan, 2-gene resistance. Stem solidness less than Conan. Yield 1 bu higher than Conan, otherwise similar to Conan.

WB Gunnison (WestBred): Gunnison is intended to replace Conan and Corbin acres. Gunnison is hollow stemmed, but shows good tolerance to cutting by the wheat stem sawfly. The yield (55) is similar to Corbin and slightly higher than Conan. Average test weight is 60 lbs/bu, with grain protein levels of 13.8%, a bit lower than both Conan and Corbin. Average plant height is 30 inches with similar maturity to Conan and Corbin. Gunnison has moderate resistance to stripe rust.

Hollow-Stem, Sawfly Intolerant Hard Red Spring Wheat Varieties:

Alsen (ND, 2004). Moderate Fusarium scab resistance (MR). Semidwarf height. Medium maturity. Average yield. High test weight. High protein. Very poor Hessian fly tolerance.

AP604CL (AgriPro-8): Medium height, med-early maturity. Avg yield. Above avg test weight & protein.

AP603CL (AgriPro): Two-gene IMI resistance for Clearfield System. Med-tall, med-late maturity. Below average yield. Above average test weight & protein. Medium scab tolerance.

Freyr (AgriPro-3, 2004): Semidwarf height. Good lodging resistance, but less than Norpro. Medium maturity, 2 days earlier than McNeal. Average yield. Above average test weight. Average protein. Fusarium Scab resistance slightly lower than for Alsen (MR). Stripe rust MR. Acceptable quality.

Hank (WestBred): Semidwarf height. Medium lodging resistance. Early heading, 3 days earlier than McNeal. Above average yield. Better shatter resistance than 926. Below average test weight. Good tolerance to dryland root rot, tolerant to Far-go. Protein above average. Good quality. Hessian fly tolerant (similar to Choteau).

Hanna (AgriPro): Fusarium Scab tolerant.

Jedd (WestBred, 2007): Clearfield System hard red with 2-gene resistance. BC-derived from Hank. Short semidwarf height, 3" shorter than Hank or Choteau. Medium heading. Above average yield and test weight, dryland or irrigated. Higher dryland yield than Hank. Average protein. High quality. Moderately susceptible to stripe rust. Tolerance to Hessian fly biotypes of Washington, but unknown for biotypes in Montana.

Kelby (AgriPro, 2006, AP06): Good scab tolerance. Semidwarf height, stiff straw. Early heading. Below average yield. Above average test weight and protein. Good foliar disease resistance.

Kuntz (AgriPro-7, 2006): Medium height and maturity. Average yield. Above avg test weight. Average protein.

McNeal (MSU, 1994): Red chaffed. Semidwarf. Good lodging resistance, but straw is less resilient, and is prone to breaking over in strong wind. Medium-late maturity. Fair tolerance to wheat streak mv (2.5 on scale of 1-3). Some tolerance to dryland root rot. Above average yield, similar to Reeder and Choteau. Average test weight. Very good quality with high protein and loaf volume. Medium-low Hessian fly tolerance. Some tolerance to root lesion nematode.

Norpro (AgriPro-1): Semidwarf, very strong straw. Medium-late maturity. Below avg yield and test weight. Average protein. Low flour yield and high ash. Not well-adapted for dryland in District 5 (Triangle), but **suitable for irrigated**.

ONeal (WestBred, bz999592, 2008): A McNeal/906R cross. Semidwarf height similar to McNeal. Head date similar to McNeal and one day later than Choteau. Above-average yield, 3-5 bu higher than McNeal and similar to Choteau. Average test weight, above-average protein. A high quality wheat for areas where McNeal is adapted. Hollow stemmed, but shows less sawfly damage than McNeal.

Outlook (MSU, 2002): Russian Wheat Aphid resistant, but susceptible to new biotype in 2004. Stiff straw, semidwarf, height equal to McNeal & Reeder. Med-late maturity = McNeal. Above average yield, similar to McNeal and Reeder. Below average test weight. Average protein. Quality acceptable, and superior to Reeder.

Reeder (ND, 1999): Semidwarf height. Medium head date, slightly earlier than McNeal, but maturity slightly later than McNeal. The "stay-green" trait provides a longer grain-fill period and higher yield, as long as moisture is available. Similar to McNeal for agronomics. Above average yield. Average test weight and protein. Quality is below average. Susceptible to Everest W.O. herbicide. Very poor Hessian fly tolerance.

Vida (MT 0245): Semidwarf height, medium straw strength. Med-late maturity, heading = McNeal, but stays green 3 to 4 days later than McNeal. High yield, 4 bu over McNeal. Average test weight and protein, acceptable quality. Possible replacement for Outlook and Reeder (except Outlook would remain in use for RWA resistance). MR stripe rust and Septoria. Partially-solid stem (stem score = 11), slightly less than Conan & Ernest for sawfly tolerance.

Volt (WestBred, 2007): Semidwarf height. Late heading. Average yield on dryland, above-average yield on irrigated. Above avg test wt. Average protein. Good tolerance to stripe rust and Fusarium head blight. Sawfly cutting similar to McNeal. A high yield, disease resistant variety **for irrigated conditions**.

WestBred - See also Agawam, Conan, Corbin, Hank, Jedd, ONeal, Triangle II, Volt.

Hard White Spring Wheat

Protein of hard white wheat for bread baking needs to be higher than wheat required for noodle markets. Some varieties are dual-purpose and can be used for both bread and noodles. Although not a concern for bread baking quality, varieties with low levels of polyphenol oxidase (PPO) are desirable for noodles, since high PPO levels are associated with noodle discoloration. At present, all Montana hard white spring varieties are high PPO, and thus better suited for bread baking. Many hard white varieties sprout more readily than hard reds, especially those developed from Australian germ plasm. The pure white trait is difficult to maintain, as pollen from red wheats may pollinate a white variety, causing a mixture of red kernels. It is very important to clean the combine, storage bins and other grain handling equipment prior to harvest to avoid mixing white wheat with other wheats. Seeding equipment and seedbed must also be free of red wheats. Seeding rate should be 10% higher than for red wheat to reduce late tillers and thereby reduce green kernels.

Agawam (WestBred, 2005): Hard White. Semidwarf height. Sawfly resistant: solid stem score = 22, similar to that of Choteau, and has a low level of sawfly-attractant cis-3-hexenylacetate . Early heading, similar to Explorer. Very high yield and test weight. Protein 1.4% lower than Explorer. Fair Hessian fly tolerance.

Blanca Grande (Gen Mills): Hard white. Short stiff straw. Early maturity. Medium high yield. High test weight and low protein.

Clarine (WestBred): Hard white. Clearfield system, 2-gene resistance. Very high milling/baking quality. A Clearfield version of Pristine. Available in 2009.

Explorer (MSU, 2002): Hard white, bread-baking type. Semidwarf, 2 inches shorter than McNeal. Slightly solid-stem, but not sufficient for sawfly resistance. Early maturing. Average yield and test weight. Very susceptible to Septoria, thus not recommended for far eastern Montana. High protein, and probably too high for noodles. Excellent bread baking quality.

Golden 86 (GP Seed & Research Inc, 1986): Hard white. Used by a commercial milling and baking firm north of Three Forks, Montana. High quality.

MTHW 9420 (MSU, 1999): Experimental for exclusive release. Medium height and maturity. Below average yield. Average test weight. Very susceptible to wheat streak mosaic virus. Excellent bread quality, but too high in protein for noodles.

Plata (Gen Mills): Hard white. Short stiff straw. Medium maturity. Medium yield & test wt. Med-low protein.

Pristine (WPB): Hard white. Semidwarf. 3 days earlier than McNeal. Yield = McNeal. Protein 0.5% < McNeal. Very high quality, and used for bread baking by industry in Mid-west. See also Clarine.

Durum

Durum is generally much more susceptible to wheat streak mv and Fusarium crown rot than spring wheat.

Quality durum has strong gluten. Growers who plan to grow weak-gluten varieties need to have a marketing organization identified that will purchase those varieties. Kernel color is a very important quality trait. Rainfall or irrigation after heading causes color loss (bleaching), but some varieties are less prone to color loss. Canadian varieties are screened for bleaching resistance. Such varieties are the preferred choice in areas of late-season rainfall. Varieties that lose color more readily may be okay for drier areas of Montana. Seeding rate for durum should be 30% higher than for spring wheat due to the larger durum kernel (fewer kernels per bushel). An additional seed-rate increase may be desirable to suppress late tillers and thereby decrease green kernels. Color score is important, and green kernels contribute to poor color and dockage. 23 to 29 seeds per square foot (approx 1.0 to 1.26 million seeds per acre) has normally been a good seeding rate for durum.

Alkabo (ND, 2006): Medium-tall height, very stiff straw. Medium maturity. Above average yield and test wt. Good quality.

Alzada (WestBred, 2005): Semidwarf height, short stiff straw. Early maturing. High yield, average test weight. Medium protein. Very good quality and gluten strength, and very good semolina color.

Avonlea (Can, 1997): Medium tall. Medium straw strength and lodging resistance. Early maturity. High yield and average test weight. Good quality and protein.

Dilse (ND): Medium height, late maturity. Below average yield. Average weight. High protein, excellent quality.

Divide: (ND, 2006): Medium-tall height, stiff straw. Medium maturity. Average yield. Above average test wt. Excellent quality.

Grenora (ND, 2006): Medium-tall height, stiff straw. Medium maturity. Average yield and test wt. Good quality.

Kyle (Canada, 1984): Very tall weak straw, poor lodging resistance. Very late maturing. Average yield and test weight, large kernel size. Kyle has the highest tolerance to color-loss (rain-bleaching). Above average protein. Strong gluten; good quality.

Lebsock (ND, 1999): Medium height, stiff straw. Late maturity. Below average yield. High test weight and excellent quality.

Levante (AllStar Seeds, 2007): Short semidwarf height. Early heading. Above average yield & test weight on dryland in 2007; and average performance on irrigated.

Maier (ND, 1998): Medium height, stiff straw, good lodging resistance. Medium maturity. Above-average yield. Medium large kernels, very high test weight. Average protein. Good milling quality.

Mountrail (ND,1998): Medium-tall, but stiff straw and fair lodging resistance. Medium-late maturity. Average yield and test weight. Medium large kernel and average protein. Medium quality, but kernel color more sensitive to late rain than some other varieties. (All durums are sensitive to late rain/irrigation relative to color loss).

Navigator (Can): Med short, but weak straw. Med late maturity. Medium test weight & protein, good quality.

Normanno (AllStar Seeds, 2007): Semidwarf height. Medium maturity. Average yield and below average test weight in 2007.

Pathfinder (Can): Med tall, weak straw. Med late maturity. Med test weight. Med low protein, good quality.

Pierce (ND): Medium-tall height and lodging resistance. Below average yield. High test weight. Average protein, good quality.

Plaza (ND): Med-short straw, med lodging resistance. Late maturity. Below-average yield on dryland; above-average yield on irrigated. Below average test weight. Low protein, medium quality.

Strongfield (WestBred/Canada, 2005): Medium tall, med-late maturity. Above average yield. Average test weight. Above-average protein. Good color and quality. Low grain cadmium concentration.

Table 10.   2012 Advanced Spring Wheat variety nursery, Conrad Dryland.

Variety	Source	Class	Yield bu/a	Test Wt lb/bu	Height in.	Head date	Protein %
MT 1053	-	-	87.2	62.6	29.7	179.6	11.5
MT 1133	-	-	82.7	62.0	30.7	180.1	13.3
VidaWht1	-	-	82.3	62.6	33.1	180.0	11.9
SY Tyra	Syngenta	-	82.3	63.2	27.4	180.7	11.8
MTHW1057	-	-	82.0	62.6	30.9	182.4	11.6
MT 1142	-	-	81.6	62.4	31.0	180.7	13.0
MT 1150	-	-	81.2	61.7	32.5	180.1	12.6
CAP197-3	-	-	81.1	60.9	33.9	180.8	12.6
MT 1103	-	-	81.0	62.6	31.4	181.7	12.2
Volt	WestBred	-	81.0	63.9	29.6	182.4	11.9
MT 1164	-	-	80.3	61.2	31.4	180.0	12.6
CAP 34-1	-	-	80.2	63.6	29.4	180.3	11.5
MT 1073	-	-	80.2	62.7	29.6	179.2	12.5
Vida	MSU	*	79.9	62.1	32.8	180.8	12.3
MT 1002	-	-	79.8	61.9	31.1	180.9	12.2
Oneal	WestBred	*	79.7	62.7	33.1	180.1	12.0
MT 1166	-	-	79.3	61.2	35.0	179.7	12.1
Corbin	WestBred	*	78.6	62.9	30.6	179.4	12.5
SY605 CL	Syngenta	-	78.6	63.1	34.3	177.7	13.0
MT 1007	-	-	78.2	63.7	30.4	179.7	12.7
MT 1173	-	-	77.7	60.7	35.0	183.9	12.0
MT 1106	-	-	77.5	61.1	30.7	181.0	12.7
MT 1157	-	-	77.4	63.3	31.1	180.0	13.0
CAP219-3	-	-	77.4	62.3	31.0	180.0	13.8
MT 1118	-	-	77.1	60.5	29.9	178.0	12.5
MT 1112	-	-	76.9	62.0	29.8	178.6	12.8
MT 1172	-	-	76.9	61.3	30.9	182.1	12.8
MT 1120	-	-	76.8	60.6	32.7	180.1	12.8
WB9879CL	-	-	76.5	62.4	31.1	180.4	12.9
SY Soren	Syngenta	-	76.4	63.2	29.3	180.3	12.9
MT 1008	-	-	75.9	62.4	30.4	181.1	12.0
MT 1119	-	-	75.7	61.5	30.2	177.4	12.8
Choteau	MSU	**	75.0	61.5	30.2	180.0	12.9
WB Mayville	WestBred	-	74.6	62.0	28.6	179.0	13.1
McNeal	MSU	*	74.5	61.7	31.7	180.0	12.5
HankWht1	-	-	74.5	59.8	27.3	179.0	12.0
Duclair	MSU	**	74.3	61.0	31.3	178.2	12.6

Table 10 continued on next page

Table 10 continued

Variety	Source	Class	Yield	Test Wt	Height	Head	Protein
Reeder	N.Dak	-	74.2	62.2	33.4	180.3	13.1
MT 1154	-	-	74.1	62.5	32.0	180.7	13.1
MT 1111	-	-	74.0	62.5	29.7	177.6	12.9
CHOTWHT 1	-	-	73.9	62.3	30.6	177.9	12.3
MTHW1152	-	-	73.6	60.0	29.8	177.0	12.8
MT 1016	-	-	73.6	62.1	30.2	180.3	13.0
WB113	-	-	72.7	62.8	25.6	179.4	14.1
AP604 CL	AgriPro-8	CL	72.7	63.7	32.1	178.7	12.5
Kelby	AgriPro	-	72.2	63.1	28.7	177.0	13.5
MT 1108	-	-	72.2	62.0	29.8	179.3	13.2
MT 1146	-	-	72.0	61.9	33.7	180.9	13.7
Mott	N.Dak	-	71.7	61.7	34.6	181.0	13.2
Jedd	WestBred	CL2	71.6	62.2	27.5	179.6	11.7
CAP400-1	-	-	71.5	61.3	31.2	180.3	12.6
MT 1168	-	-	71.4	60.7	29.2	179.6	12.6
MT 1156	-	-	71.2	62.3	31.3	179.3	13.6
WB Gunnison	WestBred	*	71.2	62.7	29.9	180.0	12.1
MTHW1064	-	-	71.0	62.0	30.8	179.9	12.4
LIMAGR3	-	-	70.9	63.9	29.4	178.7	12.8
Brennan	Syngenta	-	70.8	63.3	28.0	177.4	13.5
MT 1113	-	-	70.5	61.8	30.4	177.4	12.6
Conan	WestBred	*	70.2	61.4	31.1	179.9	13.3
Vantage	WestBred	-	70.0	64.2	30.2	184.0	13.3
MTHW1060	-	-	69.6	62.3	29.2	177.1	12.2
Buck Pronto	Trigen	-	68.2	61.1	30.2	177.4	13.3
Fortuna	N.Dak	**	62.6	62.1	37.2	180.0	12.6
Thatcher	N.Dak	-	57.9	51.1	41.8	182.7	12.7
Mean			75.4	62.0	31.0	179.8	12.7
LSD (.05)			7.56	3.37	1.89	1.05	
C.V (%)			5.87	3.34	3.59	0.35	

Planted April 17, 2012. Harvested August 20, 2012.
Fertilizer, actual: lb/acre:11-22-0 with seed at planting, 154-0-20 broadcast while planting
Sprayed with Huskie @ 11 oz/a and Axial @ 16.4 oz/a on 6/1/2012 using a spray volume of 10 gal/a.
Precipitation from planting to harvest: 6.48 inches.
** = Solid stem sawfly-resistant (solid stem score of 19 or higher). * = Less preferred by sawfly (behavioral preference) in small plots.
Location: MSU Western Triangle Ag Research Center, Conrad, MT

Table 11. Six-year means, Advanced dryland Spring Wheat varieties, Conrad area, Pondera, County MT. 2012.

Variety	Source	Class	6-Year Mean Yield bu/a	Test Weight	Height in.	Head date	Protein %
AP604 CL	AgriPro	CL	54.5	62.0	30.8	182.2	14.1
Choteau	MSU	**	65.1	60.4	29.7	183.2	13.9
Conan	WestBred	*	56.8	60.9	29.5	184.0	13.8
Corbin	WestBred	*	62.7	60.2	31.2	182.8	13.7
Duclair	MSU	**	66.5	60.2	31.0	181.6	13.6
Fortuna		**	53.4	61.0	37.2	184.3	13.8
Jedd	WestBred	CL2	55.8	60.9	26.5	182.7	13.1
Kelby	AgriPro	-	53.8	61.9	27.8	181.8	14.5
McNeal	MSU	-	60.4	60.1	32.3	184.3	13.4
Oneal	WestBred	*	62.8	61.3	31.3	184.7	13.3
Reeder	N. Dak.	-	58.6	60.9	31.5	183.3	14.0
Vida	MSU	*	63.9	60.6	31.8	184.8	13.1
Volt	WestBred	-	58.0	62.7	29.2	186.2	13.2
WB Gunnison	WestBred	*	61.6	61.1	29.7	183.2	13.3
Mean			59.4	61.0	31	184	13.6

** = Solid stem sawfly-resistant (solid stem score of 19 or higher). * = Less preferred by sawfly (behavioral preference) in small plots. CL = Clearfield System (2-gene). HW = Hard White
Location: MSU Western Triangle Ag. Research Center, Conrad, MT.

Table 12. 2012 Advanced Spring Wheat variety nursery, Conrad Dryland.
Condensed List.

Variety	Source	Class	Yield bu/a	Test Wt lb/bu	Height in.	Head date	Protein %
SY Tyra	Syngenta	-	82.1	63.2	27.4	180.7	11.8
Volt	WestBred	-	81.0	63.9	29.6	182.4	11.9
Vida	MSU	*	79.9	62.1	32.8	180.8	12.3
ONeal	WestBred	*	79.7	62.7	33.1	180.1	12.0
Corbin	WestBred	*	78.6	62.9	30.6	179.4	12.5
SY605 CL	Syngenta	-	78.6	63.1	34.3	177.7	13.0
SY Soren	Syngenta	-	76.4	63.2	29.3	180.3	12.9
Choteau	MSU	**	75.0	61.5	30.2	180.0	12.9
WB Mayville	WestBred	-	74.6	62.0	28.6	179.0	13.1
McNeal	MSU	-	74.5	61.7	31.7	180.0	12.5
Duclair	MSU	**	74.3	61.0	31.3	178.2	12.6
Reeder	N.Dak	-	74.2	62.2	33.4	180.3	13.1
AP604 CL	AgriPro-8	CL	72.7	63.7	32.1	178.7	12.5
Kelby	AgriPro	-	72.2	63.1	28.7	177.0	13.5
Mott	N.Dak	-	71.7	61.7	34.6	181.0	13.2
Jedd	WestBred	CL2	71.6	62.2	27.5	179.6	11.7
WB Gunnison	WestBred	*	71.2	62.7	29.9	180.0	12.1
Brennan	Syngenta	-	70.8	63.3	28.0	177.4	13.5
Conan	WestBred	*	70.2	61.4	31.1	179.9	13.3
Vantage	WestBred	-	70.0	64.2	30.2	184.0	13.3
Buck Pronto	Trigen	-	68.2	61.1	30.2	177.4	13.3
Fortuna	N.Dak	**	62.6	62.1	37.2	180.0	12.6
Thatcher	N.Dak	-	57.9	51.1	41.8	182.7	12.7
Mean			75.4	62.0	31.0	179.8	12.7

Planted April 17,2012. Harvested August 16,2012.
Fertilizer, actual lbs/acre 11-22-0 with seed at planting. 154-0-20 broadcast at planting.
Sprayed on 6/1/2012,with 11oz./a Huskie and 16.4 oz/a Axial
Total precipitation from planting to harvest 7.63 inches
** = Solid stem sawfly-resistant (solid stem score of 19 or higher). * = Less preferred by sawfly (behavioral preference) in small plots. CL = Clearfield System.
Location: MSU Western Triangle Ag Research Center, Conrad, MT.

Table 13. 2012 Irrigated Spring Wheat variety trial, Conrad, MT.

Variety	Soure	Class	Yield bu/a	Test Wt lb/bu	Height in.	Head date	Protein %
SY Tyra	Syngenta	-	113.8	62.8	32.7	179.7	12.4
Duclair	MSU	**	108.5	61.8	35.0	177.0	13.7
IMICHT79	-	-	108.0	62.8	36.0	180.0	13.5
ONeal	WestBred	*	107.3	63.6	37.7	180.0	12.4
WB Gunnison	WestBred	*	107.2	63.1	35.7	180.0	12.9
MT 1008	-	-	107.2	63.0	35.7	180.7	12.6
MT1053	-	-	105.8	62.2	34.3	179.7	12.6
Hank	WestBred	-	105.5	61.7	34.3	179.0	12.8
Volt	WestBred	-	104.0	63.8	35.3	182.3	13.1
Jedd	WestBred	CL2	103.9	62.3	31.0	179.3	12.9
Choteau	MSU	**	102.2	62.5	34.7	179.3	13.9
Corbin	WestBred	*	92.9	63.4	37.7	179.0	13.4
McNeal	MSU	-	92.0	62.3	37.7	179.7	13.6
Kelby	ArgiPro	-	83.1	62.0	33.7	177.7	14.9
AP 604CL	AgriPro	CL	82.8	63.9	37.7	178.0	13.5
Vida	MSU	*	81.4	62.1	36.7	180.0	13.5
Reeder	N.Dak	-	76.5	62.9	39.0	180.0	13.5
Fortuna	N.Dak	**	75.9	63.1	44.7	180.0	13.8
Outlook	MSU	-	75.3	61.6	37.7	180.3	13.5
Mott	N.Dak	-	63.6	61.4	41.3	181.0	13.9
Mean			94.8	62.6	36.4	179.6	13.3
LSD (.05)			9.48	0.74	2.48	0.65	
C.V. (s/mean)*100			6.05	0.71	4.11	0.22	

Planted April 17, 2012 on no-till. Harvested August 30, 2012.
Fertilizer, actual: 224-22-20, 11-52-0 placed with seed, Urea and potash topdressed while seeding.
Sprayed with: Bronate @ 1.5 pt/a and Axial @ 16.4 oz/a on 6/2/12.
Total precipitation from planting to harvest: 7.63 inches with 7.55 inches irrigation water applied.
** = Solid stem sawfly-resistant (solid stem score of 19 or higher). * = Less preferred by sawfly (behavioral preference) in small plots.
Location: MSU Western Triangle Ag Research Center, Conrad, MT

Table 14. Six-year Means, Irrigated Spring Wheat varieties, Conrad area, Pondera County. 2006 - 07 and 2009 -2012.

Variety	Source	Class	6-Year Means Yield bu/a	Test wt.	Height in.	Head date	Protein %
Choteau	MSU	**	87.3	61.7	32.2	184.7	14.2
Hank	WestBred	-	85.3	60.4	30.2	182.7	13.6
Oneal	WestBred	*	83.7	61.7	35.9	184.5	13.3
Jedd	WestBred	CL2	82.6	61.3	28.6	183.5	13.0
Corbin	WestBred	*	80.0	62.2	34.3	183.0	13.9
Vida	MSU	*	76.7	60.6	34.0	184.7	13.9
McNeal	MSU	-	74.5	60.9	34.3	184.7	13.7
Reeder	N.Dak	-	73.5	62.1	34.8	183.8	14.0
AP604 CL	AgriPro-8	CL	72.7	62.6	34.9	182.8	14.2
Fortuna	N.Dak	**	68.9	62.1	40.0	184.2	14.3
Outlook	MSU	-	68.3	60.1	35.3	185.5	13.9
Kelby	AgriPro	-	66.7	61.4	29.8	181.5	15.2
Nursery Mean			77.4	61.4	33.7	183.6	13.9

** = Solid stem sawfly-resistant (solid stem score of 19 or higher). * = Less preferred by sawfly (behavioral preference) in small plots.
Location: MSU Western Triangle Ag. Research Center, Conrad, MT.

Table 15. Off-station Spring wheat variety trial located northeast of Choteau, MT.
Teton county. Western Triangle Ag. Research Center. 2012.

Variety	Source	Class	Yield bu/a	Test Wt lb/bu	Height in.	Protein %
MT 1053	-	-	45.0	57.4	26.3	15.0
WB Gunnison	Westbred	*	43.9	57.0	26.7	15.2
MT 1008	-	-	43.7	56.8	27.7	15.3
McNeal	MSU	-	42.7	57.4	29.7	15.2
Jedd	WestBred	CL2	41.9	58.0	24.0	15.4
Vida	MSU	*	41.7	57.3	27.3	15.0
Outlook	MSU	-	41.6	57.0	29.3	14.4
Volt	WestBred	-	41.5	61.3	28.0	14.6
IMICHT79	-	-	39.5	56.5	27.3	15.9
Mott	N.Dak	-	39.3	57.9	30.0	16.0
ONeal	WestBred	*	38.9	57.9	28.3	16.1
Duclair	MSU	**	38.7	57.3	29.7	15.3
Reeder	N.Dak	-	38.3	58.9	28.3	15.8
SY Tyra	Syngenta	-	38.0	57.5	25.0	-
Choteau	MSU	**	36.3	57.0	25.0	16.0
Corbin	WestBred	*	35.8	58.6	26.3	15.8
Hank	WestBred	-	35.7	56.5	24.7	15.8
AP604 CL	AgriPro-8	CL	34.9	59.5	27.3	15.7
Fortuna	N.Dak	**	33.6	59.5	32.3	15.0
Kelby	AgriPro	-	32.5	61.5	26.3	15.7
Mean			39.2	58	27.5	15.4
LSD (.05)			4.0	1.6	2.5	
C.V. 1 (%) (S/mean)*100			6.1	1.7	5.6	

Cooperator and Location: Inbody Farms, Teton county.
Planted April 21, 2012 on chem-fallow. Harvested August 17, 2012.
Fertilizer, actual lbs/a: 112-22-0 actual lbs/acre applied with seed. 148-0-20 lbs/acre applied with broadcast while seeding
Sprayed : none
Precipitation ; N/A
** = Solid stem sawfly-resistant (solid stem score of 19 or higher). * = Less preferred by sawfly (behavioral preference) in small plots.
Conducted by MSU Western Triangle Ag. Research Center

Table 16. Off-station spring wheat variety trial located north of Devon. Eastern Toole County. Western Triangle Ag. Research Center. 2012.

Variety	Source	Class	Yield bu/a	Test Wt lb/bu	Height in.	Protein %	Lodging %
MT 1008	-	-	35.8	57.8	24.7	14.2	2.7
MT 1053	-	-	35.7	57.5	25.0	14.2	5.0
Vida	MSU	*	34.2	57.7	25.7	14.4	10.3
WB Gunnison	WestBred	*	33.6	57.7	25.7	14.9	0.3
Duclair	MSU	**	33.1	55.4	26.0	15.4	4.0
Outlook	MSU	-	33.0	56.8	25.7	14.5	2.7
Reeder	N.Dak	-	32.9	58.9	28.0	14.7	4.3
Mott	N.Dak	-	31.7	57.8	27.0	15.6	0.7
ONeal	WestBred	*	31.3	59.4	26.3	15.5	0.3
Volt	WestBred	-	29.7	59.6	25.0	15.0	1.3
Jedd	WestBred	CL2	29.5	58.2	24.7	15.2	0.3
Fortuna	N.Dak	**	29.4	57.7	29.3	14.8	6.3
McNeal	MSU	-	28.7	57.0	27.3	15.6	5.7
Hank	WestBred	-	28.6	57.4	25.3	15.5	1.7
SY Tyra	Syngenta	-	28.5	59.0	24.0	14.2	5.7
Choteau	MSU	**	28.0	56.6	24.7	15.5	7.7
IMICHT79	-	-	27.0	56.6	23.0	15.5	1.7
Corbin	WestBred	*	26.9	57.9	26.3	15.6	1.7
Kelby	AgriPro	-	25.6	58.3	26.3	15.9	6.7
AP604 CL	AgriPro-8	CL	24.9	56.2	26.7	16.0	2.0
Mean			30.4	57.7	25.8	15.1	3.6
LSD (.05)			5.4	1.5	1.9		5.6
C.V. 1 (%) (S/mean)*100			10.8	1.6	4.4		94.8

Cooperator and Location: Brian Aklestad, eastern Toole county.
Planted April 19, 2012 on chem-fallow. Harvested August 7, 2012.
Fertilizer, actual lbs/a: 11-22-0 with seed at planting, with broadcast 105-0-20 applied while seeding.
Sprayed with Huskie at 11 oz/a and Axial XL at 16.4 oz/a on 6/18/2012.
Precipitation: Gauge had 5.5 inches then was stolen.
** = Solid stem sawfly-resistant (solid stem score of 19 or higher). * = Less preferred by sawfly (behavioral preference) in small plots.
Conducted by MSU Western Triangle Ag. Research Center.

Table 17. Four-year Mean, Spring Wheat varieties, Devon area, western Chouteau County. 2009-2012.

Variety	Source	Class	4-Year Mean Yield bu/a	Test weight	Height in.	Protein %
Vida	MSU	*	39.7	57.9	26.7	13.5
Volt	WestBrd	-	38.4	60.8	25.9	14.1
Fortuna	N.Dak	**	37.9	58.3	31.3	14.4
Duclair	MSU	**	37.6	55.2	27.2	14.5
Oneal	WestBred	*	36.9	59.5	27.3	14.9
Outlook	MSU	-	36.7	56.4	26.9	14.4
Reeder	N.Dak	-	35.4	57.7	27.4	14.8
Corbin	WestBred	*	35.2	58.1	26.8	14.8
Choteau	MSU	**	34.9	56.7	24.8	14.7
McNeal	MSU	-	34.6	57.3	27.7	15.2
Hank	WestBred	-	32.3	56.7	25.8	15.2
AP604 CL	AgriPro-8	CL	32.1	56.5	27.9	15.6
Jedd	WestBred	CL2	32.0	58.1	24.2	14.6
Kelby	AgriPro	-	31.1	59.2	24.9	15.3
Mean			35.3	57.8	26.8	14.7

** = Sawfly resistant (solid stem score of 19 or higher).
* = Partial sawfly resistance.
CL= Clearfield technology
Conducted by MSU Western Triangle Ag. Research Center

Table 18. Off-station spring wheat variety trial located near the Knees.
Chouteau county. Western Triangle Ag. Research Center. 2012.

Variety	Source	Class	Yield bu/a	Test Wt lb/bu	Height in.	Protein %	Lodging %
WB Gunnison	WestBred	*	56.7	60.2	29.0	13.3	0.7
IMICHT79	-	-	54.8	59.7	27.0	13.6	2.3
MT 1008	-	-	54.7	60.2	27.3	13.0	6.6
Duclair	MSU	**	53.3	57.9	29.3	13.6	1.6
Oneal	WestBred	*	52.9	60.0	29.7	13.4	7.6
Vida	MSU	*	52.5	60.0	28.7	12.8	4.7
MT 1053	-	-	51.4	59.4	28.3	12.5	6.3
Jedd	WestBred	CL2	50.9	59.4	24.0	14.4	14.0
Corbin	WestBred	*	50.6	59.1	30.0	14.4	7.7
McNeal	MSU	-	50.6	57.8	29.7	13.7	61.7
Outlook	MSU	-	50.0	58.4	29.0	13.3	28.3
Mott	N.Dak.	-	48.8	60.9	32.3	14.5	6.7
Hank	WestBred	-	48.5	57.8	28.0	13.8	42.7
Fortuna	N.Dak	**	47.3	59.5	34.7	14.0	4.7
Choteau	MSU	**	47.3	59.3	27.0	14.0	3.3
AP604 CL	AgriPro-8	CL	45.8	59.5	31.3	13.6	21.0
Kelby	AgriPro	-	45.8	61.0	25.7	14.0	16.3
SY Tyra	Syngenta	-	45.1	58.8	25.3	13.4	4.0
Volt	WestBred	-	44.5	61.6	26.3	13.4	56.7
Reeder	N.Dak	-	43.1	59.3	29.3	14.5	30.0
Mean			49.7	59.5	28.6	13.7	16.4
LSD (.05)			5.22	0.93	1.77		20.3
C.V. %			6.4	0.94	3.7		75.2

Cooperator and Location: Aaron Killion, western Chouteau county.
Planted April 22, 2012 on chem-fallow. Harvested August 14, 2012.
Fertilizer, actual lbs/a:11-22-0 with seed at planting, 105-0-20 broadcast while planting
Preplant sprayed with Roundup WeatherMax™ @ 22 oz/a on April 22, 2012.
Precipitation, rain gauge cracked.
** = Solid stem sawfly-resistant (solid stem score of 19 or higher). * = Less preferred by sawfly (behavioral preference) in small plots.
Conducted by MSU Western Triangle Ag. Research Center.

Table 19. Four-year Means, Spring Wheat varieties, Knees area, western Chouteau County. 2009-2012.

Variety	Source	Class	4-Year Means Yield bu/a	Test weight	Height in.	Protein %
Duclair	MSU	**	51.2	57.9	27.4	14.0
Corbin	WestBred	*	47.9	59.1	27.5	13.8
Vida	MSU	*	47.1	60.0	28.3	13.6
Choteau	MSU	**	46.5	59.3	26.3	14.3
Oneal	WestBred	*	46.2	60.0	28.0	13.8
McNeal	MSU	-	44.3	57.8	29.3	14.0
Outlook	MSU	-	44.1	58.4	27.5	14.0
Volt	WestBred	-	42.8	61.6	26.0	13.4
Reeder	N.Dak	-	41.5	59.3	27.5	14.6
Jedd	WestBred	CL2	40.9	59.4	22.5	14.0
Kelby	AgriPro	-	38.5	61.0	24.0	14.8
Fortuna	N.Dak	**	38.0	59.5	33.0	14.5
AP604 CL	AgriPro-8	CL	37.8	59.5	27.3	14.1
Hank	WestBred	-	35.5	57.8	25.8	14.2
Mean			42.9	59.3	27.2	14.1

** = Sawfly resistant (solid stem score of 19 or higher).
* = Partial sawfly resistance.
CL= Clearfield technology
Conducted by MSU Western Triangle Ag. Research Center

Table 20. 2012 Dryland Durum variety nursery, WTARC, Conrad, MT.

Variety	Yield bu/a	Test Wt lb/bu	Height in.	Heading, days from planting
Strongfield	84.5	61.9	39.4	76.0
Alkabo	80.8	61.5	37.1	76.0
MT05183	80.6	61.4	27.2	76.3
MT05166	77.8	60.7	29.4	76.7
Mountrail	77.3	60.0	36.7	76.7
Westmore	77.2	59.7	24.7	72.0
Kronos	76.1	58.8	26.1	70.3
MT05158	74.7	63.5	27.4	76.0
MT06584	74.5	60.0	26.0	77.0
Grenora	73.7	61.2	33.1	75.3
Alzada	73.2	60.6	28.0	72.7
Tioga	73.0	62.0	39.4	75.7
Divide	72.8	61.0	37.7	76.0
Silver	71.3	60.8	27.7	72.3
Belfield	70.9	61.5	26.4	70.3
D7-12	69.6	56.9	26.8	77.3
Normanno	68.7	59.2	26.1	71.7
D6-419	67.9	59.7	29.0	75.3
D1-35	67.3	55.9	23.8	73.7
Westhope	61.3	60.6	34.9	76.3
Means	73.7	60.4	30.4	74.7
LSD (.05)	12.6	1.1	3.0	1.0
CV, S/mean	10.4	1.1	5.9	0.8
P value (0.05)	0.143	<0.001	<0.001	<0.001

Planted April 17, 2012. Harvested August 16, 2012.
Fertilizer, actual: 165-22-20, 11-52-0 place with seed, Urea and potash broadcast on April 17, 2012.
Sprayed with: Bronate 1.5 pt/a and Axial XL @ 16.4 oz/a on 6/1/2012.
Total precipitation from planting to harvest: 7.63 inches.
Location: Western Triangle Ag. Research Center, Conrad, MT.

Table 21. Six-year means, dryland Durum varieties. Western Triangle Ag. Research Center Conrad, MT, Pondera County, 2007 – 2012.

		6 year mean			
Variety	Source	Yield bu/a	Test weight	Height in.	Head date
Strongfield	WestBred	70.6	61.3	35.0	186.8
Grenora	N. Dak.	64.1	61.2	32.5	185.3
Alkabo	N. Dak.	63.6	61.8	34.5	185.7
MT03012	MSU	60.9	60.8	27.2	182.0
Divide	N. Dak.	59.4	61.1	35.5	186.7
Alzada	WestBred	57.0	60.6	27.5	182.8
Normanno	AllStar	55.9	59.5	24.8	184.5
Mountrail	N. Dak.	50.8	60.2	34.8	187.0
Nursery Mean		62.1	60.8	31.6	185.2

Spring Barley Evaluations in the Western Triangle Area

Personnel: John Miller and Gadi V.P. Reddy, Western Triangle Ag. Research Center, Conrad, MT. Dave Wichman, Central Ag. Research Center, Moccasin, MT, and Tom Blake, PSPP, Bozeman.

The uniform, intrastate barley nursery was grown on dryland and irrigated conditions at the Research Center. Four off station locations were carried out during 2012. Off station trials were grown north of Cut Bank, MT, north of Devon, MT, near the 'Knees' east of Brady, MT, and northeast of Choteau, MT in Teton county. All nurseries were grown on no-till chemical fallow, with the exception of the intrastate dryland barley trial. The intrastate dryland barley nursery was grown on conventional fallow. For the 2013 growing season, all nurseries will be grown on to-till chemical fallow.

Results: Results are reported in Tables 22 thru 32. Table 22 is the intrastate dryland variety nursery, with Table 23 showing the five year average for the dryland variety trial. Tables 24 and 25 contain the results for the intrastate irrigated nursery. Results are tabulated in Table 26 for the irrigated off-station barley nursery and Table 27 is six year averages for selected varieties in the irrigated off-station barley trial. Table 28 is for the Choteau location. Tables 29 and 30 are for the Devon location, with Table 31 and 32 representing the 'Knees' location. Table 33 contains soil test values for the on and off-station locations. The Cut Bank location was lost due to a hailstorm.

The 2012 growing season at WTARC began with temperatures a bit warmer than normal; there was a less precipitation than the 27 year average, this trend continued throughout the growing season.

Grain yields averaged 97.9 bu/acre for the irrigated off-station barley (Table 26), 47.3 bu/acre at the Choteau location (Table 28), and 57.7 bu/acre at Devon (Table 29), while the barley averaged 67.5 bu/acre at the 'Knees' (Table 31). Multiyear yields for the irrigated off-station barley trial were about the same (Table 27), and multiyear averages for yield at Devon and the 'Knees' were about the same as for 2012 (Tables 30 and 32). Kernel plumpness averaged 75.4% at Choteau, 77.8% at Devon, and 81.1% at the 'Knees'. Top yielding varieties at Choteau were MT070158, Eslick, and MT070159. Top yielding barleys north of Devon were Champion, MT070158, and MT070159. While top yielding barleys at the Knees location were Champion, MT080279, and Harrington. Yields for the irrigated off-station trail ranged from 81.3 to 112.0 bu/acre. Yields ranged from 38.1 to 55.4 bu/acre at Choteau, 44.8 to 67.0 bu/acre at Devon, and 58.2 to 77.6 bu/acre at the Knees.

<u>**Off station cooperators**</u>: Bradley Farms, north of Cut Bank, MT
Brian Aklestad, north of Devon, MT
Aaron Killion, east of Brady, MT
Inbody Farms, northeast of Choteau

These data should be used for comparative purposes rather than using absolute numbers. Statistics are used to indicate that treatment or variety differences are really different and are not different due to chance or error. The least significant difference (LSD) and coefficient of variability (CV) values are useful in comparing treatment or variety differences. The LSD value represents the smallest difference between two treatments at a given probably level. The LSD at p=0.05 or 5 % probability level is usually the statistic reported, and it means that the odds are 19 to 1 that treatment differences by the amount of the LSD are truly different. The CV value measures the variability of the experiment or variety trial, and a CV greater than 15 % indicates a high degree of variability and less accuracy.

Funding Summary: Office of Special Projects will provide expenditure information. No other grants support this project.

MWBC FY2014 Grant Submission Plans**:** A similar project will be proposed for FY 2014. The continuation of on and off-station variety trials help to elucidate researchers and farmers which varieties are better suited for that particular region in Montana.

Barley Variety Notes & Comments

Western Triangle Agricultural Research Center, Conrad, MT

Baroness (WestBred): 2-row feed. Short straw and good lodging resistance; 2.5" shorter than Harrington. Equal or slightly later maturity than Harrington. High yield when tested in favorable moisture conditions. Average test weight. Stripe rust resistant.

Boulder (WestBred, 2005): 2-row feed. Composite-cross, non-Baroness derived. Height similar to Haxby. Heading 1 day later than Haxby, and 1 day earlier than Baroness. High yield, similar to Haxby. High test weight, 0.5 lb less than Haxby. Replacement for Baroness and Xena.

Challenger (WestBred, 2008): 2-row feed. Above average yield and test weight. Average height and maturity.

Champion (WestBred, 2007): 2-row feed. Medium stiff straw. Heading one day later than Haxby and Boulder. Very high yield, greater than for Boulder & Baroness. High test weight, 1 lb less than Haxby.

Charles: 2-row malt. Grown as a winter barley in Idaho, but has very low winter hardiness. Winter survival on tillage-fallow at Conrad was 40% in 2007, and 10% in 2008.

Conlon (ND, 1996): 2-row malt. Medium height, weak straw. Early maturity, 1-2 days earlier and higher test weight than Bowman. Developed for areas of heat & drought stress. High resistance to net blotch; susceptible to spot blotch & Fusarium head blight.

Conrad (Busch Ag): 2-row malt, Busch Agr Resources. About 2 inches shorter than Harrington. Medium maturity, similar maturity as Harrington. Higher yield than Harrington. Slightly higher test weight and plump than Harrington.

Copeland (Sask. Canada, 1999): 2-row malt. Better straw strength and earlier maturity than Harrington. Similar yield, test weight, and plump than Harrington. Net blotch resistant. Scald & Septoria susceptible.

Craft (MT970116; MSU, 2006): 2-row malt. Taller than Harrington & Merit. 2 days earlier heading than Harrington, but later heading than Hockett. High yield, test weight, & plump. Moderate stripe rust resistance. Susceptible to net blotch. European style of malt enzyme activity for microbrew market. AMBA approved for organic malt production.

Drummond (ND 15477): 6-row malt. Stronger straw than other 6-row malt types. Improved yield over Morex, Robust and Foster. Plump higher than Morex.

Eslick (MSU, 2005): 2-row feed. Height 1” taller than Baroness, 1” shorter than Haxby. Heading date similar to Harrington, and 1-2 days later than Haxby. Yield similar to Baroness and Haxby. Test wt = Baroness, greater than Harrington, and 2# less than Haxby. Eslick has superior performance in areas of ample moisture, while Haxby is preferred where lower moisture conditions are expected.

Geraldine (MT960101; MSU, Miller Brewing): 2-row malt for Miller Brewing Co. One day later heading than Harrington. Good performance on irrigated conditions; below average performance on dryland. Moderate stripe rust resistance.

Harrington (Sask. Can): 2-row malt. Medium height; medium weak straw. Medium-late maturity. Sensitive to hot dry areas; yields good in moist areas. Can sprout or germinate (internal falling number) at a lower moisture content than other varieties.

Haxby (MSU, 2002): 2-row feed. 3 inches taller and two days earlier than Baroness. Among highest yielders in Triangle Area. Highest test weight of all varieties. High feed quality. Non-Baroness derived, providing good diversity. Haxby has superior yield performance in lower moisture conditions, while Eslick has a yield advantage in high moisture conditions.

<u>Hays</u> (MSU, 2004): Hooded 2-row forage. Shorter than Haybet and more resistant to lodging. Higher grain yield than Haybet. Low test weight. Higher forage yield than Haybet and Westford (8%). Harvest between heading stage and 5 days post-heading for highest protein. Caution: any cereal grain grown for hay should be tested for nitrate level prior to cutting. Nitrates decrease during grain filling, but in drought conditions, nitrates may be high all season, unless irrigation is available.

<u>Hockett</u> (MSU, MT910189): 2-row malt for dryland. 4 days earlier than Harrington, and retains plump on dryland much better than Harrington. 5 bu/a higher yield than Harrington. Very susceptible to stripe rust.

<u>Kendall</u> (Can): 2-row malt. High irrigated yield.

<u>Lacey</u> (M98, MN 1999): 6-row malt. Intended to replace Robust. Height intermediate between Robust & Stander. Lodging resistance greater than Robust, but less than Stander.

<u>Legacy</u> (Busch Ag): 6-row malt. 2 to 4 inches taller than Harrington. Higher yield than Morex and Robust, but lower than Harrington. Has 30% resistance to vomatoxin. Very susceptible to stripe rust.

<u>Merit</u> (Busch Ag): 2-row malt. Late maturing, too late for dryland. Lodges easier than Harrington, but yields higher. Very high diastatic power for excellent malting ability. Net blotch resistance, and moderate Scald resistance.

<u>Metcalfe</u> (Manitoba Canada, 1994): 2-row malt. Replacement for Harrington in Canada. Medium straw strength. Latitude sensitive - higher yield, test weight and plump than Harrington in Canada, but similar to Harrington in Montana. Similar protein as Harrington. Medium-late, slightly earlier to head than Harrington. Moderate resistance to spot-form net blotch. Susceptible to scald and Septoria.

<u>Stellar</u> (ND16301, 2005): 6-row malt. Medium-short. Good straw strength and widely adapted across North Dakota. Medium maturity. High plump and low protein. Excellent malt quality. Moderate spot-blotch resistance. Net-blotch susceptible.

<u>Stockford</u> (WestBred, 2005). 2-row hooded hay barley. Height is 2” taller than Hays. Heading is 2 days earlier than Hays. Forage yield is similar to Hays and Haybet. Harvest between heading stage and 5 days post-heading for highest protein. Caution: any cereal grain grown for hay should be tested for nitrate level prior to cutting (see note for Hays).

<u>Tradition</u> (Busch Ag,): 6-row malt. Stiffer straw than Legacy, good lodging resistance. Higher yield, test weight and plump than Legacy and other 6-row varieties. Very susceptible to stripe rust.

<u>Xena</u> (WPB bz594-19): baroness/stark cross. 2-row feed. Two inches taller and better boot emergence than Baroness. Lodging resistance equal to Baroness. Late maturity, similar to Baroness. Better adapted to dryland than Baroness, (higher test wt and plump than Baroness on dryland). Equal or better yield than Baroness on dryland.

“BG Barley”: A food barley classification, and includes waxy hulless and waxy covered varieties. Beta glucan levels of BG varieties are 50% higher than for oats or pearled barley. Grain yields are generally lower than other barley varieties. End-use includes various foods, including rice-extender, ‘Heart Balance Cereal’ etc.

Table 22. Dryland Intrastate Barley variety trial, Conrad 2012.

Variety	Yield[1] bu/a	Test Wt lb/bu	Plump %	Thin %	Protein[2] %	Head date	Height in.
MT070158	113.6	52.2	96.9	0.7	8.6	179.8	30.1
MT090193	113.6	50.8	95.7	1.3	8.3	179.8	37.2
Champion	108.9	52.9	93.9	1.5	9.5	177.0	34.2
MT100130	105.2	52.6	95.4	1.2	8.4	179.1	34.2
MT061035	105.1	51.2	93.5	1.9	8.4	179.8	31.2
MT100126	102.1	51.3	96.2	1.4	8.2	180.3	35.0
MT100120	101.9	52.5	97.3	0.7	8.1	178.6	37.1
MT100124	101.7	51.7	97.3	0.8	8.3	179.8	35.4
MT100125	100.5	51.1	96.2	1.2	8.3	180.1	33.7
MT090186	100.3	52.0	97.6	0.8	8.7	179.6	35.2
MT090181	99.8	50.8	96.8	1.2	8.3	179.0	35.0
MT100128	99.5	52.4	95.8	1.9	8.6	179.7	34.5
MT100051	99.5	53.9	97.0	0.9	9.2	175.6	31.6
MT080281	98.6	51.4	93.2	1.8	8.6	179.8	29.0
MT100064	98.5	52.9	94.6	1.6	8.3	177.2	32.5
MT070086	98.3	49.1	92.3	2.4	8.6	181.4	25.9
MT090182	98.2	52.7	95.2	1.4	8.1	179.6	34.1
MT100136	97.8	51.8	94.6	1.5	8.0	179.1	34.5
MT090180	97.8	51.0	96.1	1.3	7.9	179.3	32.5
MT103022	97.7	51.5	97.1	1.0	9.8	179.4	31.3
EM090081	97.5	50.6	94.7	1.4	9.0	181.8	32.2
Eslick	97.4	52.2	94.0	1.3	8.4	179.5	28.8
MT070159	97.4	52.0	96.6	1.0	8.8	179.4	28.8
Expedition	97.2	50.2	95.9	1.5	9.0	183.5	26.1
EM090061	96.8	49.7	96.7	0.9	9.8	184.0	28.9
MT100070	96.5	53.2	96.5	1.0	8.2	177.1	35.7
Metcalfe	96.1	51.0	96.1	1.5	9.2	177.7	35.0
MT080285	95.8	51.3	94.9	1.8	9.1	180.2	27.9
MT100060	95.7	54.3	97.4	1.0	9.1	176.3	32.2
MT070175	95.6	51.2	95.5	1.5	8.2	176.3	37.1
MT080279	95.4	52.1	94.8	1.4	8.3	179.5	28.5
MT080243	95.3	52.4	93.7	1.3	8.8	177.8	33.8
MT090184	95.1	52.9	96.1	1.1	8.0	178.9	34.9
MT080081	94.9	48.9	94.0	2.2	8.6	182.5	27.7
MT070161	94.7	52.2	96.7	1.0	8.8	178.1	28.9
MT100132	94.7	50.7	94.5	1.5	7.8	179.5	34.6
Scarlett	94.5	51.5	97.0	1.0	8.9	181.7	25.6
Haxby	94.5	54.2	93.0	2.0	8.9	176.9	32.0
MT020155	94.0	51.5	95.6	1.3	9.3	174.5	31.4

Table 22 continued on next page

Table 22 continued

Variety	Yield[1] bu/a	Test Wt lb/bu	Plump %	Thin %	Protien[2] %	Head date	Height in.
MT090190	94.0	51.9	96.4	0.9	7.6	179.3	33.5
Conrad	93.9	50.7	97.0	1.4	8.9	180.0	27.4
MT100063	93.3	53.1	95.1	1.4	8.1	175.5	30.6
MT061169	93.0	51.4	94.1	1.6	9.1	179.8	30.4
MT100113	92.1	52.9	96.1	1.3	8.0	176.6	29.2
MT070125	91.1	52.5	96.8	0.8	9.1	178.6	35.1
EM090105	91.0	51.2	96.5	1.1	8.2	178.3	31.3
Harrington	90.6	49.9	94.2	1.8	9.0	179.1	34.9
MT100074	90.4	52.9	95.6	1.5	8.8	178.0	34.0
MT090001	90.2	48.1	63.0	16.5	7.6	174.6	32.4
Hockett	89.0	52.5	96.5	1.0	9.1	177.7	30.5
Pinnacle	88.7	52.3	98.3	0.8	7.9	174.2	33.6
Tradition	86.7	49.2	94.8	1.0	9.1	177.1	36.5
MT070111	86.5	51.9	89.9	2.4	8.4	179.7	31.7
Craft	85.4	53.2	95.3	1.3	8.9	176.1	34.4
Hays	85.2	49.0	84.4	6.3	8.5	178.7	30.5
MT080179	84.2	52.3	96.3	1.3	8.5	176.6	34.4
MT010160	83.2	51.8	94.7	1.3	8.5	179.7	33.7
CDC Cowboy	79.6	51.5	97.4	1.1	9.7	178.8	38.2
Geraldine	78.9	52.1	88.6	2.3	7.9	181.6	30.8
MT103015	72.1	60.2	72.2	12.0	9.4	173.6	31.6
MT103031	65.9	60.0	46.1	12.3	10.4	176.6	33.8
MT103043	62.9	52.5	42.5	32.6	9.8	176.6	29.8
MT100170	59.8	60.3	87.5	4.3	12.1	177.5	39.2
MT010158	57.0	51.1	96.7	1.0	11.6	179.3	29.2
Means	92.9	52.1	92.7	2.5	8.76	178.6	32.3
LDS	14.5	1.2	3.1	1.9	-	1.2	3.6
CV%	10.0	1.6	2.3	52.4	-	0.5	7.7
Lattice Re%[3/]	128	101	102	100	-	111	102

Planted April 4, 2012 on fallow. Harvested August 6, 2012.
Fertilizer, actual: with seed 11-22-20.Broadcast at planting 11-00-20
Sprayed with Huskie @ 11 oz/a and Axial @ 16.4 oz/a on 6/1/ 2012.
Growing season ppt.: 6.06 inches.

[1/]Grain yields are based on a 48 pound per bushel standard weight on a ‘as is’ moisture basis
[2/]Grain protein values determined from subsamples bulked across replication
[3/]Adjusted means provided for Lattice RE% values equal to or greater than 105%
Location: MSU Western Triangle Ag Research Center, Conrad, MT.

Table 23. 5-year means, Intrastate Dryland Barley varieties, Conrad, MT, 2006 – 2007, 2009, 2011 and 2012

Variety [1]	Yield bu/a	Test Wt lb/bu	Plump %	Thin %	Protein %	Head date	Height in.
Champion	102.4	51.0	80.5	3.1	11.3	181.2	28.6
Conrad	94.0	51.5	86.2	4.7	11.5	183.6	26.5
Haxby	93.2	54.8	84.0	3.9	11.3	180.4	28.6
Hockett	90.2	53.3	90.9	2.2	11.1	180.3	27.3
Craft	90.1	53.8	90.6	2.6	11.2	180.4	29.5
Harrington	89.4	51.4	86.8	3.6	11.3	182.8	28.6
MT020155	88.9	52.5	86.6	2.6	11.6	178.3	27.9
Metcalfe	87.5	51.9	84.8	4.7	11.5	180.9	29.4
Geraldine	86.8	52.3	73.7	9.9	10.9	184.4	25.8
Tradition	85.0	51.0	81.9	4.2	11.5	179.8	32.3
Mean	90.7	52.6	84.6	4.2	11.3	181.2	28.4

[1] Tradition is 6-row; all others are 2-row.
Location: MSU Western Triangle Ag. Research Center, Conrad, MT.

Table 24. Irrigated Intrastate Barley variety trial, Conrad 2012.

Variety	Yield[1/] bu/a	Test Wt lb/bu	Plump %	Thin %	Grain[2/] Protein %	Head date	Height in.
MT100130	116.3	52.7	96.5	1.0	9.1	180.3	33.6
MT090180	109.3	51.4	94.8	1.5	8.0	181.7	34.3
MT100124	109.2	52.0	96.2	1.0	8.2	180.3	35.3
MT090184	109.0	53.2	97.5	1.0	8.1	180.3	34.9
MT100125	108.8	51.5	96.3	1.0	8.8	182.7	36.0
MT100126	108.6	52.7	96.5	0.9	7.9	182.7	34.2
MT090186	108.1	53.1	97.3	1.0	8.7	181.7	29.8
MT090193	107.1	52.4	95.5	1.4	8.6	181.7	34.5
Expedition	106.6	50.4	95.8	1.8	8.5	184.0	25.0
MT070125	106.5	52.2	97.0	1.0	9.0	181.0	33.6
EM090061	106.3	49.9	97.7	0.9	9.3	184.0	27.4
Conrad	105.0	51.3	97.1	1.2	9.5	181.7	30.1
Eslick	105.0	51.9	94.1	2.1	8.5	184.0	28.6
MT090190	104.9	52.4	96.8	0.9	8.1	181.3	34.5
MT061035	104.7	50.8	95.4	0.8	8.9	182.0	29.0
MT100136	104.6	52.0	95.9	0.9	8.6	181.0	35.5
EM090081	104.3	51.5	95.1	1.3	8.9	184.3	31.9
MT100128	104.1	53.0	96.1	1.5	8.0	183.7	34.1
Champion	103.8	52.7	97.8	0.7	8.4	179.3	32.2
MT090182	103.2	53.1	95.6	1.2	8.3	177.3	32.8
MT090181	102.8	52.1	97.0	0.9	8.2	180.3	32.6
MT100113	102.7	52.4	96.1	1.7	9.1	179.7	30.7
MT080243	101.1	51.9	96.0	1.3	9.1	182.3	31.0
Geraldine	100.9	52.0	92.8	2.6	8.4	184.3	29.9
MT100064	100.7	53.2	97.5	0.8	8.4	179.0	35.0
MT010160	100.0	52.0	96.7	1.0	10.0	180.3	33.9
MT070086	99.9	49.6	93.8	2.2	8.7	183.7	31.1
MT070159	99.9	51.1	95.9	1.4	9.3	180.7	27.6
MT100120	99.6	52.8	97.3	0.8	8.4	181.3	32.3
MT100060	99.5	52.6	96.0	1.3	8.5	178.7	30.4
MT080285	99.2	51.4	94.5	1.7	9.2	180.0	31.5
MT100063	99.0	52.7	96.6	0.9	8.4	179.0	33.5
MT103022	98.7	51.5	97.6	0.9	8.4	180.3	29.5
MT070175	98.3	51.9	96.5	1.2	8.6	179.0	34.7
MT070161	98.3	51.4	96.9	1.0	8.8	179.0	31.4
MT020155	98.0	51.9	94.4	2.0	9.5	176.3	33.1
MT100132	97.9	51.2	94.4	1.4	8.1	182.3	32.9
EM090105	97.4	50.7	95.0	1.8	8.7	180.0	30.9

Table 24 continued on next page

Table 24 continued

Variety	Yield[1/] bu/a	Test Wt lb/bu	Plump %	Thin %	Grain[2/] Protein %	Head date	Height in.
MT080281	97.3	51.1	95.8	1.5	9.0	179.7	27.9
Craft	97.1	53.7	96.5	1.1	9.4	178.7	34.3
Haxby	96.9	53.7	96.4	1.2	9.2	178.3	31.8
MT090001	95.9	46.3	55.9	21.2	7.5	177.3	30.8
MT100070	95.8	52.4	96.6	1.0	8.9	178.7	34.0
MT070158	95.7	52.3	97.1	1.4	8.8	180.0	30.2
MT100074	95.7	53.5	96.6	1.5	8.8	179.3	31.3
MT100051	95.3	53.1	96.7	1.2	8.3	177.7	29.6
Tradition	94.0	48.3	95.9	0.5	9.6	179.0	36.4
Metcalfe	93.6	50.5	95.6	1.5	9.7	180.3	33.0
MT070111	93.2	50.8	92.1	10.8	8.2	183.3	29.6
Scarlett	92.9	50.0	97.0	1.0	9.3	184.3	24.2
Pinnacle	92.8	51.9	98.8	1.4	8.3	177.3	32.2
Hockett	92.8	51.3	96.3	0.5	9.2	178.7	33.4
MT061169	92.6	49.9	93.6	2.2	9.0	183.3	28.8
MT080279	92.4	51.0	95.4	1.2	9.0	179.7	27.7
MT080081	90.7	48.6	91.7	3.0	9.3	184.0	26.1
Hays	90.0	46.9	78.7	9.9	9.2	181.3	32.2
MT010158	88.1	52.8	98.1	0.6	11.2	179.7	30.7
MT080179	87.9	51.6	96.1	1.4	9.2	179.0	33.1
Harrington	87.7	50.0	94.7	1.6	9.1	180.7	30.8
CDC Cowboy	85.7	51.9	98.4	0.7	10.3	182.7	40.7
MT103031	78.7	59.0	48.0	7.3	11.9	179.7	34.6
MT103043	72.8	50.3	58.7	23.9	10.8	178.7	31.6
MT103015	69.2	60.1	69.0	13.8	10.1	176.0	31.1
MT100170	58.8	59.4	87.4	5.2	12.6	178.3	36.1
Mean	97.7	51.9	93.2	2.6	9.0	180.6	31.9
PLSD (0.05)	10.3	1.0	1.9	3.4	-	1.9	4.2
CV %	6.1	1.2	1.2	80.4	-	0.7	7.7
Lattice RE%[3/]	181	109	107	100	-	100	110

Planted April 20, 2012 on fallow. Harvest August 20, 2012.
Fertilizer, actual (lbs/a): 11-22-0 place with seed at planting, 30-0-20 broadcast while seeding.
Growing season ppt: 6.06 inches. Irrigation = 7.55 inches
Sprayed with Huskie @ 11 oz/a and Axial @ 16.4 oz/a on 6/1/2012.
[1/] Grain yields are based on a 48 lb/bu standard bushel weight on a "as is" moisture basis.
[2/] Grain protein values are determined from subsamples bulked across replications.
[3/] Adjusted means provided for Lattice RE% values equal to or greater than 105%.
Location: MSU Western Triangle Ag Research Center, Conrad, MT.

Table 25. 5-year Means, Intrastate Irrigated Barley varieties, Conrad, MT, 2006 – 2007,2009, 2011, and 2012.

Variety [1]	Yield bu/a	Test Wt lb/bu	Plump %	Protein %	Head date	Height in.
Champion	114.3	53.8	94.9	10.1	183.1	30.2
Haxby	108.0	54.4	92.8	11.2	181.8	28.2
Geraldine	106.5	52.7	88.1	10.2	186.3	28.8
Conrad	105.3	52.0	92.9	11.3	185.1	28.0
Craft	103.2	53.7	91.4	11.0	182.6	32.5
Tradition	97.2	50.8	92.8	11.0	181.2	32.9
Hockett	94.9	52.3	90.4	10.7	183.0	29.5
Harrington	94.5	51.3	88.7	10.7	184.3	29.0
Metcalfe	94.2	51.9	92.5	10.8	184.5	30.8
Mean	102.0	52.6	91.6	10.8	183.5	30.0

[1] Tradition is 6-row; all others are 2-row.
Location: MSU Western Triangle Ag. Research Center, Conrad, MT.

Table 26. Irrigated Barley variety trial, Conrad 2012.

Variety	Yield bu/a	Test Wt lb/bu	Plump %	Thin %	Protein %	Head date	Height in.
Champion	112.0	53.9	96.4	1.1	9.4	178.3	32.7
Eslick	111.4	52.9	94.2	2.2	8.8	184.3	32.7
MT070158	106.9	52.6	97.2	1.0	9.3	180.0	30.0
MT080279	101.9	52.3	95.5	1.7	8.9	179.0	27.7
MT070159	100.7	52.6	96.7	1.1	9.6	179.7	30.0
Geraldine	100.2	53.1	94.0	2.1	8.5	184.3	32.3
MT010160	100.1	53.7	96.0	1.3	9.8	180.3	30.7
Haxby	99.5	55.2	96.6	1.4	9.7	179.0	32.7
Gallatin	99.3	53.8	95.1	1.8	9.9	178.0	29.7
Conrad	97.7	52.6	97.6	1.0	9.2	181.3	26.7
Tradition	96.4	50.4	96.2	0.6	9.7	177.7	35.0
Metcalfe	94.8	52.2	95.9	1.5	9.5	180.3	30.7
Harrington	88.9	51.8	95.3	1.6	9.3	180.0	32.0
CDC Cowboy	88.2	53.6	98.4	0.7	10.3	181.7	39.0
Hockett	86.5	52.3	96.0	1.6	9.5	179.3	31.0
Amsterdam	81.3	53.3	98.0	0.7	11.1	179.0	32.0
Mean	97.9	52.9	96.2	1.3	9.5	180.1	31.5
LSD (.05)	14.1	0.6	1.2	0.5	-	1.6	5.5
C.V. (%)	8.6	0.68	0.74	22.0	-	0.52	10.5
P-value (0.05)	0.0043	<0.0001	<0.0001	<0.0001	-	<0.0001	0.0318

Planted: April 17, 2012 on no-till. Harvested: August 20, 2012.
Fertilizer, actual: 41-22-20, 11-52-0 placed with seed, Urea and potash top-dressed while seeding.
Sprayed with Bronate @ 1.5 pt./a and Axial @ 16.4 oz/a on 6/2/2012.
Irrigated with 7.55 inches of water. Precipitation from planting to harvest: 7.10 inches.
Location: MSU Western Triangle Ag Research Center, Conrad, MT.

Table 27. 6-year means, Irrigated (Expt. 3719) Barley varieties, Conrad, MT, 2005 - 2009 2011 - 2012.

	6-Year Means						
Variety	Yield bu/a	Test Wt lb/bu	Plump %	Thin %	Protein %	Head date	Height in.
Geraldine	107.4	53.0	90.2	3.3	11.1	186	30
Haxby	103.4	54.4	93.0	2.6	11.2	182	32
Conrad	102.2	52.0	92.2	3.3	11.3	184	30
Hockett	95.3	52.6	91.6	4.0	11.3	181	31
Harrington	93.5	49.7	83.7	6.3	11.3	184.	32
Metcalfe	93.6	51.7	90.3	3.9	11.5	184	33
Mean	99.2	52.1	90.5	3.5	11.6	183.3	31.6

Location: MSU Western Triangle Ag. Research Center, Conrad, MT.

Table 28. Off-station spring barley variety trial located in the Choteau area.
Western Triangle Ag. Research Center. 2012.

Variety	Yield bu/a	Test Wt lb/bu	Plump %	Thin %	Protein %	Plant Ht (in)
MT070158	55.4	46.8	84.2	6.3	14.1	25.0
Eslick	53.4	48.2	58.3	17.5	15.8	19.3
MT070159	52.6	46.0	79.3	9.5	15.5	21.7
Champion	51.7	50.2	76.3	7.5	12.4	25.3
Geraldine	50.3	49.6	71.6	14.0	14.4	20.0
Conrad	50.2	47.8	74.4	12.8	15.7	20.7
MT010160	48.0	47.9	75.9	10.0	14.5	23.7
Haxby	47.7	50.4	63.8	14.5	13.3	21.3
MT080279	47.5	46.8	80.7	8.3	15.0	23.3
Harrington	47.0	46.8	77.6	9.4	14.1	22.3
Amsterdam	46.3	47.1	76.5	10.8	14.6	23.7
Hockett	44.9	47.8	74.6	10.8	14.1	21.3
Metcalf	44.3	47.7	82.8	6.3	13.9	23.7
Tradition	40.2	45.2	69.4	12.6	14.8	27.7
Gallatin	39.8	49.0	73.3	12.7	13.8	24.0
CDC Cowboy	38.1	49.3	88.1	4.8	13.5	30.3
Means	47.3	47.9	75.4	10.5	14.3	23.3
LSD (.05)	8.9	1.4	8.0	4.9	-	3.5
C.V.	11.3	1.8	6.4	27.9	-	9.0
P-Value (0.05)	0.0119	<0.0000	<0.0000	0.0005	-	<0.0000

Cooperator and Location: Inbody Farms , Teton county.
Planted April 21, 2012 on chem-fallow.   Harvested August 17, 2012.
Fertilizer, actual lbs/a: 22-22-20. 11-52-0 Placed with seed while planting. Topdressed with 10-0-20 while planting.
Herbicide: None
Precipitation: N/A, rain gauge cracked

Table 29. Off-station spring barley variety trial located in the Devon area.
Toole County. Western Triangle Ag. Research Center. 2012.

Variety	Yield bu/a	Test Wt lb/bu	Plump %	Thin %	Protein	Plant Ht (in)
Champion	67.0	50.6	73.2	5.9	10.2	25.7
MT070158	62.4	48.0	77.3	3.0	10.2	25.0
MT070159	61.3	47.6	84.2	3.8	10.3	23.7
Conrad	61.2	48.5	87.3	4.1	10.4	25.3
Eslick	61.0	49.6	74.8	7.6	9.5	22.0
Tradition	60.4	47.0	78.3	5.0	10.7	29.0
Geraldine	59.3	47.7	54.1	16.9	10.4	23.0
MT010160	59.2	47.7	76.1	6.9	10.2	25.3
MT080279	58.4	47.1	78.3	6.4	9.8	24.7
Haxby	57.1	48.9	74.7	6.9	9.7	24.0
Hockett	57.0	48.0	79.0	6.1	9.7	25.0
Harrington	56.4	46.2	78.8	7.5	10.8	25.0
Metcalf	54.1	46.7	81.3	5.4	10.9	26.3
Gallatin	53.8	47.6	67.5	10.9	10.8	26.3
CDC Cowboy	50.0	48.9	88.9	3.5	11.5	33.3
Amsterdam	44.8	46.4	90.4	3.0	12.1	25.3
Means	57.7	47.9	77.8	6.4	10.5	25.6
LSD (.05)	8.5	2.7	13.4	5.7	-	2.6
C.V. %	8.8	3.3	12.6	52.7	-	6.2
P-Value (0.05)	0.0033	0.1297	0.0219	0.0036	-	<0.0000

Cooperator and Location: Brian Aklestad, eastern Toole county.
Planted April 19 ,2012 on chem-fallow. Harvested August 7, 2012.
Fertilizer, actual lbs/a: 22-22-20. 11-52-0 placed with seed while planting. Topdressed with 10-0-20 while planting.
Herbicide: None
Precipitation from April 19, 2012 until rain gauge was stolen was: 5.5 inches.

Table 30. 3-year means, dryland Barley varieties, Devon . 2010- 2012.

Variety	3-Year means					
	Yield bu/a	Test Wt lb/bu	Plump %	Thin %	Protein %	Height in.
Conrad	61.3	48.7	88.2	3.9	10.0	24.7
Tradition	59.1	48.1	83.5	5.3	10.1	28.4
Geraldine	58.9	48.9	69.0	13.3	9.7	23.5
Haxby	58.7	51.1	80.5	6.3	9.4	24.9
Harrington	58.3	47.9	85.9	5.1	9.7	24.2
Gallatin	57.3	48.8	78.5	7.9	9.8	26.7
Metcalfe	56.2	48.4	85.8	4.7	9.8	26.2
Hockett	53.5	48.7	81.4	7.1	9.6	25.7
Mean	57.9	48.9	81.5	6.7	9.7	25.5

Table 31. Off-station spring barley variety trial located in the Knees area. Chouteau County. Western Triangle Ag. Research Center. 2012.

Variety	Yield bu/a	Test Wt lb/bu	Plump %	Thin %	Protein %	Plant Ht (in)
Champion	77.6	51.6	76.4	4.9	9.9	31.0
MT080279	75.3	49.3	81.7	4.8	10.2	26.0
Harrington	70.9	49.4	88.7	3.3	10.6	30.0
Geraldine	70.2	50.1	66.2	13.2	10.3	26.3
MT070158	69.4	48.6	86.4	4.1	11.6	26.7
Eslick	69.3	50.2	65.6	11.2	9.9	25.3
MT070159	69.2	49.3	84.3	3.8	10.3	27.0
Haxby	68.9	52.4	72.5	7.5	10.4	28.7
Metcalf	67.8	49.5	87.9	3.6	10.6	31.3
MT010160	66.2	50.5	84.3	4.3	10.3	30.3
Hockett	65.9	49.7	81.1	6.5	10.6	29.3
Conrad	65.9	48.7	77.8	7.5	11.4	27.3
Gallatin	65.1	51.5	87.1	3.7	10.2	31.0
CDC Cowboy	61.1	50.0	91.8	2.8	12.3	38.3
Tradition	59.9	48.1	79.1	3.6	10.6	33.3
Amsterdam	58.2	49.8	86.1	3.1	13.0	26.7
Mean	67.5	49.9	81.1	5.5	10.8	29.9
LSD (.05)	5.6	1.1	12.2	4.8	-	1.1
C.V.	4.9	1.4	9.0	52.4	-	1.4
P-Value (0.05)	<0.0001	<0.0001	0.0022	0.0029	-	<0.0001

Cooperator and Location: Aaron Killion, western Chouteau county.
Planted April 22, 2012 on chem-fallow. Harvested August 1, 2012.
Fertilizer, actual lbs/a: 22-22-20. 11-52-0 placed with seed while planting. Topdressed with 10-0-20 while planting.
Herbicide: Preplant sprayed with 20 oz/a with Roundup WeatherMax® on April 22, 2012
Precipitation: N/A cracked rain guage

Table 32. 4-year means, dryland Barley varieties, Knees, MT, 2009 - 2012.

Variety	4-Year Means					
	Yield bu/a	Test Wt lb/bu	Plump %	Thin %	Protein %	Height in.
Conrad	73.0	50.1	83.6	5.9	13.2	26.7
Haxby	72.8	52.7	81.8	5.4	12.4	27.4
Harrington	72.1	50.1	87.9	4.5	12.5	28.0
Geraldine	71.8	50.2	68.7	14.1	12.7	25.2
Gallatin	67.6	51.3	85.2	5.5	12.3	28.5
Metcalfe	67.4	50.2	86.8	4.6	12.7	29.2
Hockett	67.0	50.3	85.8	5.8	12.3	27.7
Mean	70.3	50.7	82.8	6.5	12.6	27.8

Table 33. Soil test values for off station plots, 2012.

Location	N (lbs/a)[1]	Olsen-P (ppm)	K (ppm)	pH	OM (%)	EC (mmhos/cm)
Cut Bank	68.5	18	428	7.3	3.0	0.4
Devon	44	17	343	7.1	1.1	0.16
Knees	43.5	18	475	7.9	3.1	0.56
Choteau	134	12	515	8.2	2.9	0.59
WTARC	44	23	423	7.1	2.9	1.08

[1]Nitrogen soil samples were to a depth of four feet in one foot increments. All other soil tests were for zero to six inches in depth.
WTARC- Western Triangle Ag. Research Center

Spring Lentil, Pea and Chickpea Variety Evaluation.

Project Coordinators: Chengci Chen and Johnna Heser, MSU/MAES, Central Ag. Research Center, Moccasin, MT.

Personnel: John Miller and Gadi V.P. Reddy, MSU/MAES, Western Triangle Ag. Research Center, Conrad, MT.

Spring pea, lentil, and chickpea were grown on no-till chemical fallow at Western Triangle Ag. Research Center. While spring pea and lentils were grown on no-till chemical fallow north of Devon and north of Joplin. Data are summarized in Tables 34 thru 40.

The 2012 growing season at WTARC began with temperatures a bit warmer than normal; there was a less precipitation than the 27 year average, this trend continued throughout the growing season.

Results: Lentil data are summarized in Tables 34 thru 36. The lentil nursery grown at WTARC yielded between 1120 and 1823 lbs/acre (Table 34). With the small green Essex lentil yielding the best followed by the medium green CDC Richlea lentil. The lentils grew to an average mature canopy height of 29 cm (11.4 inches), with an average yield of 1496 lbs/acre.

The lentil variety trial north of Devon yielded between 417 and 1254 lbs/acre (Table 35). The medium green lentil LC01602300R was the highest yielder, followed by the small green lentil Essex. The lentil trial yielded an average of 685 lbs/acre, with a mature canopy height of 28 cm (11.0 inches).

North of Joplin the lentil variety nursery yielded between 1479 and 2421 lbs/acre (Table 36). Leading the yield was the medium green lentil LC016002300R, followed by the large green lentil Riveland. The average yield north of Joplin was 2077 lbs/acre with an average mature canopy height of 33 cm (13.0 inches).

Pea data are summarized in Tables 37 thru 39. The pea variety trial grown at WTARC yielded between 2002 and 3251 lbs/acre with an average mature canopy height of 71 cm (28.0 inches). The highest yielding yellow pea was Pro 793 with Pro 083-7406 yielding slightly less. The green pea with the highest yield was Stirling with Pro 091-7137 slightly less.

North of Devon the pea nursery yielded between 1306 and 2077 lbs/acre (Table 38). The trial mean for pea was 1664 lbs/acre with an average mature canopy height of 60 cm (23.6 inches). Delta, Bridger, and Montech 4152 were the highest yielding yellow pea while Stirling, Arcadia, and K2 were the best yielding green pea.

The pea variety trial north of Joplin yielded between 1202 and 2017 lbs/acre (Table 39). The mean yield was 1570 lbs/acre, with an average mature plant height of 63 cm (24.8 inches). The two highest yielding yellow pea were SW Midas and Montech 4152, with the two highest yielding green pea was Arcadia and Stirling.

Chickpea data are summarized in Table 40. The chickpea nursery was grown at WTARC and averaged between 1311 and 2103 lbs/acre (Table 40). The highest yielding variety was CDC Frontier with CDC Orion yielding the second highest.

A similar project will be proposed for FY 2014. The continuation of on and off-station variety trials help to elucidate researchers and farmers which varieties are better suited for that particular region in Montana.

Table 34. Statewide Lentil Variety Evaluation. Western Triangle Ag. Research Center. 2012.

Variety	Lentil Color and size	Yield (lbs/a)	Mature Canopy Height (cm)	Test Weight (lbs/bu)	1000 Kernel Weight (g)	Flower Date (Julian)
Essex	sg	1823	29	62.5	43.3	178.5
Eston	sg	1674	30	62.1	30.5	179.5
CDC Richlea	mg	1800	32	61.2	47.5	178.3
LC01602300R	mg	1696	31	61.9	47.3	177.3
Brewer	mg	1120	25	49.4	50.0	177.3
CDC Greenland	lg	1654	32	60.1	62.0	178.3
Riveland	lg	1464	35	59.1	67.5	177.0
Merrit	lg	1243	28	58.8	58.5	177.3
Crimson	sr	1543	23	62.6	31.3	178.3
Morena	sb	1358	30	63.7	36.3	178.3
CDC Redberry	sr	1338	29	62.3	38.8	178.3
CDC Impact	sr	1246	21	63.5	31.3	180.8
Means		1496	29	60.6	45.33	178.2
P-Value		0.1488	<0.0001	0.1533	<0.0001	<0.0001
$LSD_{0.05}$ (by t)		NS	3.63	NS	1.73	0.95
CV% (s/means)		25.11	8.84	10.21	2.66	0.37

Seeding Date: April 11, 2012.
Harvest Date: August 11, 2012.
Fertilizer (actual): 11-22-20. 11-22-0 was applied with the seed with 0-0-52 being broadcast while planting.
Precipitation: 7.13 inches.
Sprayed with Prowl H_2O @ 32 oz/a on March 30, 2012.
Lentil color: Small Green = sg; Medium Green = mg; Large Green = lg; Small Red = sr; Spanish Brown (Pardina) = sb Western Triangle Ag. Research Center, Conrad, MT.

Table 35. Statewide Lentil Variety Evaluation. North of Devon, Liberty County. Western Triangle Ag. Research Center. 2012.

Variety	Lentil Color and Size	Yield (lbs/a)	Test Weight (lb/bu)	Mature Canopy Height (cm)	1000 Kernel Weight (g)	Flowering Date (Julian)
Essex	sg	970	62.9	29	39.8	178.5
Eston	sg	881	63.6	29	32.0	179.5
LC01602300R	mg	1254	59.8	30	48.3	177.3
CDC Richlea	mg	551	58.7	30	52.0	178.3
Brewer	mg	508	56.6	29	52.7	177.3
CDC Greenland	lg	577	59.5	30	62.3	178.3
Riveland	lg	536	58.6	28	65.3	177.0
Merrit	lg	528	56.0	28	59.0	177.3
Crimson	sr	722	63.1	24	32.0	178.3
Morena	sb	843	62.9	28	35.0	178.3
CDC Impact CL	sr	867	62.5	27	34.7	180.8
CDC Redberry	sr	417	61.5	28	42.0	178.3
Means		685	60.0	28	46.67	178.2
P-Value		0.4163	0.0002	0.5844	<0.0001	0.0000
$LSD_{0.05}$ (by t)		NS	2.81	NS	2.45	0.95
CV% (s/means)		55.41	2.77	13.54	3.11	0.37

Cooperator: , Devon, MT.
Seeding Date: April 19, 2012.
Harvest Date: August 7, 2011.
Fertilizer (actual): 11-22-20. 11-22-0 was applied with the seed with 0-0-52 being broadcast while planting.
Precipitation: 5.5 inches then rain gauge stolen
Lentil color: Small Green = sg; Medium Green = mg; Large Green = lg; Small Red = sr; Spanish Brown (Pardina) = sb
Western Triangle Ag. Research Center, Conrad, MT.

Table 36. Statewide Lentil Variety Evaluation. North of Joplin, Liberty County.
Western Triangle Ag. Research Center. 2012.

Variety	Lentil Color and Size	Yield (lbs/a)	Test Weight (lbs/bu)	Mature Canopy Height (cm)	1000 Kernel Weight (g)	Flowering Date (Julian)
Essex	sg	1823	62.0	32	44.2	178.5
Eston	sg	1674	63.3	34	33.1	179.5
LC01602300R	mg	2421	61.8	35	51.1	177.3
Brewer	mg	2027	60.2	33	55.9	177.3
CDC Richlea	mg	1919	60.9	37	52.0	178.3
Riveland	lg	2303	58.9	38	72.4	177.0
CDC Greenland	lg	2284	59.5	34	65.8	178.3
Merrit	lg	2127	59.7	30	61.5	177.3
Crimson	sr	1479	62.7	28	33.0	178.3
Morena	sb	2257	64.1	31	38.1	178.3
CDC Redberry	sr	1717	62.7	33	41.8	178.3
CDC Impact	sr	1685	63.3	31	34.8	180.8
Means		2077	61.6	33	46.6	178.2
P-Value		0.1104	<0.0001	0.0467	<0.0001	<0.0001
$LSD_{0.05}$ (by t)		NS	0.49	5.26	2.71	0.95
CV% (s/means)		19.85	0.47	9.49	3.31	0.37

Cooperator: Moog Farms, Joplin, MT.
Seeding Date: April 25, 2012.
Harvest Date: August 8, 2012.
Fertilizer (actual): 11-22-20. 11-22-0 was applied with the seed with 0-0-52 being broadcast while planting.
Precipitation: 7.1 inches
Sprayed with Prowl H2O @ 30oz/a on April 19, 2012 .
Lentil color: Small Green = sg; Medium Green = mg; Large Green = lg; Small Red = sr; Spanish Brown (Pardina) = sb
Western Triangle Ag. Research Center, Conrad, MT.

Table 37. Statewide Dry Pea Variety Evaluation. Western Triangle Ag. Research Center. 2012.

Variety	Pea Color	Yield (lbs/a)	Test Weight (lbs/bu)	Plant Height (cm)	1000 Kernel Weight (g)	Flower Date (Julian)
Pro 793	Y	3251	66.0	73	271	172.8
Pro 083-7406	Y	3209	65.9	64	209	178.0
Montech 4152	Y	3116	67.1	79	253	174.0
Bridger	Y	2793	65.8	74	222	174.8
AC Agassiz	Y	2746	65.8	75	227	178.0
SW Midas	Y	2674	65.1	67	214	176.3
Pro 127-2	Y	2656	66.4	67	235	175.8
Pro 822	Y	2598	65.3	74	252	173.5
Delta	Y	2526	65.8	66	247	175.3
Spider	Y	2426	67.1	79	245	177.5
DS Admiral	Y	2204	65.0	77	237	176.8
Stirling	G	2746	649	67	211	173.0
Pro 091-7137	G	2639	65.4	70	204	175.0
Pro 7040	G	2549	65.7	69	202	174.5
Banner	G	2497	65.8	72	210	173.5
Aragorn	G	2465	64.1	76	225	174.0
Majoret	G	2407	65.9	66	215	177.5
Arcadia	G	2281	64.6	58	199	175.8
CDC Striker	G	2254	659	68	233	176.5
K2	G	2246	65.2	71	203	175.8
Pro 081-7116	G	2237	64.5	72	223	173.5
Cruiser	G	2002	64.4	71	209	175.0
Trial Means		2569	65.53	71	224	175.3
P-Value		0.7368	<0.0001	0.8308	<0.0001	0.0000
$LSD_{0.05}$ (by t)		NS	0.91	NS	14.71	1.01
CV% (s/means)		28.77	0.98	17.43	4.64	0.41

Seeding Date: April 11, 2012.
Harvest Date: July 30, 2012.
Precipitation: 5.81 inches.
Fertilizer (actual): 11-22-20. 11-22-0 was applied with the seed with 0-0-52 being broadcast while planting.
Sprayed with Prowl H_2O @ 32 oz/a on March 30, 2012.
Western Triangle Ag. Research Center, Conrad, MT.

Table 38. Statewide Dry Pea Variety Evaluation. North of Devon, eastern Toole County, MT. Western Triangle Ag. Research Center, Conrad, MT. 2012.

Variety	Pea Color	Yield (lbs/a)	Test Weight (lb/bu)	Mature Canopy Height (cm)	1000 Kernel Weight (g)	Flower Date (Julian)
Delta	Y	2077	66.1	56	172	175.3
Bridger	Y	1768	65.5	63	205	174.8
Montech 4152	Y	1753	65.9	61	230	174.0
DS Admiral	Y	1573	64.4	67	190	176.8
Spider	Y	1463	65.7	64	186	177.5
SW Midas	Y	1453	64.6	57	192	176.3
Stirling	G	1976	64.4	57	183	173.0
Arcadia	G	1933	64.1	55	174	175.8
K2	G	1706	65.0	64	201	175.8
Majoret	G	1603	65.2	58	198	177.5
Cruiser	G	1355	63.8	62	191	175.0
CDC Striker	G	1306	64.9	62	208	176.5
Trial Means		1664	64.91	60	194	175.3
P-Value		0.0047	0.0076	0.2104	0.4416	<0.0001
$LSD_{0.05}$ (by t)		386	1.12	NS	NS	1.01
CV% (s/means)		13.78	1.03	8.91	13.80	0.41

Cooperator: Devon, MT.
Seeding Date: April 19, 2012.
Harvest Date: July 26, 2012.
Fertilizer (actual): 11-22-0. 11-22-0 was applied with the seed with 0-0-52 being broadcast while planting.
Precipitation: 5.5 inches then rain gauge stolen
Western Triangle Ag. Research Center, Conrad, MT.

Table 39. Statewide Dry Pea Variety Evaluation. North of Joplin, Liberty County, MT. Western Triangle Ag. Research Center, Conrad, MT. 2012.

Variety	Pea Color	Yield (lbs/a)	Test Weight	Mature Canopy Height (cm)	1000 Kernel Weight (g)	Flower Date (Julian)
SW Midas	Y	1702	64.3	58	200	176.3
Montech 4152	Y	1679	63.7	72	256	174.0
Delta	Y	1454	65.1	56	232	175.3
Bridger	Y	1387	64.7	63	216	174.8
DS Admiral	Y	1299	63.4	73	240	176.8
Spider	Y	1202	63.5	70	238	177.5
Arcadia	G	2017	65.9	60	200	175.8
Stirling	G	1854	64.5	52	207	173.0
Majoret	G	1688	64.6	64	220	177.5
CDC Striker	G	1517	64.6	69	230	176.5
Cruiser	G	1588	64.3	62	204	175.0
K2	G	1457	63.8	59	211	175.8
Trial Means		1570	64.31	63	221	175.3
P-Value		0.3395	0.2796	0.0002	<0.0001	<0.0001
$LSD_{0.05}$ (by t)		NS	NS	7.88	14.87	1.01
CV% (s/means)		23.45	1.76	7.40	3.99	0.41

Cooperator: Moog Farms. Joplin, MT.
Seeding Date: April 19, 2012.
Harvest Date: August 8, 2012.
Fertilizer (actual): 11-22-20. 11-22-0 was applied with the seed with 0-0-52 being broadcast while planting.
Sprayed on 4/19/2012 with Prowl H2O 30 oz/a.
Precipitation: 7.1 inches
Western Triangle Ag. Research Center, Conrad, MT.

Table 41. Statewide Chickpea Variety Evaluation. Western Triangle Ag. Research Center, Conrad, MT. 2012.

Variety	Yield (lbs/a)	Test Weight (lb/bu)	1000 Kernel Weight (g)	Flower date (Julian)
CDC Frontier	2103	62.2	361.3	179.0
CDC Orion	2090	62.0	447.3	178.0
CDC Alma	1946	63.3	389.5	178.3
Myles	1626	58.6	188.7	180.0
Sawyer	1493	62.2	439.3	178.3
Sierra	1311	62.1	495.7	179.7
Means	1750	61.6	386.82	178.9
P-Value	0.0521	<0.0001	<0.0001	NS
$LSD_{0.05}$ (by t)	575	0.76	43.50	1.4
CV% (s/means)	18.28	.06	4.97	0.43

Seeding Date: April 11, 2012.
Harvest Date: August 28, 2012.
Fertilizer (actual): 11-22-20. 11-22-0 was applied with the seed with 0-0-52 being broadcast while planting.
Precipitation: 5.81 inches.
Sprayed with Prowl H_2O @ 30 oz/a on March 30, 2012.

1. COMPARISON OF FOLIAR APPLIED NITROGEN FERTILIZERS IN SPRING WHEAT

Principal Investigators and Cooperators:

Dr. Olga Walsh, Assistant Professor, WTARC, Conrad, MT
Robin Christiaens, Research Associate, WTARC, Conrad, MT
Dr. Mal Westcott, Professor and Supt., WARC, Corvallis, MT
Jack Patton, Producer, Choteau County, MT

Objectives:

- To compare the efficacy of foliar N fertilizers (UAN, liquid urea, and High NRG-N) applied to spring wheat
- To determine the optimum N rate and dilution ratio of foliar fertilizers and the threshold at which spring wheat grain yield is reduced due to leaf burn

Materials and Methods:

This study has been funded by Montana Fertilizer Advisory Committee and initiated in spring of 2012. The results of first year of study are summarized in this report. Three experiments were established: two dryland - at WTARC (near Conrad, MT) and in a cooperating producer's field (Jack Patton, Choteau County, MT), and one irrigated – at WARC (near Corvallis, MT) using Choteau spring wheat. Prior to establishment, composite soil samples were collected, processed and analyzed for soil texture, and all major and minor essential plant nutrients. Soil test results were used to determine preplant fertilizer application rates for all nutrients except N. Appropriate weed and pest management control were employed when necessary. Due to equipment and labor constraints, the originally proposed treatment structure (Table 1) has been modified to make the experiment more manageable. The modified treatment structure employed at each location is reported in Table 2. The first major difference between the originally proposed and the modified treatment structures was that one fertilizer N rate of 80 lb N ac^{-1} was applied at planting to all treatments except for the unfertilized check plot. Having two different preplant rates was not crucial to achieving the objectives of this study, which are focusing on the effects of topdress application. Also, one topdress N fertilizer rate was applied instead of originally proposed two rates. Again, the objectives are aimed to determine the potential effect of wheat canopy damage due to burn associated with application of three foliar products at different fertilizer-to-water ratios - not the effect on topdress N rate - on spring wheat grain yield. Three product-to fertilizer ratios were used instead of proposed four; this dramatically improved the efficiency of foliar product application and helped to prevent the excessive soil compaction and crop damage by driving through the plots numerous times. As suggested by the Montana Fertilizer Tax Advisory Committee, at Feekes 5 growth stage, 40 lb N ac^{-1} was foliar applied utilizing an all-terrain vehicle (ATV)-mounted stream-bar equipped sprayer (Figures 1 and 2). Three foliar N sources – urea ammonium nitrate (UAN), liquid urea (LU), and high NRG-N (HNRGN) and three dilution ratios of fertilizer%/water% - 100/0, 66/33, and 33/66 - were evaluated.

Project Results and Relevancy to Montana:

Spring wheat grain yield results are reported in Table 2. The samples are currently analyzed for grain protein content. The highest yields were obtained at WTARC, where the unfertilized check plot yielded 4795 lb ac^{-1}, and Treatment 10 (100% LU to 0% water ratio) was highest-yielding (5757 lb ac^{-1}). At Patton, the unfertilized check plot yielded 2256 lb ac^{-1}, and Treatment 4 (33% UAN to 66% water ratio) yielded 1863 lb ac^{-1}. At the irrigated site – WARC –the check plot's yield was 5022 lb ac^{-1} and the highest yield of 5728 lb ac^{-1} obtained with Treatment 8 (100% HNRGN to 0% water ratio). At WARC, the unfertilized check plot was not the lowest yielding treatment; Treatments 5, 6, and 7 (all the LU treatments) yielded notably lower compared to any other treatments - between 4825 and 4949 lb ac^{-1}).

When undiluted N products were used (100% product to 0% water ratio), the highest grain yields were obtained with HNRGN at all 3 sites (Table 2, Figure 3). These results support the product manufacturer's claim that HNRGN is less corrosive to plant tissues compared to other liquid products, including UAN, due to its lower free ammonia content and reduced salt index. The higher yield could also be the result of HNRG's formulation which, according to manufacturer, has been developed to minimize N loss and increase its' plant uptake.

At the ratio of 66% product to 33% water, both HNRGN and LU performed better than UAN at dryland sites. This also supports the suggestions that both HNRGN and LU are less corrosive and that damage incurred due to foliar application of these products should be lower compared to UAN. At the irrigated site – WTARC, however, grain yields were lower with LU, compared to when UAN and HNRGN were used (Table 2, Figure 4).

Similarly, when the solutions were most diluted (ratio of 33% product to 66% water), at the irrigated site, LU resulted in lower grain yields compared to UAN and HNRGN. On the other hand, at both of the dryland sites grain yields increased significantly depending on product used as: UAN<LU<HNRGN (Table 2, Figure 5).

It is important to note that these are results from just one year of study. It is difficult to hypothesize why LU performed worse at the irrigated site compared to other products, and especially compared to UAN. If this trend continued in the next growing season, it will be reasonable to suggest that different products should be recommended for dryland and for irrigated wheat production systems. Overall, due to LU and HNRGN's lower corrosiveness compared to UAN, even when applied undiluted, LU and HNRGN may be a better choice among the three foliar products evaluated. The cost of HNRGN at the time of application was approximately 25% higher than cost of LU, and almost 30% higher than cost of UAN.

Multiple foliar N fertilizer products are currently marketed as more efficient, advantageous N sources. Proposed benefits of foliar N products include increased N use efficiency (NUE), higher yields and, and savings in money, labor and time to wheat producers. This study aims to determine if any of the three evaluated foliar N fertilizers – UAN, LU, and HNRGN – have any advantage such as grain yield increase, enhanced protein content, increased NUE, or minimized leaf burn when applied to spring wheat crop canopy midseason. This will allow us to make improved recommendations regarding the efficacy of foliar fertilization in spring wheat in Montana. It is expected that this study will be continued for two more growing seasons at three locations to further access foliar N cost-effectiveness and effects on spring wheat grain yield and protein content.

2. EVALUATION OF SENSOR-BASED TECHNOLOGIES AND NITROGEN SOURCES FOR IMPROVED RECOMMENDATIONS FOR DRYLAND AND IRRIGATED SPRING WHEAT PRODUCTION IN MONTANA

Principal Investigators and Cooperators:

Dr. Olga Walsh, Assistant Professor, WTARC, Conrad, MT
Robin Christiaens, Research Associate, WTARC, Conrad, MT
Dr. Mal Westcott, Professor and Supt., WARC, Corvallis, MT
Lindsey Martin, Producer, Pendroy, Teton County, MT

Objectives:

1. To evaluate two sensors (GreenSeeker, and Pocket Sensor) for developing normalized difference vegetative index (NDVI)-based topdress fertilizer nitrogen (N) recommendations in spring wheat in Montana.
2. To determine whether sensor-based recommendations have to be adjusted depending on what N fertilizer source (liquid urea ammonium nitrate (UAN), or granular urea) is used.

Materials and Methods:

This project was originally established in the spring of 2011. In 2012, this study was repeated at three experimental locations: two dryland sites - at WTARC near Conrad, MT and in cooperating producer's field (Lindsey Martin, Pendroy, Teton County) and one irrigated site at WARC, near Corvallis, MT, using the spring wheat variety Choteau. Sites where N is known to have been liberally applied over the years were avoided. Prior to establishment, composite soil samples were collected, processed and analyzed for soil texture, and all major and minor essential plant nutrients. Appropriate weed and pest management control were employed when necessary.

Treatment structure is reported in Table 3. Four preplant N rates - 20, 40, 60, and 80 lb N ac^{-1} were applied as broadcasted urea. Treatment 1 was established as an unfertilized check plot. Treatment 2 received 220 lb N ac^{-1} preplant as urea and served as a non-limiting N-rich reference. Each treatment was replicated 4 times. The plot size was 5'x 25'. Wheat crop reflectance measurements (NDVI) from each plot were collected at Feekes 5 growth stage. Feekes 5 - early jointing (beginning of stem elongation, prior to first visible node) - has been identified in a course of multiple field studies as the most appropriate sensing time for wheat because it provides reliable prediction of both N uptake and biomass. The GreenSeeker (model 505) and Pocket Sensor were used to collect the NDVI measurements. According to treatment structure, topdress N fertilizer was applied as urea (as dry prills, manually broadcasted) or as UAN (as a foliar spray, using a battery operated backpack sprayer with a fan nozzle). Topdress N recommendations for Treatments 2-10 were made using algorithms experimentally developed specifically for spring wheat: 1. Spring Wheat (Canada), 2. Spring Wheat (US, Canada, Mexico), and 3. Generalized Algorithm. (available at: http://www.soiltesting.okstate.edu/SBNRC/SBNRC.php). Grain yield and protein content data were analyzed to determine whether there were statistically significant differences depending what sensor was used to make fertilizer N recommendations.

Project Results and Relevancy to Montana:

Spring wheat grain yield results are summarized in this report; spring wheat grain samples are currently being analyzed for protein content.

Spring wheat grain yields for WTARC, WARC, and Martin obtained in 2012, as well as grain yields for WTARC and WARC for 2011, are reported in Table 4. Overall, grain yields were significantly higher in 2012 compared to those in the first year of this study. Spring wheat grain yields varied substantially from one site-year to the other. The lowest grain yield was observed at WTARC in 2011 (unfertilized check plot) and the highest – at WARC in 2012 (treatment 10) (Table 4). In 2012, WARC (irrigated site) was the highest yielding site with the average yield of 5290 lb ac^{-1} compared to 4893 and 1978 lb ac^{-1} at WTARC and Martin, respectively (dryland sites). The notable difference between the two dryland sites could be explained by the large amount (74 lb N ac^{-1}) of residual soil N at WTARC compared to only 24 lb N ac^{-1} at Martin. There was a strong relationship observed between NDVI values obtained with GreenSeeker and with Pocket Sensor (Figures 6 and 7). Understandably, the relationship was improved dramatically when mean NDVI values averaged by treatment were used (R^2 = 91 vs R^2 = 50), (Figures 6 and 7). This emphasizes the importance of replication when taking the canopy reflectance readings because it helps to account for spatial variability present within a field.

Strong linear relationship was observed between GreenSeeker NDVI values obtained at Feekes 5 growth stage and spring wheat grain yields at 4 of 5 site-years evaluated in the 2011 and 2012 growing seasons (Figure 8). GreenSeeker NDVI values were able to predict 75 to 97 percent of variation in spring wheat grain yields. Lower correlation was observed in 2012 at WTARC (R^2 = 0.39). Notably, at WARC in 2012, 80% of variation in mean spring wheat grain yields was explained by variation in NDVI; however, unexpectedly, the observed trend was: the higher NDVI, the lower the yield. This might be one of the situations Labus et al. (2002) referred to by noting that "early season NDVI parameters were not consistent indicators of wheat yields". In the extensive study carried out in Montana, they found that the strength of NDVI-yield relationships was highly dependent on site-specific and region-specific characteristics. What is important to remember, is that crop reflectance measurements aim not to predict yield, but accurately estimate yield potential. However, overall, GreenSeeker NDVI was able to predict 91 % of variation in spring wheat grain yields across site-years (R^2 = 0.91) (Figure 9).

Robust linear relationship was also evident between Pocket Sensor NDVI and spring wheat grain yields at 3 of 5 site-years in 2011 and 2012, where spring wheat grain yield was predicted midseason with 83 to 92 % accuracy (Figure 10). As with GreenSeeker NDVI, Pocket Sensor NDVI relationships with grain yield were weaker at WTARC and WARC in 2012. Nevertheless, when averaged across site-years, Pocket Sensor NDVI values collected at Feekes 5 growth stage were able to predict 96 % of variation in spring wheat grain yields (Figure 11).

Notable response to preplant fertilizer N was apparent at all 5 site-years evaluated (Table 3). Grain yields increased incrementally at all site-years from Treatment 3 through Treatment 6, as well as from Treatment 7 through Treatment 10. For example, at WARC in 2011, as urea fertilizer rate applied at planting increased from 20 to 40, 40 to 60, and from 60 to 80 lb N ac^{-1}, grain yields increased as follows: $2488<3061<3453<3558$ for Treatments 3, 4, 5, and 6 respectively (Table 3). Similarly, at WTARC in 2012, as UAN fertilizer rate applied at planting increased from 20 to 40, 40 to 60, and from 60 to 80 lb N ac^{-1}, grain yields increased as follows: $4824<4958\approx4951<5160$ for Treatments 7, 8, 9, and 10 respectively (Table 3). Also, as expected, strong polynomial relationships between the total amounts on N applied (preplant plus topdress) was observed at all 5 site-years (Figure 12). It is apparent that the highest topdress N rates prescribed did not result in increase in grain yield, but in most cases, caused yield reduction. At WTARC in 2012, sensor-based generated topdress N rate for Treatment 2 was 62 lb N ac^{-1}, and for Treatment 6 – 24 lb N ac^{-1}. These prescriptions resulted in total (preplant plus topdress) N rates of 282 and 104 lb N ac^{-1}, and the grain yields were 4433 and 5262 lb ac^{-1} for Treatments 2 and 6, respectively. Similar trends were observed at all site-years, except for WTARC in 2011, where prescribed topdress N rate of 18 lb N ac^{-1} optimized grain yield of Treatment 2 (Figure 12).

As in the first growing season, in 2012, Spring Wheat (Canada) Algorithm and Generalized Algorithm did not prescribe any topdress N fertilizer to be applied at any of the 3 experimental locations. The recommended application rates generated by the Sensor-Based Nitrogen Optimization Algorithm (USA/Canada/Mexico) ranged from of 0 lb N ac^{-1} at Martin in 2012 to 99 lb N ac^{-1} at WARC at 2012, depending on the NDVI values (Table 4).

As in the first growing season, the rates generated by the USA/Canada/Mexico Algorithm were not appropriate for grain yield optimization. For example, much higher rates were prescribed for the irrigated site (WARC) compared to those for dryland sites WTARC and Martin. This makes sense since the expected yield potential at the irrigated site was much greater. On the other hand, grain yields obtained at WTARC were just as high as at WARC, indicating that the yield potential was either underestimated at WTARC or overestimated at WARC. This puts forward a question of whether there need to be two separate algorithms developed for dryland spring wheat and for irrigated spring wheat production systems.

At Martin in 2012, a very strong relationship between NDVI and grain yield was observed - i.e. the sensors performed well in terms of identifying the differences in yield potential among the treatments. The topdress N rates prescribed at this site-year did not optimize yields. Topdress rates of 0 and 16 lb N ac^{-1} were generated for Treatments 2 and 3 respectively; Treatment 3 yielded significantly higher than Treatment 2, indicating that a higher N rate was needed to optimize yield for Treatment 2. On the other hand, Treatment 6 that received 80 lb N ac^{-1} at planting was prescribed the topdress rate of 17 lb N ac^{-1} and yielded the highest (2115 lb ac^{-1}) at that site-year. Considering the soil test N of 24 lb N ac^{-1} at Martin in 2012, it indicates that that a total of 121 lb N ac^{-1} should be enough to maximize grain yields. Treatment 2 was established as the N-rich treatment (220 lb N ac^{-1} applied at planting in the fall) that supposed to serve as a benchmark for other treatments in terms of N status. Out of 5 site-years, Treatment 2 outperformed other Treatments only once (at WTARC in 2011). It is possible that a significant N loss from all treatments, but especially from the highly-fertilized plots during the fall and winter could distort the perception of N rate applied vs yield. Up to 35% of applied urea was shown to volatilize in a period of 1 to 2 weeks, especially in a semi-arid, high pH environment of Montana (Engel, 2010, personal communication). Another very important pathway of significant N loss (up to 40% of total N applied) is immobilization of soil N; it is known to be especially prevalent in high-residue no-till cropping systems, such as one used in this study (Nielsen, 2006; McKenzie, 2010).

Consistently, there were no substantial differences in grain yields associated with topdress fertilizer N source (urea vs UAN) at any of 5 site-years. This indicated that topdress N fertilizer rates do not need to be adjusted based of fertilizer sources used, i.e. the same N rates should be prescribed whether urea or UAN is applied.

There is a need to develop a research program that would allow us to generate accurate, crop - specific and site - specific fertilizer rates that account for temporal and spatial variability (natural and acquired), improve fertilizer use efficiency, increase and make grain protein in wheat uniform, save time, money and labor for crop producers, increase crop yields, and maintain environmental integrity. Precision sensing technologies will allow us to establish state-of-the-art soil nutrient management field-oriented research program that will meet the needs of Montana producers.

So far, the obtained data indicate that 1. Both sensors perform well and are useful in predicting spring wheat grain yield potential mid-season; 2. Algorithms developed in other regions do not provide the topdress N rates appropriate for Montana spring wheat varieties and growing conditions.

It is expected that this study will continue for one more growing season at 3 experimental locations to expand database and to summarize results. Future studies are needed to pinpoint the rate of N loss due to volatilization and immobilization and other pathways in Montana wheat production systems for improved N recommendations.

3. EFFECT OF NITROGEN SOURCES, RATES, AND APPLICATION TIME ON SPRING WHEAT YIELD AND GRAIN PROTEIN

Principal Investigators and Cooperators:

Dr. Olga Walsh, Assistant Professor, WTARC, Conrad, MT
Robin Christiaens, Research Associate, WTARC, Conrad, MT
Jack Patton, Producer, Knees, Chouteau County, MT
Lindsey Martin, Producer, Pendroy, Teton County, MT

Objective:

1. To determine the most efficient nitrogen (N) fertilizer source, rate, and application time combination for optimizing Montana spring wheat yield while maximizing grain protein.

Materials and Methods:

Three dryland experiments were established: one at WTARC and two in cooperating producers' fields (Jack Patton, Knees, Chouteau County, and Lindsey Martin, Teton County) using Choteau spring wheat variety. Sites where N is known to have been liberally applied over the years were avoided. Prior to establishment, composite soil samples were collected, processed and analyzed for soil texture, and all major and minor essential plant nutrients. Soil test results will be used to determine preplant fertilizer application rates for all nutrients except N. Appropriate weed and pest management control were employed when necessary. The plot size was 5'x 25' at each site. The treatment structure is reported in Table 5. A combination of 4 preplant N rates (0, 40, 80, and 120 lbs N ac^{-1}), 3 topdress N rates (0, 40, and 80 lb N ac^{-1}), 2 topdress N fertilizer sources (granual – urea, 46-0-0, and liquid – urea ammonium nitrate (UAN) , 28-0-0), and 2 topdress application times (before flowering and after flowering) were evaluated. Urea was manually broadcasted and UAN was applied as a foliar spray using backpack sprayers. Dates for foliar UAN application were determined by collecting 20 random wheat heads from each experimental area and examining them under a 10x hand lens to assess maturity. Each treatment was replicated 4 times at each location. Treatment effect (preplant N rate, topdress N source, rate, and application time) on spring wheat grain yield, and grain protein content were evaluated using statistical procedures.

1. Project Results and Relevancy to Montana:

Grain yield results are summarized in this report, grain subsamples have been sent to the lab for protein analysis and protein results will be reported at a later date.

Grain Yield

For easy comparison, grain yield results for both 2011 and 2012 growing seasons are reported in Table 6. Overall, the grain yields were significantly higher in 2012 compared to 2011. Grain yields of unfertilized check plots were 648 and 1319 lb ac^{-1} in 2011 at WTARC and Patton respectively, compared to grain yields of 4062, 2566, and 1723 lb ac^{-1} in 2012 at WTARC, Patton, and Martin respectively. In 2012, strong linear relationship between soil nitrate-N and spring wheat grain yields was observed at all sites. Ninety six percent of variation in spring wheat grain yields was explained by the variation in soil test nitrate-N content (Figure 13). High amount of residual N in the soil in 2012 - 74 lb N ac^{-1} compared to only 15 lb N ac^{-1} in 2011 - resulted in higher grain yields at WTARC site.

In most site-years evaluated, the rate of preplant N fertilizer rate affected spring wheat grain yields. For example, at WTARC in 2011 and 2012, and at Martin in 2012, preplant application of 80 lb N ac^{-1} resulted in significantly higher grain yields. On the other hand, increasing preplant N fertilizer rate to 120 lb N ac^{-1} did not further increase grain yields at most site-years, except for WTARC in 2012 (Table 6) (Figure 2).

There were no notable differences in spring wheat grain yields associated with topdress N fertilizer source (urea vs UAN) at any of the 5 site-years (Table 6). The plots that received topdress N as broadcasted urea yielded the same as those that were foliar sprayed with UAN solution. Also, the small amount of water (0.01 – 0.02 gal/plot) added to the UAN prior to spraying the plots had no obvious affect on grain yields.

Similarly, no substantial differences in grain yields associated with the time of topdress N fertilizer application (before flowering vs after flowering) were observed at any of the site-years (Table 6). Practically the same yields were achieved whether the topdress was applied prior to or after the anthesis.

Due to comparable prices of urea and UAN at the time of topdress application (urea cost of $0.15 per lb of N vs UAN cost of $0.16 per lb of N), and taking into an account the lack of response to topdress N fertilizer source, either source could have been recommended. However, overall, there was no response to topdress N fertilization at any application rate. This was the case at both growing seasons and at all locations; the same trend was observed both at highest- (WTARC in 2012) and the lowest-yielding site-years (WTARC in 2011) (Table 6). The lack of response to topdress N fertilizer in 2012 at WTARC could be due to the high residual soil N. On the other hand, at all other site-years, this could not have been the case.

Clearly, more research is needed to pinpoint the most productive and efficient way to managing N in wheat. Spring wheat is one of the major cereal crops grown in Montana. Wheat production represents almost 25% of Montana's agricultural revenue. There is a need to develop more efficient soil fertility and nutrient management strategies in order to maximize wheat grain yields and increase grain protein levels. It is expected that this project will be continued for one more year at 3 experimental sites.

4. A COMPARISON OF NITROGEN SOURCES FOR SPRING WHEAT PRODUCTION

Principal Investigators:
Dr. Mal Westcott, Professor and Supt., WARC, Corvallis, MT
Dr. Olga Walsh, Assistant Professor, WTARC, Conrad, MT
Robin Christiaens, Research Associate, WTARC, Conrad, MT
Brooke Bohannon, NWARC, Kalispell, MT

Objectives:

1. To evaluate environmentally smart nitrogen (ESN) as nitrogen (N) fertilizer source for spring wheat production in Montana in comparison to urea.
2. To evaluate nitrogen use efficiency and grain yield and protein response to these two fertilizer materials, alone and in combination.

Materials and Methods:

Field trials were conducted at three locations in Montana: an irrigated site at WARC and two dryland sites, one at NWARC and one at WTARC. Plots were arranged in a split-plot design with N source (urea, ESN, and a 50:50 blend of urea and ESN) x N fertilizer rate (0, 50, 100, and 150 lb N ac^{-1}) as the main plot factor and topdress (0 or 40 lb N ac^{-1}) as the subplot factor. Hard red spring wheat (cv. Choteau) was seeded into plots measuring 5' x 25'. At all locations, each plot was split into two subplots at Feekes 5 growth stage. One subplot received an additional 40 lb N ac^{-1} urea as a topdress, while the other plot received no topdress. The employed treatment structure is reported in Table 7. Also at this stage, crop canopy reflectance was measured in each plot using the GreenSeeker sensor at all locations and the Pocket Sensor at WARC and NWARC. The GreenSeeker optical sensor (model 505) developed by Oklahoma State University and later licensed to and commercialized by Trimble, and the Pocket Sensor, a more portable and significantly less costly normalized difference vegetative index (NDVI) sensor recently developed in the U.S. were used to evaluate wheat nutrient status mid-season. Sensor-based reflectance measurements will contribute to the volume of reflectance measurements data collection from field experiments initiated across Montana in 2011.

Following harvest, plot yields were determined and grain subsamples were sent for protein analysis. Grain yield data adjusted for moisture (12%) is reported in this report.

Project Results and Relevancy to Montana:

Grain Yield Results

Mean spring wheat grain yields by experimental location are reported in Table 7. Spring wheat responded to N fertilizer application - the lowest grain yields were observed at the unfertilized check plots at all three sites. High amount of residual N in the soil at WTARC (74 lb N ac^{-1}, compared to 50 lb N ac^{-1} - at WARC, and 47 lb N ac^{-1} - at NWARC) could have resulted in comparable yields at WTARC (dryland site) and WARC (irrigated site).

At WARC the highest grain yield was obtained with the application of ESN at 100 lb N ac^{-1} and no topdress. At WTARC, the best yielding treatment was 150 lb N ac^{-1} as ESN, followed by topdress of 40 lb N ac^{-1}. This was not expected since ESN is a slow-release fertilizer and it is not recommended for spring topdress application in wheat in Montana conditions because the ESN prills may not release sufficient N in time for the plants' high nutrient demand which may lead to nutrient deficiency and decreased yields (Middleton et al., 2004). On the other hand, at NWARC, the highest yield was achieved with 50 lb N ac^{-1} applied as urea at seeding plus 40 lb N ac^{-1} topdress. Thus, there was no trend in grain yields associated with N source at any of the sites. Also, there was no definite trend in grain yield associated with application of 40 lb N ac^{-1} topdress. For example, at WARC and NWARC, in 2012, Treatment 3 yielded 651 lb ac^{-1} and 391 lb ac^{-1} more than Treatment 2. On the other hand, at WTARC, there was a slight decrease in yield from Treatment 2 to Treatment 3 (Table 7). By-location analysis showed that grain yield was strongly correlated with preplant N rate at all three sites (Figure 15).

Application of 50 lb N ac^{-1} at seeding increase grain yield significantly compared to unfertilized check plot. Similarly, increasing preplant N rate from 50 to 100 lb N ac^{-1} resulted in significantly higher yields. On the other hand, increasing the preplant N rate from 100 to 150 lb N ac^{-1} did not further increase grain yield (Table 7, Figure 15).

GreenSeeker Sensor and Pocket Sensor results

The mean NDVI data obtained with the GreenSeeker (at WTARC, WARC, and NWARC) and the Pocket Sensor (at WARC and NWARC) by treatment are reported in Table 8. Very weak relationship between the GreenSeeker NDVI and spring wheat grain yield was observed at all three experimental sites in 2012 (Figure 16). Only 16 to 28% of the variation in grain yield was explained by the variation in NDVI values. This is a trend that is typically observed at locations where no apparent response to agronomic treatments is observed. Again, the results of pair wise analysis done utilizing orthogonal contrasts showed that there were no significant ($P<0.05$) differences in spring wheat grain yield associated with preplant N source and topdress N fertilizer rate in 2012.

A negative slope between the NDVI and grain yield observed at two of three locations - WTARC and WARC - suggest that environmental conditions from the time when the sensor measurements were collected until harvest substantially affected crop development and grain production. This also suggests that the stronger, healthier plants that had higher NDVI values at the time of sensing have been more negatively affected by these adverse environmental conditions compared to weaker, less green plants. At WTARC, it is most likely that water-limiting conditions from sensing to harvest have adversely affected the NDVI-yield relationship. On the other hand, WARC - being an irrigated site – does not fit into this pattern. There has not been a noted deficiency of any micronutrients or a notable disease infestation at any of the experimental sites to justify such a low correlation between the sensor measurements and wheat grain yield. One possible explanation to the inversed NDVI-yield relationship at the irrigated WARC site is that strong lush green biomass produced earlier in the season - due to sufficient nutrient and water supply – resulted in high NDVI values. As the crop continued to develop, the grain yield was not optimized due to higher N requirements in the irrigated cropping system, compared to the dryland; the same N rates were applied at both dryland and irrigated locations.

Also, a very weak relationship between NDVI values obtained with the GreenSeeker and with the Pocket Sensor at both sites, where the Pocket Sensor readings were taken (WARC and NWARC) (Figure 17). These results are highly unusual and do not support results obtained with the same GreenSeeker and Pocket Sensor units used in other sensor-based field studies. We have typically seen a very strong linear correlation between the GreenSeker and the Pocket Sensor NDVI values with the R^2 between 0.85 and 0.99. Further, as commonly observed in other sensor-based experiments, the GreenSeeker NDVI values at WARC were slightly lower than the Pocket Sensor NDVI values. At NWARC however, the GreenSeeker NVDIs are much higher compared to those obtained with the Pocket Sensor (Table 8). Furthermore, the NDVIs were generally higher at WTARC compared to WARC, which corresponded to greater grain yield harvested at WTARC tan at WARC. On the other hand, the GreenSeeker NDVIs for all treatments were substantially higher at NWARC, the lowest yielding experimental site in this study. One of the probable explanations could be that the weak relationships between the NDVI values obtained with the two types of sensors, as well as between NDVI and grain yield, could be a result of a human error at the time of sensing.

On the other hand, analysis of crop reflectance data from several other experiments has shown that the NDVI-yield relationship is not as straight forward as some researchers suggests. A study by Sawasawa (2003) showed that variation in NDVI alone explained only 25% of variation in rice grain yield, while NDVI combined with other factors (cropping intensity, soil type, variety, management practices) explained almost 45% of the variation in grain yield. Studies by Gal et al. (2000) and Ray et al. (2002) also reported a poor correlation between NDVI and harvest grain yield in wheat and beets. Sawasawa (2003) concluded that not all the factors affecting grain yield are also affecting NDVI. In particular, they showed that water shortage has a significant effect on grain yield, but not on the NDVI values, especially if the water shortage occurs on a temporary basis. Also, the time at which the water shortage is occurring is crucial - if water limiting conditions are present during the critical stages of crop development (like tiller development, which is closely related to yield potential for wheat), they have a significantly greater effect on grain yield than on NDVI values.

The crop reflectance data has been successfully utilized in sensor-based algorithms for a wide variety of crops in many regions of the world. This study has significantly contributed to the understanding of NDVI-yield relationship and the results underlined the complexity of the challenge that we are facing in terms of developing a strong, well-functioning yield potential prediction algorithm for wheat in Montana. The important lesson from analyzing these data is that the sensor-based technologies are not able – and not aiming, to predict final grain yield. The objective is to accurately estimate yield potential so that more informed decisions can be made in terms of topdress fertilization.

It is expected that this study will be continued for one more growing season to increase data volume and to make more concrete conclusions both on N fertilizer source efficacy (urea vs blend vs ESN) and on the value of crop reflectance data.

5. IMPROVING NITROGEN USE EFFICIENCY IN WINTER WHEAT USING SENSOR-BASED TECHNOLOGIES AND SPLIT NITROGEN APPLICATION

Principal Investigators and Cooperators:

Dr. Olga Walsh, Assistant Professor, WTARC, Conrad, MT
Robin Christiaens, Research Associate, WTARC, Conrad, MT
Dr. Mal Westcott, Professor and Supt., WARC, Corvallis, MT
Dr. Chengci Chen, Professor, CARC, Moccasin, MT

Objectives:

1. To determine which sensor bands or combination of bands forming vegetation indices are optimum for predicting N status in Montana winter wheat.

2. To establish relationships between vegetation indices calculated using crop canopy reflectance measurements obtained with Crop Circle hand-held sensor, preplant soil N, flag leaf N, SPAD chlorophyll meter readings, total plant biomass, grain yield, and grain protein content of irrigated and dryland winter wheat.

Materials and Methods:

This project has been originally initiated in 2009-2010, and continued in 2010-2011 and in 2011-2012 growing seasons; three years of data has been compiled and are currently being analyzed. Two dryland studies at WTARC and CARC, and one irrigated study at WARC were established using winter wheat cultivars of Rampart and Yellowstone with four preplant N rates based on the initial soil N status and individual location yield goal. The NARC location was discarded in 2011-2012 growing season due to personnel constrains. Crop N indices were calculated using crop canopy reflectance measurements obtained with Crop Circle handheld sensors - ACS-470 and ACS-210 - at tillering, heading, flowering and maturity. At the irrigated location, the plots were divided into three subplots to receive 0 lb N ac^{-1}, 40 lbs N ac^{-1} at tillering, and 40 lb N ac^{-1} after flowering followed by irrigation. At dryland sites, two subplots were established to receive 0 and 40 lb N ac^{-1} at tillering. Flag leaf N measurements and SPAD chlorophyll meter readings were taken at heading. Total yield and total crop N uptake were determined at crop maturity and grain yield and grain subsamples were sent to the lab for protein content analysis. Grain yield response to N were regressed against the measures of crop N status and vegetation indices to determine their effectiveness in detecting crop N deficiencies.

Project Results and Relevancy to Montana:

This project has been originally initiated in 2009-2010 (NARC, WARC, and CARC), and continued in 2010-2011 (NARC, WARC, CARC, and WTARC) and in 2011-2012 (WARC, CARC, and WTARC); three years of data (total of 10 site-years) has been compiled and are currently being analyzed. Great volume of agronomic and spectral reflectance data from four experimental sites has been compiled and is being analyzed. This report contains summarized results of some of agronomic data and raw measurements for 2012 growing season, as well as some observations from analysis of all 10 site years. The NDVI-based spectral indices are currently being analyzed for all four experimental sites. Once all the laboratory results are obtained for all sites, complete statistical analysis will be performed and data will be reported and prepared for publication. Treatment structure for WARC is reported in Table 9, and treatment structure for WTARC and CARC are shown in Table 10.

Noted response to applied N fertilizer was observed at all three sites. Overall the grain yields were highest at WTARC, and the lowest – at CARC (Table 10). In 2012, as with other field experiments, WTARC produced higher grain yields than the irrigated WARC site. This could be possibly due to the greater volume of biomass developed at the irrigated site early in the growing season (late fall) compared to the dryland sites. Similarly, while the biomass at the irrigated site at early tillering ranged between 5.4 and 7.3 g per foot of row; the biomass at the dryland locations ranged between 3.3 and 6.5 at WTARC and between 3.2 and 4.8 at CARC. Also, in 2012, there was large amount (74 lb N ac^{-1}) of residual soil N at WTARC, compared to 50 lb N ac^{-1} at WARC.

The was a strong linear relationship between plant height measured at maturity and winter wheat grain yield, independent of the variety, for all 10 site years (Figure 18). Grain yield increased with increasing height of wheat plants (R^2=31). This indicates the possibility of predicting yield potential of wheat by combining crop reflectance measurements with plant height. The challenge of using plant height as a factor to better predict yield potential is that it must be tied with some other parameter that takes into account the spatial variability of the plants. It is possible that a variable is not related to the yield in a field because the range of variation within that field is above or below the range in which it influences yields (Mallarino et al., 1999). On the other hand, Machado et al. (2002) reported that plant height explained 61% of the variation in corn grain yields. Recognizing the difference between corn and wheat canopy structure, but acknowledging the concept discussed here, plant height in wheat could likely be effective in predicting final grain yield, especially if another dimension of plant characteristics, such as leaf area index, number of tillers, or plant population.

Schepers et al. (1992), and Singh et al (2002) results indicated that SPAD readings, as an estimate of leaf chlorophyll content, correlated with yield as accurately as leaf N concentrations in corn and wheat. This was not the case in this study, where there was no relationship between SPAD measurements and wheat grain yield (Figure 19). Also, Wood et al. (1992) reported that chlorophyll measurements correlated well with N concentration in the plant tissue. Again, our data from 10 site years did not support these findings. Figure 20 shows that SPAD measurements were not correlated with flag leaf N content. On the other hand, flag leaf N content was highly correlated with grain yield at all site-years (Figure 21); although the relationship was slightly different at WTARC, where both high yields and protein levels were achieved even at lower N concentration in flag leaves. Further analysis of data, specifically – grain protein data, is needed to make more confident conclusions.

The detailed statistical analysis of spectral reflectance data is in progress and the results will be prepared for publication once the complete analysis is carried out for all 10 site-years. Preliminary results indicated that the canopy reflectance readings are highly variable due to a number of factors, including wheat variety and location. Figure 22 shows a relationship between the spectral measurements (GNDVI1 as an example) and final grain yield. Distinct differences were observed in the GNDVI at tillering relationship with grain yield dependent on the variety evaluated (Figure 23). Fifty six percent of variation in grain yield was explained by the variation in GNDVI for Rampart, and only 20% - for Yellowstone (Figure 23). Also, the relationship between GNDVI at tillering vs grain yield was notably different depending on the experimental location (Figure 24). The results of this study suggested that there was a great potential for using sensor-based indices for in-season wheat grain yield. Also, findings indicate that there is a possibility to improve the accuracy of N status assessment and wheat yield potential prediction mid-season with the incorporation other parameters such as plant height.

6. SENSOR-BASED NITROGEN FERTILIZATION ALGORITHM FOR WINTER WHEAT VARIETIES

Principal investigators and cooperators:
Dr. Olga Walsh, Assistant Professor, WTARC, Conrad, MT

Robin Christiaens, Research Associate, WTARC, Conrad, MT

Summary: The results from one site-year - WTARC (2011-2012) - are summarized in this report. Therefore, it is difficult to make any concrete assumptions or conclusions related to both grain yield and sensor measurements. Three N rate field experiments were established in the fall of 2011 - one at WTARC, Conrad MT, and two in producers' fields (Jack Patton, Chouteau County, and Lindsay Martin, Teton County). Prior to establishment, composite soil samples were collected, processed and analyzed for soil texture, and all major and minor essential plant nutrients. Treatment structure is summarized in Table 11. At each site, 6 N rates: 0, 40, 80, 120, 160, and 200 lb N ac^{-1} (all applied at the time of seeding as urea, sidebanded) were evaluated. This wide array of fertilizer N rates was necessary to obtain an accurate curve illustrating the relationship between N rate and wheat yield. Six winter wheat varieties: Genou, Judee, Rampart, Bearpaw, Yellowstone, and Decade were planted at each location. Treatments 1, 7, 13, 19, 25, and 31 were used as the unfertilized reference plots, and Treatments 6, 12, 18, 24, 30, and 36 were used as non-limiting N-Rich reference plots for each of evaluated varieties. The plot size was 5'x 25'. Each treatment was replicated 4 times. Appropriate weed and pest management control was employed when necessary.

Unfortunately, two out of three initiated sites were lost: Patton site – due to wheat volunteer problems, and Martin site – due to weed (cheat grass) infestation. Patton site was established in a re-crop situation, glyphosate was used prior to seeding. Good volunteer control was not achieved and the plots were lost. At Martin, the plots were sprayed with PowerFlex - herbicide suggested for winter wheat - in the fall prior to seeding and three times throughout the growing season at the recommended rate of 2 oz ac^{-1}. PowerFlex herbicide application did not result in weed control and the Cheat grass population was not diminished – the plots were swathed and the weed infested biomass was removed from the field and destroyed to prevent further contamination of surrounding crop land. The WTARC experimental site was seeded on September 26, 2011. At crop maturity, the final plot yield was obtained at harvest (August 13, 2012), grain sub-samples were sent to the lab for protein content analysis. One day prior to harvest (August 12, 2012), to quantify the amount of produced biomass, whole plant biomass samples were collected from each plot by hand-harvesting all above-ground biomass produced in 1 foot of row. The sub-samples of the biomass were sent to the lad and analyzed for total N content. Biomass weight (adjusted to 5% moisture) and total N results and grain yield results (adjusted to 12% moisture) are reported in Table 12.The following data was obtained from plots at WTARC at Feekers 5 growth: Normalized Difference Vegetative Index (NDVI) using GreenSeeker sensor (May 2, 2012), NDVI using Pocket Sensor (May 3, 2012), SPAD chlorophyll meter readings (May 4, 2012) (Table 13).

Grain yield

Although the crops response to applied N was evident during visual evaluation (Figure 25), higher N rates did not always result in higher winter wheat grain yield. This illustrates the complete independence of crops yield potential and crops responsiveness to applied N. Not only optimum N rates change year to year in each field, the crops responsiveness also changes annually, independently of one another. Averaged over all treatments, variety Yellowstone was the highest yielding closely followed by Decade, and Rampart was the lowest yielding.

Statistically significant differences in winter wheat grain yield associated with varieties were observed ($p<0.05$). The effect of fertilizer N rates applied at seeding on grain yield for six winter wheat varieties is shown in Figure 26.

Biomass

The amount of produced biomass (dry weight per foot of row) varied from 343 g for Bearpaw to 408 g for Yellowstone (Table 2). Preplant N rate significantly affected biomass %N for all the varieties. Biomass % N was highly correlated with GreenSeeker Sensor abd Pocket Sensor NDVI measurements, ($p<0.0001$ and $P<0.05$, respectively) which illustrates that GreenSeener NDVI could be successfully used as an indicator of N stress in wheat.

There were no statistically significant differences in mean biomass weight associated with varietal differences.

Similar trend was observed with biomass total N content. The effect of N fertilizer rates applied at seeding on biomass weight and biomass total N content are reported in Figures 27 and 28, respectively.

NDVI

The NDVI measurements obtained with both GrenSeeker and Pocket Sensor were low at WTARC in 2012 (Table 13). No-till conditions with a substantial amount of pale colored residue and stubble is present in the field at the time of sensing (Figure 29) may have resulted in lower than expected NDVI values.

GreenSeeker NDVI values were correlated with NDVIs obtained with the Pocket Sensor (Figure 30). At lower NDVI values, the measurements obtained with the two sensors were highly correlated; as NDVI values increase – the relationship becomes weaker. There were statistically significant ($p<0.0001$) differences in GreenSeeker NDVI values associated with differences in Pocket Sensor NDVIs; and mean Pocket Sensor NDVIs were linearly correlated with GreenSeeker NDVI. However, still only 27% of the variation in mean GreenSeeker NDVI was explained by the variation in mean Pocket Sensor NDVI (Figure 31). Figure 32 shows the differences in the Pocket Sensor vs GreenSeeker NDVI associated with winter wheat varieties. It is interesting that Genou's, Bearpaw's and Decade's readings were much stronger correlated, while Yellowstone's, Judee's, and especially Rampart's – were very poorly correlated.

Figure 33. shows that the relationships between GreenSeeker NDVI values and harvested grain yield varied greatly between the six varieties. As NDVIs increased, grain yield for Genou and Yellowstone has also increased. This was not the case with the other hand other four varieties: a distinct negative slope was observed for Judee, Decade, and especially – Bearpaw and Rampart. This suggests that treatments that had higher crop reflectance values earlier in the season had yielded less than those with initially lower NDVIs. This could be a result of a combination of these two factors. 1) Due to warm fall and relatively mild first part of winter, there is a possibility that treatments that received higher N fertilizer rates produced high volume of biomass earlier in the season, using greater amounts of N, leaving less N available for grain development. 2) These more developed, taller more vigorous plants had higher NDVIs, compared to those that received lower N rates, but later in the season, they were requiring more moisture to optimize their yield potential. Water shortage negatively affected these plants to much greater degree because there was a need to support the vigorous lush

biomass produced at the beginning of the growing season. It has been reported, that wheat plants are likely to produce more tillers when environmental conditions like temperature, moisture, and light are beneficial. And, as conditions become limiting, including water and/or nutrient shortage - wheat plants tend to produce fewer tillers and even aborting initiated tillers. Also, not all of the tillers remain productive, in fact - very few of the secondary tillers normally develop a head and contribute to grain yield (Herbek and Lee, 2009). Warm and moist soil conditions in the fall, can result in rank growth in the fall resulting in inefficient water use that can leave the wheat crop more susceptible to winter kill (McVay at al., 2010). Sensor-based studies were carried out in spring wheat in Montana showed a very high correlation between GreenSeeker NDVI and Pocket Sensor NDVI values as well as NDVI and grain yield. Winter wheat moisture requirements are higher than for spring wheat and there is a longer period for N applied in the fall to be lost through immobilization and volatilization.

SPAD

There were statistically significant ($p<0.01$) differences in SPAD chlorophyll readings associated with varieties. Figure 34 shows that SPAD chlorophyll meter readings were correlated differently with fertilizer N rates applied at seeding, depending on variety. Decade, Yellowstone and Rearpaw followed the same trend: SPAD readings increased as N rate increased from 0 to 40 lb N ac^{-1}, then decreased as N rate was increased from 40 to 80 lb N ac^{-1}, and then gradually increased again. Judee's SPAD readings gradually increased as the N rate increased, except for a drop in SPAD measurements at the 120 lb N ac^{-1} rate. Rampart's SPAD readings increased ad the N rate increased from 0 to 40 lb N ac^{-1}, and then very gradually decreased with further increase in N rates. The results illustrate possible variations in chlorophyll accumulation and content at the time of sensing associated with varietal differences. This could also explain the inconsistent NDVI readings between the varieties, because NDVI reflects biomass volume and vigor as well as greenness.

The fact that SPAD meter readings were highly correlated with harvested grain yield ($P<0.05$) indicates that mid-season SPAD measurements could be utilized to predict wheat yield potential.

It is clear, that more data needs to be collected to verify the negative slope of the relationship between NDVI values and grain yield and to discard the possibility of data contamination, human error or other factors that possibly could have affected the data. Five experimental locations were established in the 2012-2013 growing season to catch-up for the loss of two experimental sites in the 2011-2012. There is a need to develop a research program that would allow to generate accurate, crop - specific and site - specific fertilizer rates that account for temporal and spatial variability (natural and acquired), improve fertilizer use efficiency, increase and make grain protein in wheat uniform, save time, money and labour for crop producers, increase crop yields, and maintain environmental integrity. Precision sensing technologies will allow establishing state-of-the-art soil nutrient management field-oriented research program that will meet the needs of Montana producers. Precision sensing will enable to focus on strategies that optimize economic and environmental sustainability of small cereal grain production.

SUPPORTING FUNDING:

Montana Wheat and Barley Committee funded this project for two growing seasons (2011-2012 and 2012-2013).

EFFECTIVENESS AND OUTCOMES:

Significant volume of agronomic and crop reflectance data has been obtained from one site year in the 2011-2012 growing season. The outcomes showed that there is a need to expand the research in winter wheat for the following reasons:

1. Mid-season crop canopy reflectance readings collected in winter wheat did not follow the same pattern as in spring wheat, where significant amount of data from several site-years have been accumulated in Montana.
2. The fact of negative slope of NDVI vs yield relationship has to be confirmed or disproven with further data collection and analysis.
3. There was not consistent trend in grain yield associated with applied N fertilizer rate, although, overall, the response to N was observed for all varieties. By-plot soil test data analysis should help to eliminate the possible plot-to-plot effect of residual N that could have been carried over from previous N applications.
4. The high correlation between GreenSeeker NDVI, Pocket Sensor NDVI, SPAD measurements and final grain yield indicate that spectral measurements and relative greenness data show a great promise for yield potential prediction in wheat.
5. Soil moisture sensors installed at each experimental location at several depths could help to account for possible moisture stress effect. Soil moisture data, in combination with NDVI sensor readings, could be useful in improving the accuracy of YP prediction in semi-arid environment of Montana no-till wheat production systems.
6. Obtaining precise wheat crop height, plant population count and number of tillers data from each plot at each location will help to evaluate the amount of biomass produced from seeding to sensing more precisely. This will also assist in assessing biomass production differences associated with varieties.
7. Sensor readings were taken at Feekes 5 growth stage, as it has been identified as growth stage at which it is possible to accurately estimate biomass production in wheat. NDVI values obtained at Feekes 5 growth stage did not strongly correlate with winter wheat grain yield. Obtaining GreenSeeker sensor readings at several growth stages (Feekes 5 – through Feekes 10) will help to determine the optimum sensing time for winter wheat Montana varieties and conditions.

Table 1. Originally proposed treatment structure.

Treatment	Preplant N Fertilizer (urea) Rate, lb N ac^{-1}	Topdress N Fertilizer Source	Topdress N Fertilizer Rate, lb N ac^{-1}	Todress N Fertilizer/Water Ratio, %
1	0	-	-	-
2	80	UAN	40	100/0
3	80	UAN	40	75/25
4	80	UAN	40	50/50

5	80	UAN	40	25/75
6	80	LU	40	100/0
7	80	LU	40	75/25
8	80	LU	40	50/50
9	80	LU	40	25/75
10	80	HNRGN	40	100/0
11	80	HNRGN	40	75/25
12	80	HNRGN	40	50/50
13	80	HNRGN	40	25/75
14	40	UAN	80	100/0
15	40	UAN	80	75/25
16	40	UAN	80	50/50
17	40	UAN	80	25/75
18	40	LU	80	100/0
19	40	LU	80	75/25
20	40	LU	80	50/50
21	40	LU	80	25/75
22	40	HNRGN	80	100/0
23	40	HNRGN	80	75/25
24	40	HNGRN	80	50/50
25	40	HNRGN	80	25/75

Table 2. Modified treatment structure employed, and mean spring grain yields obtained at WTARC, Patton, and WARC in 2012.

Trt	Preplant N Fertilizer (urea) Rate, lb N ac^{-1}	Topdress N Fertilizer Source	Topdress N Fertilizer Rate, lb N ac^{-1}	Todress N Fertilizer/Water Ratio, %	Mean spring wheat grain yield, lb ac^{-1}		
					WTARC	PATTON	WARC
1	0	-	-	-	4795 (c)	2256 (bcd)	5022 (abc)

2	80	UAN	40	100/0	5331 (ab)	1893 (de)	5364 (abc)
3	80	UAN	40	66/33	5182 (bc)	1994 (cde)	5094 (abc)
4	80	UAN	40	33/66	5209 (bc)	1863 (e)	5666 (ab)
5	80	LU	40	100/0	5391 (ab)	2299 (bc)	4825 (c)
6	80	LU	40	66/33	5527 (ab)	2303 (bc)	4834 (bc)
7	80	LU	40	33/66	5539 (ab)	2399 (ab)	4949 (abc)
8	80	HNRGN	40	100/0	5692 (ab)	2511 (ab)	5728 (a)
9	80	HNRGN	40	66/33	5681 (ab)	2331 (bc)	5610 (abc)
10	80	HNRGN	40	33/66	5757 (a)	2705 (a)	5486 (abc)

The means in the same column followed by the same letter are not significantly different, $p<0.05$.

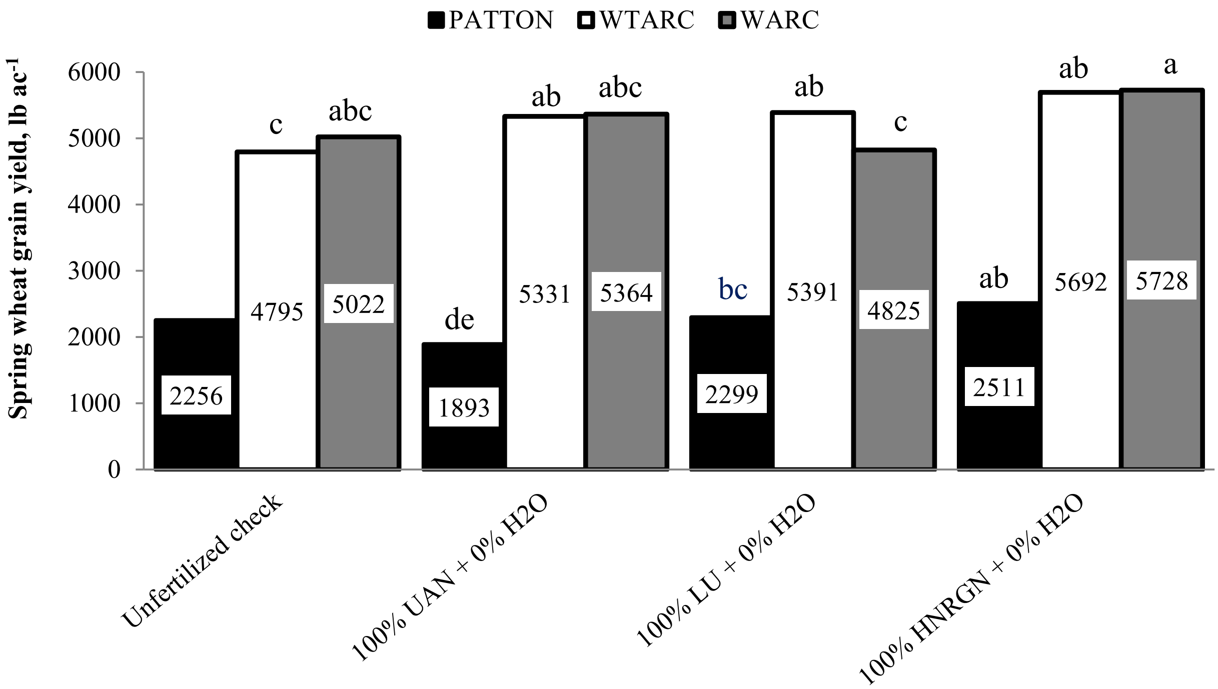

Figure 3. The effect of N fertilizer topdress source at 100% to 0% product-to-water ratio on spring wheat grain yields, Patton, WTARC, and WARC, 2012.

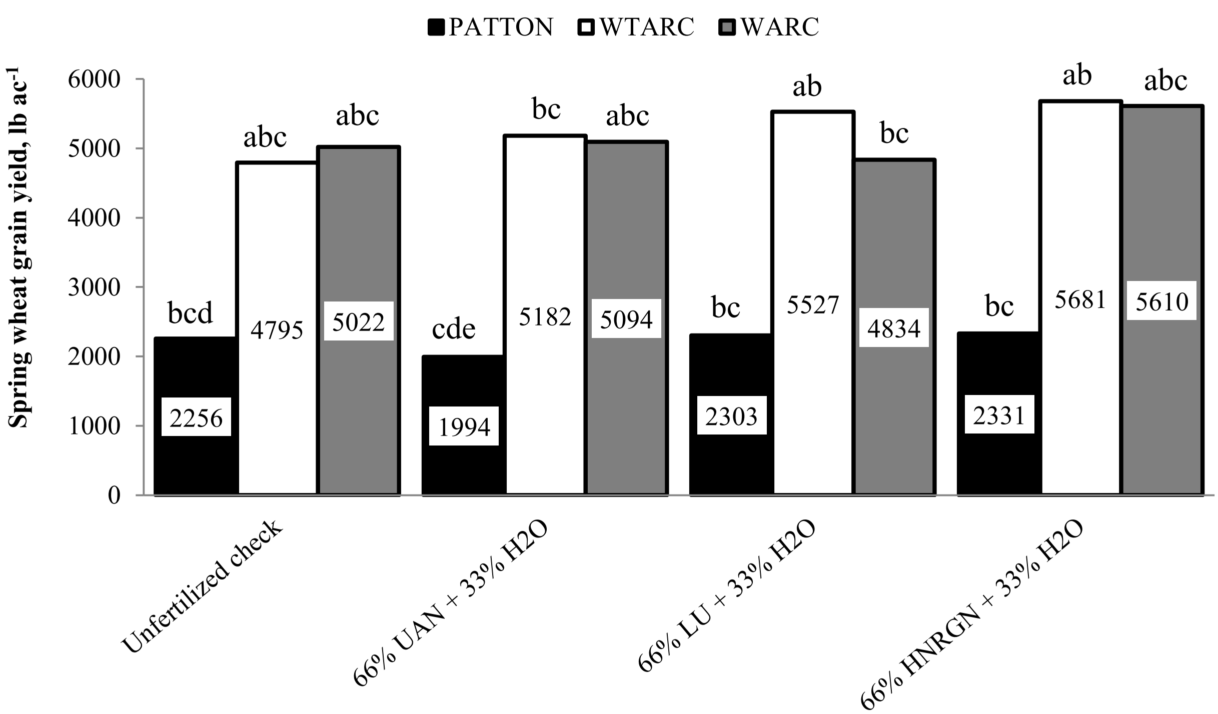

Figure 4. The effect of N fertilizer topdress source at 66% to 33% product-to-water ratio on spring wheat grain yields, Patton, WTARC, and WARC, 2012.

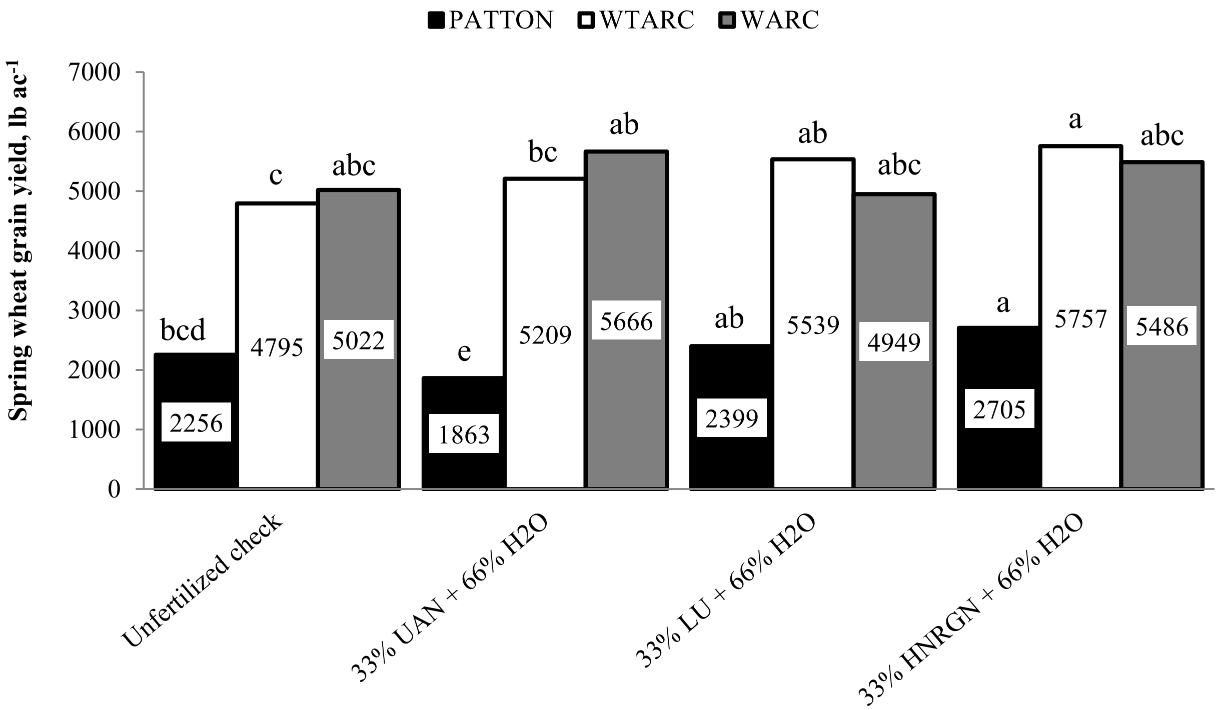

Figure 5. The effect of N fertilizer top-dress source at 33% to 66% product-to-water ratio on spring wheat grain yields, Patton, WTARC, and WARC, 2012.

Table 3. Preplant N (lb N ac^{-1}), top-dress N, grain yield (lb ac^{-1}), WTARC and WARC, 2011, and WTARC, WARC, and Martin, 2012.

Trt	Preplant N Fertilizer Rate, lb N ac^{-1}*	Topdress N Fertilizer Source**	Mean spring wheat grain yield, lb ac^{-1}				
			2011		2012		
			WTARC	WARC	WTARC	WARC	Martin
1	0	-	829 (f)	1822 (e)	4229 (d)	3512 (f)	1698 (c)
2	220	urea	2378 (a)	3335 (abc)	4433 (d)	4981 (e)	1837 (bc)
3	20	urea	1369 (e)	2488 (d)	4797 (c)	5121 (de)	1995 (ab)
4	40	urea	1388 (e)	3061 (bc)	5178 (a)	5299 (bcde)	1996 (ab)
5	60	urea	1662 (cd)	3453 (ab)	5140 (abc)	5746 (abc)	2072 (ab)
6	80	urea	1925 (b)	3558 (a)	5262 (a)	5273 (cde)	2115 (a)
7	20	UAN	1298 (e)	2907 (cd)	4824 (bc)	5563 (abcd)	1997 (ab)
8	40	UAN	1465 (de)	3136 (abc)	4958 (abc)	5674 (abcd)	2065 (ab)
9	60	UAN	1771 (bc)	3004 (bc)	4951 (abc)	5862 (ab)	1980 (ab)
10	80	UAN	1935 (b)	3210 (abc)	5160 (ab)	5871 (a)	2027 (ab)

* Preplant fertilizer N was applied as urea. ** Top-dress fertilizer N rates for Treatments 3-10 were determined based on the NDVI values obtained using Green Seeker.

Table 4. Green Seeker NDVI, Pocket Sensor NDVI, and prescribed top-dress N rate (lb N ac^{-1}), at WTARC and WARC, 2011, and at WTARC, WARC, and Martin, 2012. The NDVI values are averaged by treatment.

Trt	2011						2012								
	WTARC			WARC			WTARC			WARC			MARTIN		
	GS	PS	N rate, lb ac^{-1}	GS	PS	N rate, lb ac^{-1}	GS	PS	N rate, lb ac^{-1}	GS	PS	N rate, lb ac^{-1}	GS	PS	N rate, lb ac^{-1}
1	0.3	0.3	-	0.4	0.4	-	0.5	0.4	-	0.5	0.4	-	0.3	0.2	-
2	0.5	0.5	18	0.5	0.5	19	0.3	0.3	62	0.5	0.4	87	0.3	0.3	0
3	0.3	0.3	18	0.5	0.5	26	0.5	0.4	13	0.5	0.4	99	0.4	0.3	16
4	0.4	0.4	18	0.6	0.6	6	0.5	0.4	13	0.5	0.4	99	0.4	0.3	16
5	0.4	0.4	18	0.6	0.5	13	0.5	0.5	13	0.5	0.5	99	0.4	0.3	0
6	0.4	0.4	9	0.6	0.6	19	0.5	0.4	24	0.5	0.4	99	0.4	0.4	17
7	0.3	0.3	27	0.5	0.5	26	0.5	0.5	20	0.5	0.5	99	0.4	0.3	14
8	0.4	0.4	18	0.6	0.6	6	0.5	0.5	13	0.5	0.5	87	0.4	0.4	14
9	0.4	0.5	9	0.6	0.6	6	0.5	0.4	17	0.5	0.4	99	0.4	0.3	19
10	0.4	0.5	9	0.6	0.6	15	0.5	0.4	17	0.5	0.5	87	0.4	0.3	5

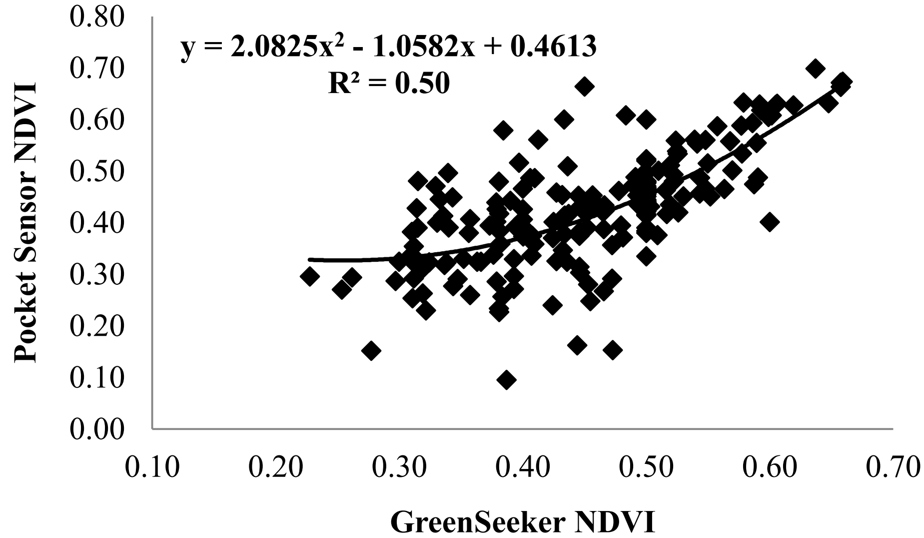

Figure 6. Relationship between Green Seeker NDVI and Pocket Sensor NDVI, WTARC, WARC, and Martin, 2012.

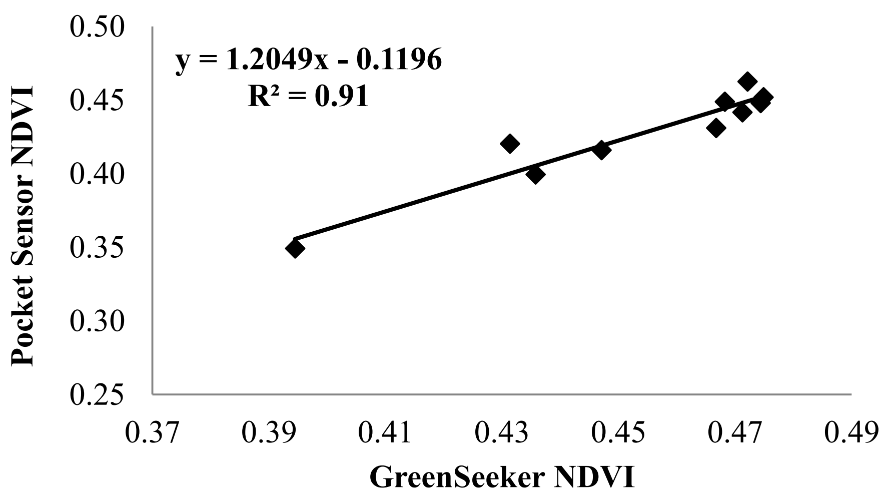

Figure 7. Relationship between Green Seeker NDVI and Pocket Sensor NDVI, WTARC, WARC, and Martin, 2012. NDVI values are averaged by treatment over all three sites.

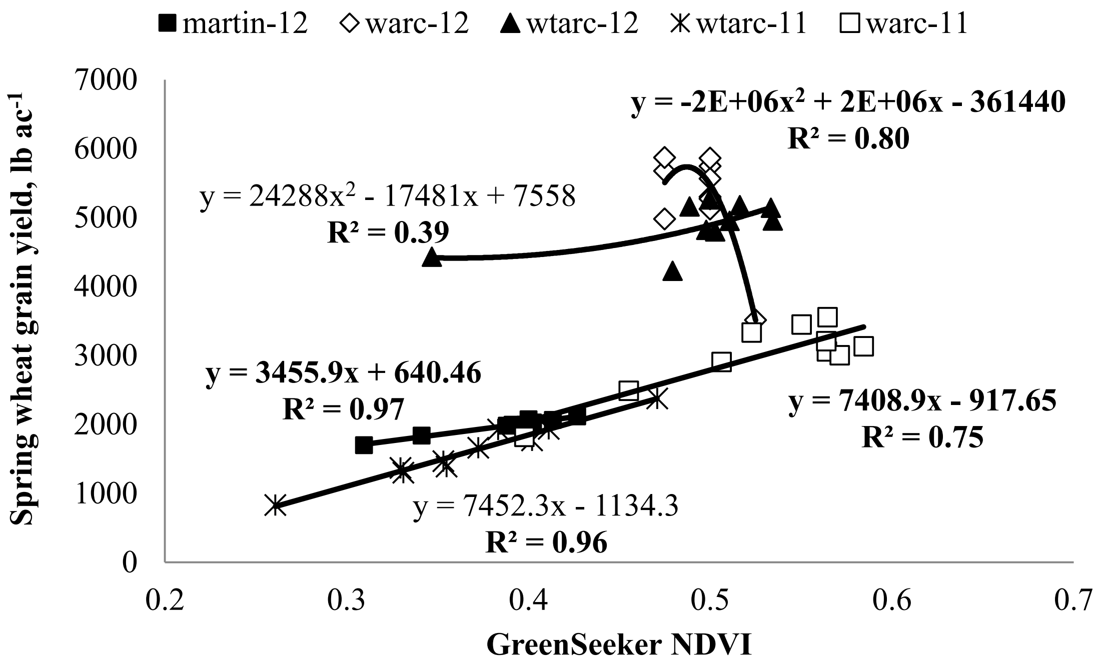

Figure 8. Relationship between Green Seeker NDVI and spring wheat grain yield at WTARC and WARC, 2011, and at WTARC, WARC, and Martin, 2012. The NDVI values are averaged by treatment.

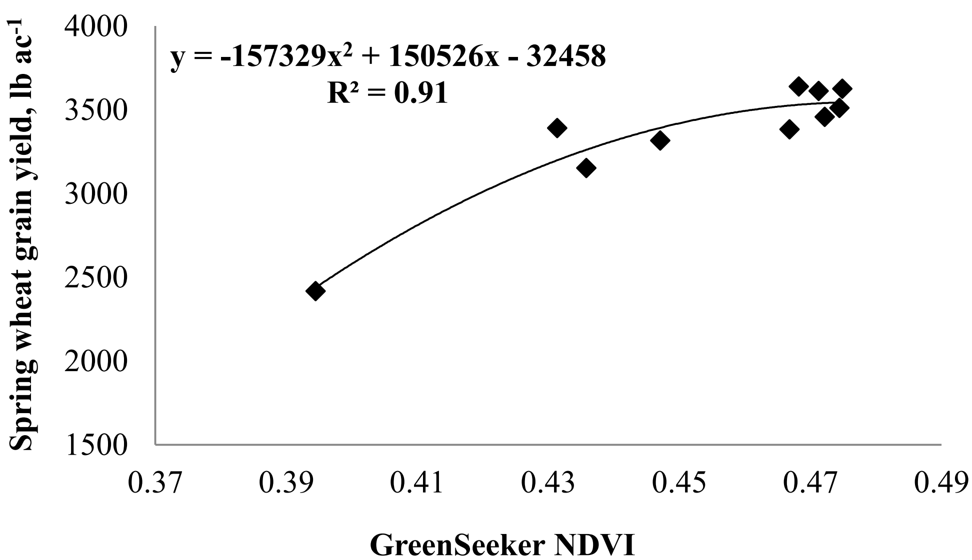

Figure 9. Relationship between mean Green Seeker NDVI values and mean spring wheat grain yields (averaged over site-years) at WTARC and WARC, 2011, and at WTARC, WARC, and Martin, 2012.

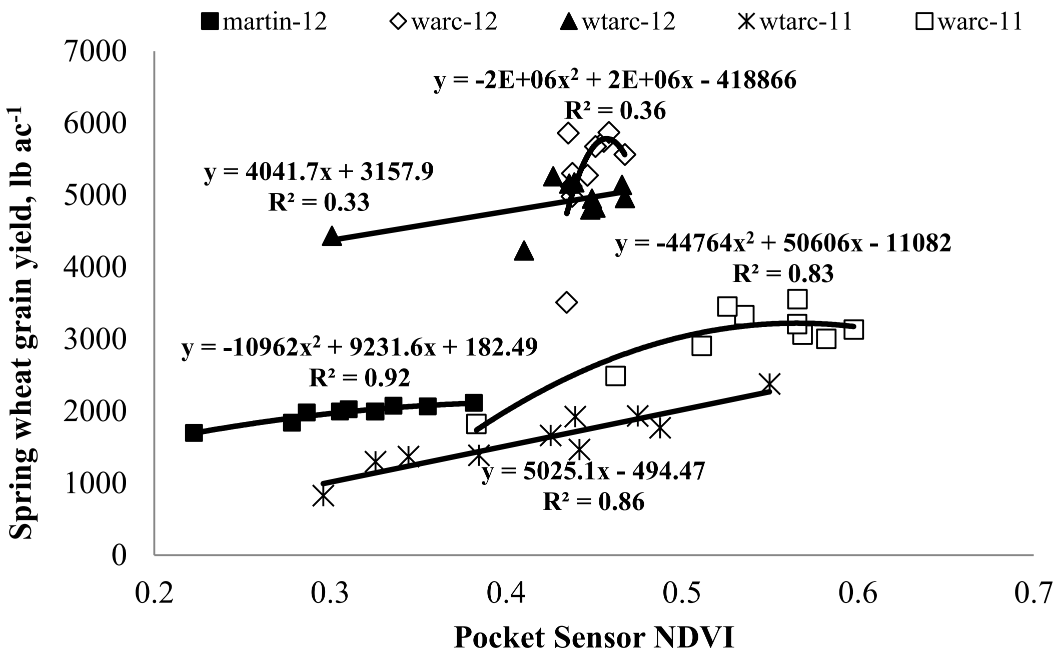

Figure 10. Relationship between Pocket Sensor NDVI and spring wheat grain yield at WTARC and WARC, 2011, and at WTARC, WARC, and Martin, 2012. The NDVI values are averaged by treatment.

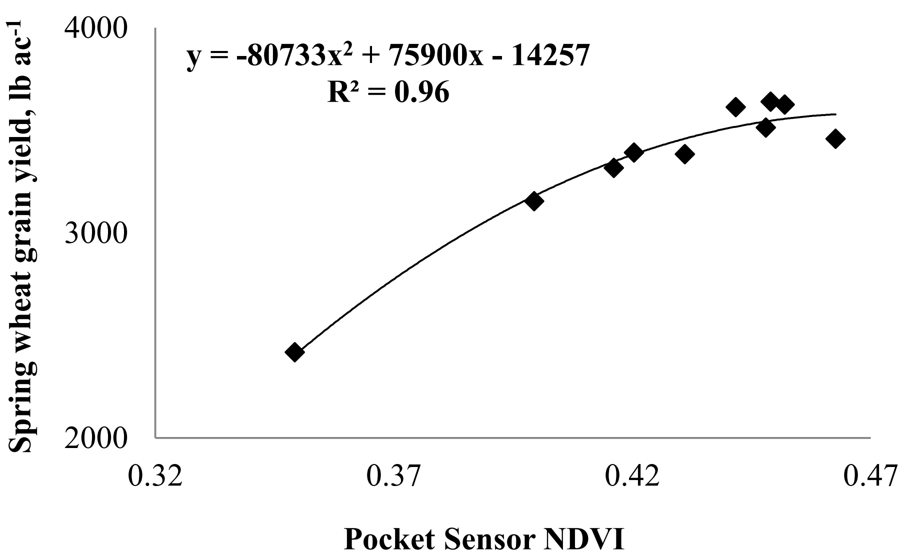

Figure 11. Relationship between mean Pocket Sensor NDVI values and mean spring wheat grain yields (averaged over site-years) at WTARC and WARC, 2011, and at WTARC, WARC, and Martin, 2012.

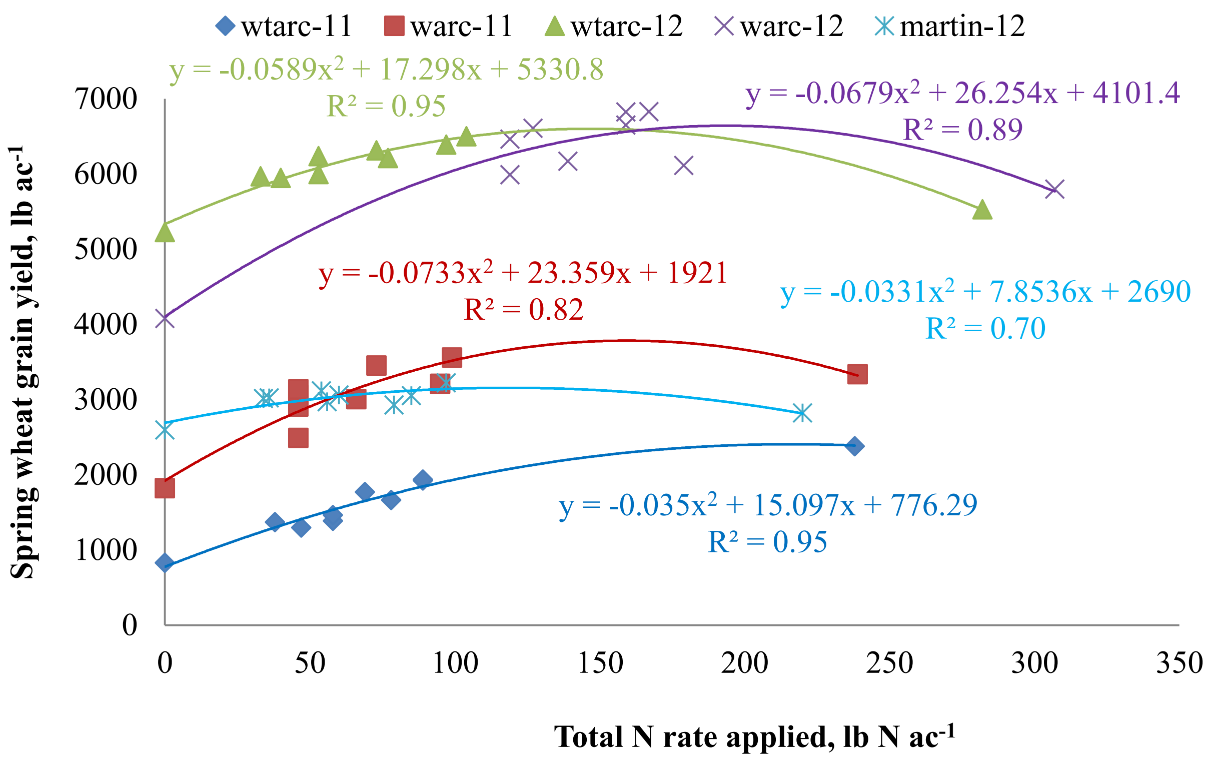

Figure 12. Relationship between mean Pocket Sensor NDVI values and mean spring wheat grain yields (averaged over site-years) at WTARC and WARC, 2011, and at WTARC, WARC, and Martin, 2012.

Table 5. Treatment structure.

Treatment	Fertilizer N Application					
	Preplant rate, lb N ac^{-1}	Preplant source	Top-dress rate, lb N ac^{-1}	Top-dress source	Top-dress application time	Total N applied, lb N ac^{-1}
1	0	n/a	0	n/a	n/a	0
2	80	urea	0	n/a	n/a	80
3	120	urea	0	n/a	n/a	120
4	40	urea	40	urea	Before flowering	80
5	40	urea	40	urea	After flowering	80
6	40	urea	80	urea	Before flowering	120
7	40	urea	80	urea	After flowering	120
8	40	urea	40	UAN	Before flowering	80
9	40	urea	40	UAN	After flowering	80
10	40	urea	80	UAN	Before flowering	120
11	40	urea	80	UAN	After flowering	120

Table 6. Mean spring wheat grain yields, WTARC and Patton, 2011, and WTARC, Patton and Martin, 2012.

Effects	Mean spring wheat grain yield, lb ac^{-1}				
	2011		2012		
	WTARC	PATTON	WTARC	PATTON	MARTIN
Preplant N rate, lb N ac^{-1}					
0	648 (b)	1319 (a)	4062 (b)	2566 (a)	1723(b)
80	1644 (a)	1411 (a)	5179 (a)	2683 (a)	2227 (a)
120	1635 (a)	1381 (a)	5482 (a)	2730 (a)	2257 (a)
Top-dress N source					
Urea	1138 (a)	1408 (a)	5242 (a)	3043 (a)	2106 (a)
UAN	1278 (a)	1374 (a)	5164 (a)	2673 (a)	2139 (a)
Top-dress N rate, lb N ac^{-1}					
0	1312 (a)	1370 (a)	5331 (a)	2706 (a)	2242 (a)
40	1187 (a)	1380 (a)	5103 (b)	2654 (a)	2142 (a)
80	1228 (a)	1402 (a)	5303 (ab)	3062 (a)	2103 (a)
Top-dress N time					
Before flowering	1278 (a)	1374 (a)	5123 (a)	3031 (a)	2137 (a)
After flowering	1137 (a)	1408 (a)	5283 (a)	2684 (a)	2109 (a)

Mean grain yields within each effect group in the same column followed by the same letter are not significantly different ($p<0.05$).

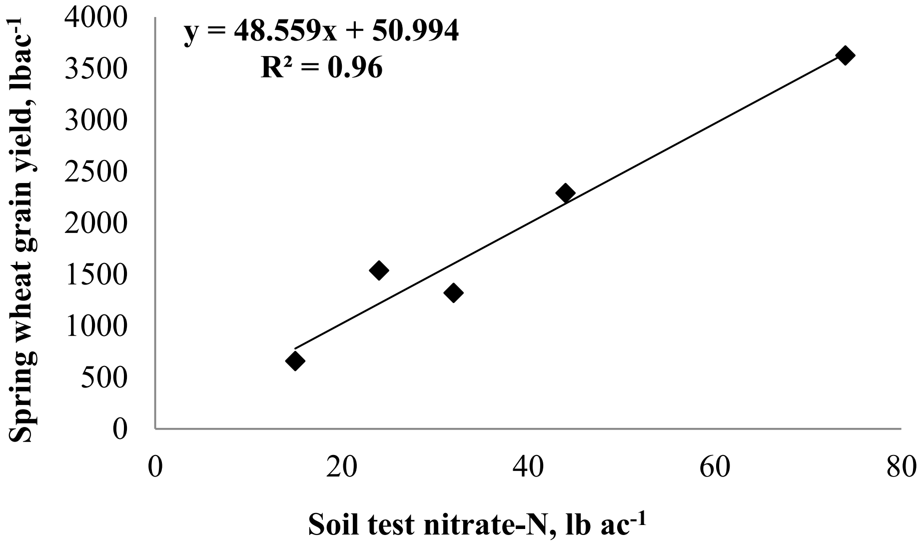

Figure 13. Relationship between mean soil test nitrate-N contents and mean spring wheat grain yields, WTARC, Patton, and Martin, 2012. Grain yields and soil test nitrate-N contents are averaged over the three locations.

Table 7. Treatment structure and spring wheat grain yield, WTARC, WARC, NWARC, 2012.

	Preplant N application			Spring wheat grain yield, lb ac^{-1}		
Trt	N rate, lb ac^{-1}	N source	Top-dress N (urea) rate, lb ac^{-1}	WTARC	WARC	NWARC
1	0	n/a	0	3626 (e)	3438 (d)	3441 (c)
2	50	Urea	0	4710 (abcd)	3581 (d)	3832 (abc)
3	50	Urea	40	4685 (bcd)	4232 (abc)	4305 (a)
4	100	Urea	0	4748 (abcd)	4065 (abcd)	3960 (ab)
5	100	Urea	40	4720 (abcd)	4567 (ab)	3966 (ab)
6	150	Urea	0	4709 (abcd)	4257 (abc)	4002 (ab)
7	150	Urea	40	4809 (abc)	4079 (abcd)	3996 (ab)
8	50	Urea/ESN	0	4728 (abcd)	3163 (d)	4002 (ab)
9	50	Urea/ESN	40	4546 (cd)	4076 (abcd)	4024 (ab)
10	100	Urea/ESN	0	5065 (abc)	4268 (abc)	3940 (ab)
11	100	Urea/ESN	40	4768 (abcd)	4642 (ab)	3868 (abc)
12	150	Urea/ESN	0	4871 (abc)	4400 (abc)	3759 (bc)
13	150	Urea/ESN	40	5182 (ab)	4478 (abc)	3796 (bc)
14	50	ESN	0	4243 (d)	3710 (bcd)	3622 (bc)
15	50	ESN	40	4845 (abc)	4468 (abc)	3776 (bc)
16	100	ESN	0	5182 (abc)	4665 (ab)	3900 (abc)
17	100	ESN	40	4864 (abc)	5011 (a)	3792 (bc)
18	150	ESN	0	5250 (a)	3948 (bcd)	4059 (ab)
19	150	ESN	40	5236 (ab)	4305 (abc)	4007 (ab)

* - Mean spring wheat grain yields for three sites, 2012. Mean grain yields followed by the same letter are not significantly different ($p<0.05$).

Table 8. Treatment structure, Green Seeker NDVI at WTARC, WARC, NWARC, and Pocket Sensor NDVI at WARC and NWARC, 2012.

Trt	Preplant N application		Top-dress N (urea) rate, lb ac^{-1}	Green Seeker NDVI			Pocket Sensor NDVI	
	N rate, lb ac^{-1}	N source		WTARC	WARC	NWARC	WARC	NWARC
1	0	n/a	0	0.53	0.35	0.61	0.45	0.37
2	50	Urea	0	0.55	0.38	0.61	0.45	0.39
3	50	Urea	40	0.54	0.36	0.65	0.46	0.35
4	100	Urea	0	0.53	0.34	0.62	0.50	0.36
5	100	Urea	40	0.54	0.34	0.61	0.51	0.38
6	150	urea	0	0.49	0.37	0.63	0.50	0.33
7	150	Urea	40	0.53	0.39	0.62	0.45	0.32
8	50	Urea/ESN	0	0.49	0.36	0.61	0.46	0.37
9	50	Urea/ESN	40	0.53	0.37	0.60	0.45	0.33
10	100	Urea/ESN	0	0.51	0.36	0.60	0.47	0.38
11	100	Urea/ESN	40	0.51	0.34	0.61	0.51	0.39
12	150	Urea/ESN	0	0.48	0.33	0.62	0.49	0.36
13	150	Urea/ESN	40	0.47	0.37	0.63	0.47	0.40
14	50	ESN	0	0.54	0.34	0.59	0.53	0.29
15	50	ESN	40	0.52	0.34	0.61	0.46	0.29
16	100	ESN	0	0.47	0.34	0.60	0.47	0.35
17	100	ESN	40	0.53	0.34	0.61	0.48	0.38
18	150	ESN	0	0.49	0.36	0.62	0.45	0.40
19	150	ESN	40	0.52	0.36	0.61	0.46	0.38

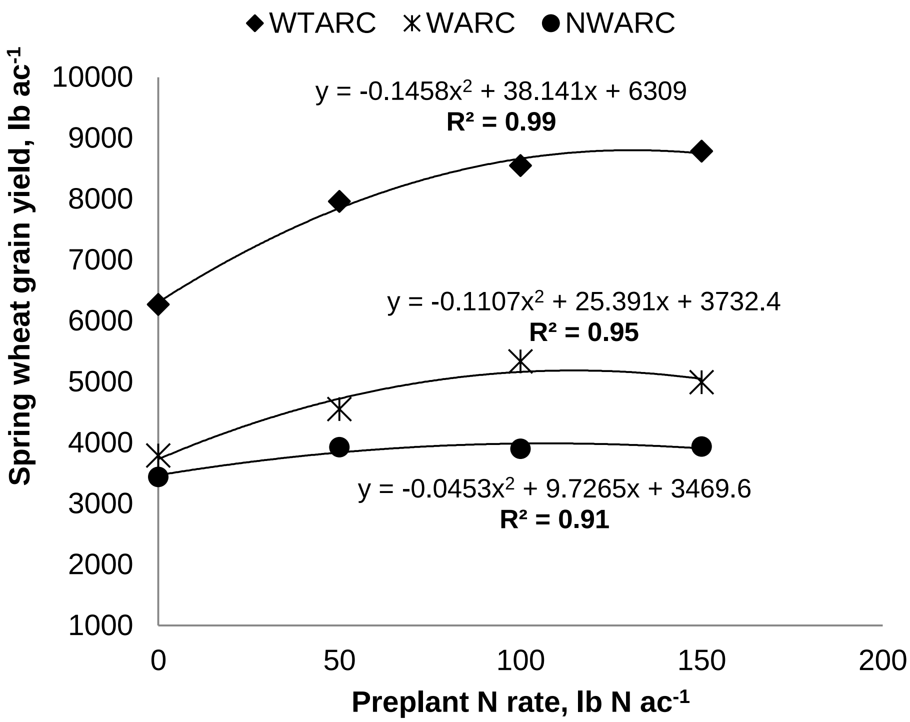

Figure 15. Effect of preplant N rate on spring wheat grain yield, WTARC, WARC and NWARC, 2012.

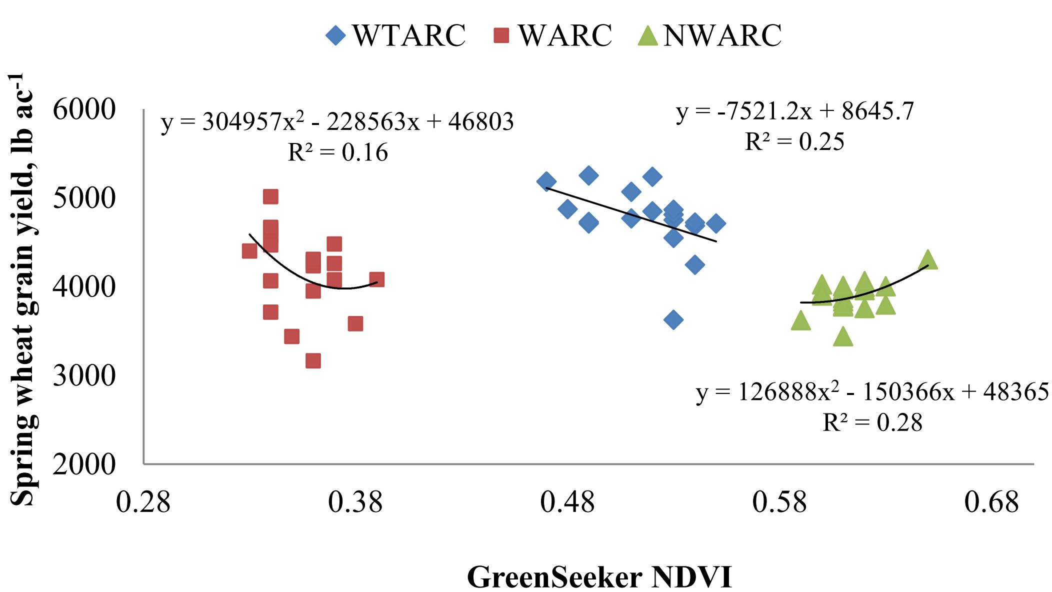

Figure 16. Relationship between the Green Seeker NDVI and spring wheat grain yield, WTARC, WARC and NWARC, 2012.

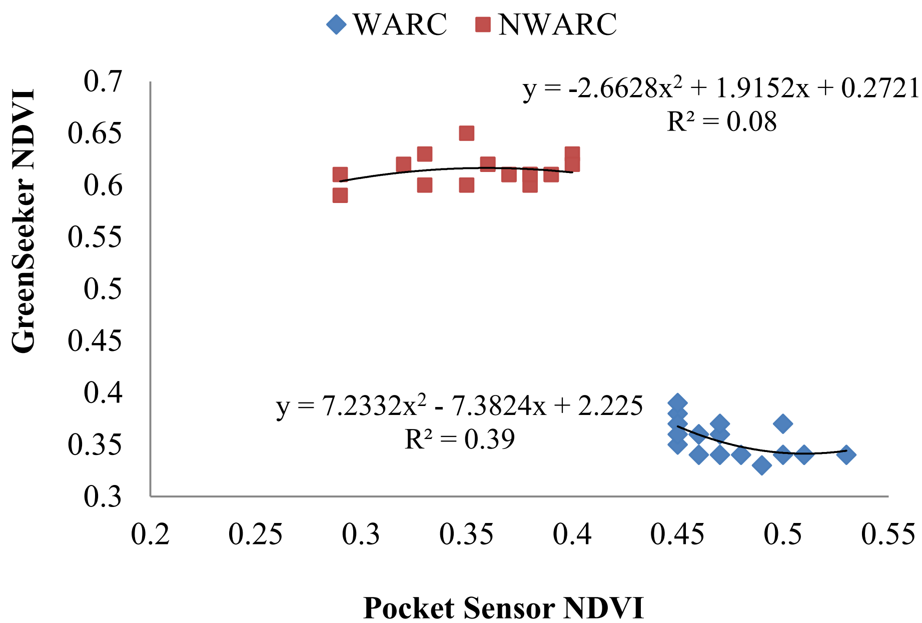

Figure 17. Relationship between the Green Seeker NDVI and the Pocket Sensor NDVI, WARC and NWARC, 2012.