AGRONOMICS OF RESEEDING

WINTERKILLED WINTER WHEAT

By

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Thomas Lee Allen

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DEDICATION

This work is dedicated to all who made it possible: Dr. Phil Bruckner, Gregg Carlson, Dr. Luther Talbert, Dr. Jack Martin, Jim Berg, Peggy Lamb, Rebecca Allen, and all the plot laborers who helped out.

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ABSTRACT

Winterkill has long been a problem for winter wheat growers in Montana. In any given year up to 50% of the seeded acres of winter wheat may have to be reseeded to spring wheat. Research has addressed injury thresholds on when to reseed winter wheat. But little information is available regarding reseeding to spring wheat. The objectives of this study were to determine the level of injury whereby it is more profitable to reseed to spring rather than leave the reduced stand of winter wheat. Eighteen treatments were used to simulate different levels of winter injury and methods of termination of the winter wheat before reseeding. Soil water and nitrogen use by the winter wheat before termination was also determined. Mechanical and chemical termination of 60%, 40% and 20% stands of winter wheat were replanted to spring wheat. An early and late reseeding was also imposed. A 20% stand of winter wheat out yielded the early seeded spring wheat check in all environments. Early reseeded treatments were significantly better than late reseeded treatments. There was no difference between mechanically and chemically terminated plots.

INTRODUCTION

Montana producers face many challenges in their struggle to make a living from the land. Historically, winterkill has always been a problem in north central Montana. In the years 1919-1978, a mean of 12% of the fall seeded winter wheat was replanted to spring wheat (Caprio, 1984). According to Montana Agricultural Statistics (2004), in 2002 1,450,000 acres of winter wheat was planted, but only 750,000 acres were harvested. This 48% reduction could be caused by several factors; drought, hail, disease and insects, but one of the leading causes is winterkill. For winter wheat growers one of the hardest decisions they have to make is whether to terminate a reduced stand of winter wheat and replant to spring wheat, or let the reduced stand grow and mature into a harvestable crop.

Winterkill is primarily caused by physiological drought, heaving of soil, smothering and freezing of the plant tissues (Heyne, 1987). In a field winterkill can range from 100% mortality to no damage. Stand loss is normally not uniformly distributed in the field. Commonly winterkill occurs in patches in a field, with 100% mortality, in some areas, and little stand loss in other areas. Along the edges of these patches and in other areas of the field a reduced stand can occur. These are the areas that cause the most concern for producers. Most producers while reseeding the 100% winterkilled patches also reseed any reduced stand areas that are in the field. With a conservative estimate of $10.00/acre (seed, fuel, labor, equipment wear) for reseeding, it would have cost $7,000,000 to reseed the 700,000 acres of winter wheat that were not harvested in 2002. Some research has been conducted to determine when a producer should reseed reduced stands of winter wheat (Holen et al., 2001; Heard and Domitruk, 2001; Peel and Endres, 1997). Little research has been completed on what to expect from the resulting spring wheat crop in terms of grain yield, and at what point is it more profitable to implement this management option.

Another important question dealing with the reseeding of reduced stands is whether to apply fertilizer when reseeding, and how much moisture the failed winter wheat stand has used before it was terminated.

This study is designed to answer some of these questions. By reseeding various levels of reduced stands of winter wheat we will try to determine the critical level of winter wheat stand reduction where it is profitable to reseed. Soil samples will help us determine how much nutrient and moisture the reduced stand of winter wheat used before it was reseeded.

LITERATURE REVIEW

Winterkill

Snow cover has been found to be the greatest factor in the reduction of winterkill. It is required to insulate the plants from extreme air temperatures and to capture residual heat from the soil. As far back as 1932 in North Dakota it was found that planting winter wheat into standing stubble which captures the snow reduced the amount of winterkill (Sarvis and Thysell, 1936). Aase and Siddoway (1979) reported that in Montana on fields with no snow cover the soil temperature at crown depth reached –16 ºC when the air temperature was below –22 ºC. In fields with 6-7 cm of snow cover the soil temperature did not go to the –16 ºC level. In Canada it was determined that 8-10 cm of unpacked snow in standing stubble was enough to adequately protect the winter wheat crop (Fowler, 1983).

Snow also protects the leaves of the plant from dehydration caused by subzero temperatures. In freezing-induced dehydration the plasma membrane of the cell remains attached to the cell wall, causing the cell wall to collapse. The growing ice crystals in the extracellular spaces also rupture the cell walls. Upon thawing, if freezing has injured the cells, their membranes leak and they are unable to regain full turgor causing the plant to die (Heyne, 1987).

In Montana we have a weather condition known as ‘Chinook’ winds. These warm winds melt snow cover, sometimes leaving our fields covered with ice when the snowmelt freezes again. This ice encasement of winter wheat is a major cause of winterkill. The ice lowers the rate of exchange of respiratory gases, inducing severe hypoxia and anoxia within the plant. This ice layer does not always kill the plants. If the soil is not completely water saturated then there may be air pockets within the soil for gas exchange. Standing stubble as seen in no-till seeding will also help aerate the crop through the internal movement of air in the hollow stems. This would be reduced with solid stem varieties (Andrews, 1996).

Spring Assessment of Stand

Spring assessment of winter wheat stand survival is usually done with plant counts. Until regrowth starts in the spring it is hard to determine just how much winterkill has occurred in a field. Leaf damage is not a reliable indicator of plant damage, if the crown of the plant is still able to produce roots there is a good chance the plant will emerge in the spring. Many government agencies have made recommendations on spring stand assessment and whether or not to replant. Most of these agencies consider a full stand of winter wheat to be 215-300 plants/meter^2.

The Montana State University Extension Service recommends that if you have less than a 40% winter wheat stand (86 plants/meter^2) that you should reseed.

Based on a thesis study of Holen et al. (2001), Montana performance recommendations indicate that fields with a stand of 95 plants/meter^2 would probably out produce a replanted spring wheat field (Berg et al., 2003).

North Dakota State University recommends that you should have a minimum of a 30-40% stand remaining, less than that you should consider reseeding (Peel and Anders, 1997).

The University of Nebraska states that you need 43 plants/meter^2 with five tillers each (Watkins et al., 1992) to achieve a yield of 1343 kg/ha, which they consider a profitable level. Spring wheat should not be interseeded into the winter wheat crop as this results in contrasting classes and price discounts when trying to market the crop. Canadian data shows that a stand of 82 plants/meter^2 would still produce 80% of the yield of a full stand of winter wheat (Manitoba Agriculture and Food, 2001).

Plant Yield Compensation

Crop yield is made up of three components; spikes per unit area (can be further divided into components, plants per unit area and spikes per plant), number of grains per spike, and individual grain weight. If one of these three components is lacking, the winter wheat plant has the capacity to increase or maintain its yield by increasing one or both of the other two. If there is a reduced stand (plants per area) then the plant could produce more tillers per plant, more kernels per spike, and/or heavier kernels.

The ability of winter wheat to compensate has been studied by many researchers. Darwinkel (1978) concluded that at lower plant densities there was increased tillering due to increased tillering time and more tillers producing ears of grain. At higher plant densities more total tillers were produced per area along with more total ears. Darwinkel determined that maximum grain yield was achieved at 100 plants/m^2, which corresponded to 430 ears/m^2. At 800 plants/m^2 almost all ears were produced from main shoots, but with decreasing plant densities tillers contributed proportionally more to the number of ears.

Holen et. al. (2001) showed that three cultivars compensated for reduced stands in different ways. The cultivars did not differ in grain yield, but did differ in individual grain yield components. Each of the cultivars was lowest in a yield component; ‘Judith’ for kernels/spike, ‘CDC Kestrel’ for kernel weight, and ‘Neeley’ for spikes per unit area. Holen’s study agreed with previous work in that at increasing plant densities, grain yield was maintained by the increased spikes per m^2 compensating for the decrease in kernels per spike and decreased kernel weight. Grain yield was maximized at 140 plants/m^2 in this study.

More efficient use of solar radiation at lower plant populations was the cause of plant compensation in a study done in England (Whaley et. al., 2000). They proposed that at low plant densities there was increased green area per plant due to increased tillering and greater shoot survival. They surmised that because of this increased green area per shoot and a decrease in ear production that there was an increase of solar radiation absorbed per shoot at the lower densities. This resulted in an increase of 66% in the number of grains per ear.

Soil Water

Water is the most important and the most limiting factor in any agricultural endeavor in Montana. How much water the failed winter wheat has taken from the soil is an important factor in determining what your spring wheat yield will be in a replanting situation. Brown and Carlson (1990) documented the water needs of spring wheat, as provided by stored soil moisture and growing season rainfall. They concluded that it takes 3.8 inches of water to give you the first bushel of grain (initial yield point). Using this and other data they calculated a yield equation for different cereal crops in Montana based on the stored soil water and growing season rainfall. They determined that in a moderately high consumptive use area (amount of water transpired by a crop if water was not limiting) grain yield would increase 5.1 bushels of grain per acre for each inch of moisture above the initial yield point of 3.8 inches of water. If the winter wheat crop is removing an inch of soil moisture before replanting, the potential is there to lose up to 5 bushels per acre of grain.

Tillage and soil disturbance to terminate a failed winter wheat stand and to prepare the seedbed for spring wheat seeding can also contribute to soil moisture loss. Soil moisture loss can range from 0.25 -0.50 inches depending on soil type, weather conditions, and implement used (Browning, 2002). Implements that stir the soil (disks, chisels, rototiller), cause more soil moisture loss than implements that cause less disturbance (sweeps, rod weeder). This can range from 0.14 inches to 0.51 inches four days after the tillage operation (Croissant et al., 1992).

Soil Nitrogen

Nitrogen is an essential nutrient for the wheat plant and one of the most limiting in cultivated soils in Montana. Nitrogen is one of two elements absorbed from the soil that are important in the production of chlorophyll, the other being magnesium. Nitrogen is one of the building blocks of protein in the grain kernel. The loss of nitrogen can lead to reduced protein in the grain and resulting loss in the price received at market for the grain. The nitrogen requirements of spring wheat have been well studied.

The Montana State University Extension Service Nutrient Management Handbook (Jones and Jacobsen, 2001) states that 2.8 lbs of nitrogen is needed for each bushel of spring wheat. Thus you would need approximately 112 pounds of soil and fertilizer nitrogen per acre to produce a 40 bushel per acre crop. A loss of

15 lbs. of nitrogen taken up by the preceding winter wheat stand would result in the potential loss of up to five bushels of grain per acre.

Grain is marketed on the basis of protein content. The level of protein in the grain determines the price you will receive per bushel. The price paid for different levels of protein content can fluctuate greatly in the market place. The Portland market average price difference for February 2005 between 13% protein and 14% protein was $0.78 (Montana Wheat and Barley Committee, 2005). On a 40 bushel per acre yield this price difference would amount to a loss of $31.20 per acre.

MATERIALS AND METHODS

Winter wheat plots were established at the Arthur Post Agronomy Farm near Bozeman, MT and the Northern Agricultural Research center near Havre, MT in September of 2002 and 2003. All trials were located in non-irrigated fields but Bozeman 2003 was sprinkler irrigated before planting due to an extremely dry seedbed. The two locations historically differed in annual precipitation, winter temperatures, soil types, and frost free periods. All trials were seeded into tilled soil that had been summer fallowed the previous season.

Eighteen treatments (Table 1) were seeded at each site to simulate various levels of winterkill and provide experimental areas to impose spring reseeding treatments. This was accomplished by planting 215 seeds/m^2 in the fall with seed replacement of the winter hardy variety ‘Erhardt’ with the spring variety ‘Fortuna’ in the appropriate percentages to achieve the target populations due to the freeze induced stand loss of the Fortuna spring wheat. Erhardt was selected for its winter hardiness, as we did not want our winter wheat to fail and cause more reduction in the stands than planned. Fortuna was selected for its awnless trait to differentiate it from the awned Erhardt winter wheat in the event that the spring wheat survived the winter.

There was considerable spring wheat survival at Bozeman in the 2003 crop. This was not evident until heading, when the awnless variety ‘Fortuna’ was seen in the plots. These heads were removed from the plots before harvest. Data from just the winter wheat harvested from the plots was used for analysis.

Table 1. Check and reseeding treatments imposed in 2003 and 2004 harvest years.

Treatment	Stand composition	Stand termination method	Planting date
100% Spring Wheat-Early	100% spring	none	early
100% Spring Wheat -Late	100% spring	none	late
100% Winter Wheat Check	100% winter	none	---
60% Winter Wheat Check	60% winter	none	---
40% Winter Wheat Check	40% winter	none	---
20% Winter Wheat Check	20% winter	none	---
60% WW-Mechanical-Early	60% winter	mechanical	early
40% WW-Mechanical-Early	40% winter	mechanical	early
20% WW-Mechanical-Early	20% winter	mechanical	early
60% WW-Chemical-Early	60% winter	chemical	early
40% WW-Chemical-Early	40% winter	chemical	early
20% WW-Chemical-Early	20% winter	chemical	early
60% WW-Mechanical-Late	60% winter	mechanical	late
40% WW-Mechanical-Late	40% winter	mechanical	late
20% WW-Mechanical-Late	20% winter	mechanical	late
60% WW-Chemical-Late	60% winter	chemical	late
40% WW-Chemical-Late	40% winter	chemical	late
20% WW-Chemical-Late	20% winter	chemical	late

The fall 2003 planting at Bozeman used the imidazolinone tolerant winter wheat variety ‘Above’. This was due to the survival of the spring wheat over the winter the previous year. This herbicide tolerant cultivar allowed the additional option of spraying with the herbicide ‘Beyond’ early in the spring to eliminate the spring wheat and still produce differential winter wheat stands. Erhardt winter wheat was used both years in Havre.

All trials were seeded using a randomized complete block design with four replications. Each trial was seeded at 66 seeds/meter of row or 67.2 kg/ha with row spacing of 0.3 meter. Individual plots were 6 rows by 10.95 meters in length. Longer than normal row lengths were used to allow for soil sampling with a truck mounted hydraulic soil probe on one end of the plots that was removed prior to harvest. All plots at Havre were fertilized with a 70-40-25 blend side-banded at the time of planting, except for the 100% spring wheat plots which were fertilized in the spring at time of planting. At Bozeman a 100-40-40 blend was broadcast and incorporated prior to planting.

In the spring, reseeding treatments were implemented at two time points following two stand termination methods. Reseeding treatments were planted either early or late, and after either chemical or mechanical termination of the surviving winter wheat. Reseeding treatments were planted on terminated winter wheat stands of 60%, 40% and 20% survival. Undisturbed winter wheat stands of 20, 40, 60 and 100% survival were maintained as check plots. Early and late planted spring wheat on fallow provide appropriate check plots to compare to reseeded spring wheat treatments.

Soil samples consisting of one core from each plot were taken. Replications 1 and 2 and 3and 4 were composited giving two replications for analysis. Soil cores were taken at Havre on April 10th and 11th, 2003, and analyzed for soil water and nitrate N. Plant counts (plants/meter) were taken on April 12th to determine winter survival. On April 13th the appropriate plots were terminated for the early reseeding. The chemical termination was achieved by applying 2.34 L/ha of glyphosate with a hand sprayer. Mechanical termination was done with a chisel plow mounted on a 16 hp Kubota tractor. The terminated plots were reseeded with 'McNeal' spring wheat on April 23rd at a rate of 66 seeds/meter of row (67.2 kg/ha).

Bozeman 2003 soil samples were taken in the same manner as in Havre on April 21st and 22nd. The plots were terminated in the same manner as the Havre site on April 22nd. The early reseed date in Bozeman was April 28th.
Prior to the late reseeding at both sites, soil samples were taken from the plots to be reseeded. This was done to evaluate how much moisture and nutrients were used by the crop since the early replant date. In Havre this took place on May 15th, and in Bozeman on May 20th.

The appropriate Havre plots were terminated for late reseeding on May16th. Glyphosate was applied at the same rate as the early termination, using a wick application to avoid spray drift. Mechanical termination was achieved using the same method as earlier, but several passes through each plot were required due to increased plant growth. The plots were reseeded on May 23rd in the same manner as the early reseed.

Termination of the plots for the late reseeding took place in Bozeman on May 21st. The glyphosate was also wick applied to avoid spray drift. The mechanical termination was done with a rototiller due to the problems associated with the chisel plow in Havre. Plots were reseeded on May 28th.

Weeds were controlled by hand hoeing during the growing season. The Havre site in 2003 had a much higher weed infestation than Bozeman because of early season rains followed by drought. On June 20, 2003 the Havre site was hit with a hailstorm, which caused differential damage among the plots. The winter wheat check plots had 5-10% damage; the early seeded spring wheat had 30-35% damage, while the late seeded spring suffered minimal losses.

In 2004, both sites were handled in the same manner as is in 2003. The Bozeman site was sprayed with ‘Beyond’ herbicide at the rate of 0.49 L/ha to control any spring wheat that survived the winter. The early reseeding took place in Bozeman on April 22nd, and at Havre on April 27th. At Bozeman the late reseeding took place on May 24th. Late reseeding did not take place at Havre 2004 due to excessive rain into the month of June. This is not a realistic seeding time for that environment. The same techniques were used for termination and reseeding as in the previous year, except that Above was planted in 2004 at Bozeman.

Agronomic data were obtained for the following variables; plant height, grain yield, test weight, and grain protein. Height was measured between physiological and harvest maturity from the front of each plot from ground level to the top of the grain head. The center four rows were harvested from each plot after measuring and/or trimming to the desired length established plot area. Seed was cleaned and processed to obtain a test weight with a Seedburo test weight apparatus. Subsamples (125 g) were taken from each plot and measured for grain protein by using an Infratec whole grain analyzer. Gross dollar return was calculated by using the August price from Montana Agricultural Statistics. These prices were used to eliminate any local market influences on the price. Each plot was given a base price relative to the different classes of wheat. Any protein premiums were calculated by multiplying the bushels by the extra value associated with the plots protein level.

Data for all variables were analyzed using SAS 9.1 using analysis of variance. Contrast analysis was used to compare early to late reseeding and chemical versus mechanical termination of the winter wheat before reseeding. While early reseeding is preferred, the contrast analysis should verify this. The chemical – mechanical contrast analysis was used to see if there are any differences between these two methods of crop termination that are being currently used by producers.

Contrast analysis also compared the 100% winter wheat check with the reduced stands of winter wheat to compare yield levels at these reduced stands. A contrast analysis also compared the lowest (20%) stand of winter wheat to the early reseeded spring wheat to see if this a feasible farming practice.

RESULTS AND DISCUSSION

Combined Analysis

The two locations used for these experiments represent two diverse climates in Montana agriculture. In general, Bozeman receives much more precipitation, is cooler, and has less wind. Havre has less snow cover and more frigid temperatures during the winter. Overall, Havre is a much harsher climate to grow winter wheat, the years 2003 and 2004 were no exceptions. In both 2003 and 2004, Havre had adequate spring rains followed by a hot, dry July and August. Bozeman did not have the hot dry winds in either year, and had adequate moisture. This difference in climates from year to year in different locations resulted in significant interaction among treatments and environments for most traits.

Since the late reseeding treatments were not implemented at Havre in 2004, the data were analyzed two ways. A three environment (Havre and Bozeman, 2003 and Bozeman, 2004) combined analysis of variance using all eighteen treatments was conducted to examine treatment responses and environment x treatment interaction (Table 2). Means (Table 3) were also obtained. Contrasts were performed to compare individual treatments in the study (Table 4). These contrasts were used to determine if there were any significant differences in yield and gross return between early and late dates of reseeding, chemical and mechanical methods of terminating the winter wheat crop, different levels of winter wheat stands remaining, and whether there was any statistical difference between a 20% winter wheat stand and the reseeded treatments.

The analysis of variance (Table 2) showed that there were significant differences among environment for all four variables. There were also significant treatment effects for all variables. The environment x treatment analysis showed significant interaction for all the variables except for test weight. The only contrast showing a statistical difference was reseeding dates (Table 4). This is to be expected as early seeding generally outperforms late seeding. There was no difference between the mechanical and chemical treatments, or between any of the reduced stands of winter wheat. There also was no statistical difference between the 20%

Table 2. Mean squares from analysis of variance of 18 winter and spring wheat planting treatments grown in three Montana environments.

Source	df	Grain yield	Test weight	Grain protein	Gross return
Env	2	180539639**	27721**	23.1**	2864780**
Rep(env)	9	184731	3484	2.00**	2828
Treatment	17	8911708**	5398*	13.4**	122251**
Env x treatment	34	1324828**	2991	2.4**	18876**

* Significant at the 0.05 probability level
**Significant at the 0.01 probability level

Table 3. Means for 18 spring and winter wheat planting treatments grown in three Montana environments.

Treatment	Yield kg/ha	Test Wt kg/m^3	Protein %	Gross Return $/ha
100% Winter Wheat Check	4301	771	14.8	518.74
40% Winter Wheat Check	3863	778	15.3	466.28
60% Winter Wheat Check	3691	772	15.3	445.40
20% Winter Wheat Check	3352	778	15.2	405.02
100% Spring Wheat Early	2938	736	17.0	375.67
40% Reseeded Early- Mechanical	2873	742	17.4	367.34
20% Reseeded Early- Mechanical	2729	743	18.0	348.91
40% Reseeded Early- Chemical	2715	743	17.9	347.13
20% Reseeded Early- Chemical	2729	741	18.1	333.96
60% Reseeded Early- Mechanical	2612	739	17.9	333.93
60% Reseeded Early- Chemical	2564	742	18.0	327.78
100% Spring Wheat Late	1837	746	17.0	234.79
20% Reseeded Late- Mechanical	1710	748	16.9	218.56
40% Reseeded Late- Mechanical	1692	749	16.6	216.31
20% Reseeded Late- Chemical	1658	686	16.8	211.91
60% Reseeded Late- Chemical	1656	632	17.1	211.72
60% Reseeded Late- Mechanical	1548	692	16.9	197.88
40% Reseeded Late-Chemical	1529	664	17.0	195.46
LSD (0.05)	1195	105	0.8	149.56
C.V. (%)	16.7	7.35	3.4	16.60

Table 4. Probability values for treatment contrasts among selected spring and winter wheat treatments grown in three Montana environments for yield and gross return per acre.

Contrast	Yield	Gross Return
Early vs late seeding	<.0001	<.0001
Mechanical vs chemical reseed	0.77	0.77
100% WW vs 60% WW	0.32	0.34
100% WW vs. 40% WW	0.47	0.49
100% WW vs. 20% WW	0.12	0.14
20% WW vs. early reseed	0.15	0.29

stand of winter wheat and the early reseeded spring wheat treatments. Although not statistically significant, early reseeded spring wheat plots averaged 8% lower than the early seeded spring wheat check and the late seeded spring wheat plots averaged about 11% lower than the late seeded spring wheat check (Table 3).

A four environment (Bozeman 2003 and 2004, Havre 2003 and 2004), 11 treatment analysis was also conducted excluding the late reseeding treatments. A summary of the analysis of variance (Table 5) and means (Table 6) are presented. The same contrasts were analyzed as in the three environment analysis except for the early vs. late contrast as there is no late seeding date in this analysis (Table 7).

The analysis of variance (Table 5) showed highly significant differences among the environments for all the variables. The treatments were also significantly different and the environment x treatment interactions significant for all the variables.

The contrasts showed no significant differences among the selected treatments. The 20% winter wheat stand was statistically no different than the early reseeded treatments. Based on the four environments, early reseeded treatments averaged about 7% less than the early seeded spring wheat check (Table 6).

The significant environment x treatment interaction means that the different treatments were not performing the same at the different environments.

Table 5. Mean squares from analysis of variance of 11 winter and spring wheat planting treatments grown in four Montana environments.

Source	df	Grain yield	Test weight	Grain protein	Gross return
Env	3	94873850*	14494*	52.9*	943464*
Rep(env)	12	606965*	1627*	3.33*	9937
Treatment	10	5638659*	5498*	9.86*	21904*
Env x treatment	30	1124405*	218**	2.11*	15709*

* Significant at the 0.05 probability level
** Significant at the 0.01 probability level

Table 6. Means of 11 spring and winter wheat treatments grown in four Montana environments.

Treatment Return	Yield	Test Wt	Protein	Gross
	kg/ha	kg/m^3	%	$/ha
100% Winter Wheat Check	4271	782	15.6	442.02
60% Winter Wheat Check	3764	784	15.6	368.41
40% Winter Wheat Check	3850	788	15.5	366.29
100% Spring Wheat Early	2909	743	16.9	354.35
60% Reseeded Early- Chemical	2587	748	17.1	342.50
20% Reseeded Early- Mechanical	2754	751	17.2	339.47
60% Reseeded Early- Mechanical	2614	748	17.4	339.47
20% Winter Wheat Check	3428	786	15.9	331.89
20% Reseeded Early- Chemical	2663	753	16.9	327.18
40% Reseeded Early- Mechanical	2866	750	17.0	320.56
40% Reseeded Early- Chemical	2712	748	17.4	313.30
LSD (0.05)	1021	15	1.0	110.86
CV (%)	13.7	1.44	0.9	21.6

Table 7. Probability values for treatment contrasts of selected spring and winter wheat treatments grown in four Montana environments for yield and gross return per acre.

Contrast	Yield	Gross Return
Mechanical vs. chemical reseed	0.76	0.91
100% WW vs. 60% WW	0.33	0.20
100% WW vs. 40% WW	0.42	0.18
100% WW vs. 20% WW	0.10	0.05
20% WW vs. early reseed	0.07	0.89

Soil Moisture and Nitrogen

One question producers have always been concerned about when reseeding is whether to fertilize when they reseed. They also are concerned about how much soil moisture the winter wheat has used before they reseed. Soil samples were taken before the first reseeding and before the late reseeding to determine how much moisture and nutrient were used by the winter wheat crop. Soil sampling is highly variable and this is reflected by the data.

Contrasts were performed in the three environment analysis to determine if any differences occurred in soil moisture or soil nitrogen between winter wheat termination and spring wheat reseeding. Statistical analysis indicated there was no significant difference between the fallow and either the mechanical or chemical treatments in the amount of moisture used (Table 8).

In contrast to reseeded plots, the fallow treatment gained moisture due to rain before planting, but there were no significant differences among the treatments (Table 9). Mechanically treated plots tended to use more water (average 0.34 inch) than the chemically treated treatments (average 0.09 inch). All the treatments gained moisture at the deepest depth as soil water moved down the soil profile but there were no significant differences among treatments at any of the depths, perhaps due to soil variability.

The contrasts showed significant differences between the fallow and the mechanical treatments (P=0.04), and between fallow and the chemical termination treatments for nitrogen use (P=0.07) (Table 8), indicating significant use of nitrogen by the failed winter wheat crop prior to replanting. The only significant difference in nitrogen use was in the 0-6 inch layer of soil (Table 10).

Table 8. Probability values for treatment contrasts for the amount of total water and nitrogen used between the early and late planting dates in three Montana environments.

	Soil moisture	Soil nitrogen
Fallow vs. mechanical	0.14	0.04
Fallow vs. chemical	0.31	0.07
Fallow vs. all reseed	0.18	0.04

Table 9. Average change in soil moisture between the early and late planting dates of seven treatments grown in three Montana environments, 2003 –2004.

Treatment	0-6 inch†	6-24 inch	24-36 inch	36-48 inch	total
Spring wheat – fallow	-0.05	0.01	-0.22	-0.17	-0.43
60% Reseed-mech	0.07	0.30	0.06	-0.14	0.29
40% Reseed-mech	0.13	0.35	0.04	-0.08	0.44
20% Reseed-mech	0.08	0.30	-0.02	-0.08	0.28
60% Reseed-chem	0.04	0.18	-0.09	-0.08	0.06
40% Reseed-chem	0.10	0.22	-0.14	-0.15	0.03
20% Reseed-chem	0.12	0.24	-0.01	-0.18	0.17
LSD	NS	NS	NS	NS	NS
C.V.	286.3	220.0	491.4	177.5	886.9

†Inches of water used, a (-) symbol represents a gain in soil moisture.

Table 10. Average change in soil nitrogen between the early and late planting dates of seven treatments grown in three Montana environments, 2003 –2004.

Treatment	0-6 inch†	6-24 inch	24-36 inch	36-48 inch	total
Spring wheat – fallow	-0.13	11.6	-3.27	-9.80	-1.60
60% Reseed-mech	33.9	41.6	10.2	-13.1	72.6
40% Reseed-mech	45.1	7.60	13.8	-1.67	64.8
20% Reseed-mech	42.7	13.0	-1.20	-6.80	47.7
60% Reseed-chem	30.6	56.7	-25.9	0.60	62.1
40% Reseed-chem	44.5	13.8	-19.0	-8.40	30.9
20% Reseed-chem	39.6	38.7	4.93	-15.9	67.3
LSD	42.8*	NS‡	NS‡	NS‡	NS‡
C.V.	108.2	195.1	1342.2	417.8	138.9

†Pounds of nitrogen used, a (-) symbol represents a gain in soil nitrogen.
* Significant at the $P < 0.05$ level
‡Nonsignificant at the $P < 0.05$ level

Average soil nitrogen use at 0-6 inches in terminated winter wheat plots was 39.4 lb/ac compared to none in the fallow check plot. There was no significant difference in total nitrogen use between the treatments (Table 10). The actual amount of nitrogen used in the top six inches seems very high, which may be explained by the movement of nitrogen down in the soil profile as five out of the six reseeded treatments gained nitrogen in the bottom foot of the soil profile. The 60% stands of remaining winter wheat used the least amount of nitrogen in both the chemical and mechanical set of treatments, which is not expected. The 40% stands used the most nitrogen.

Producers may want to add a small amount of nitrogen when reseeding. Only a small amount is needed as there are still significant amounts of nitrogen present at the deeper soil levels to supply the plants needs, but some supplemental nitrogen in the 0-6 level will help the reseeded spring wheat get established.

Because of the treatment interaction with environments each environment was analyzed individually.

<u>Havre 2003</u>

The crop season started off well in 2003 at Havre, with adequate moisture and good stand establishment. A total of 3.38 inches of precipitation was recorded between April 10th and May 15th. In mid-June, two thunderstorms hit the Research

Center, which caused hail damage. Different levels of damage occurred due to the varying stages of crop development. The winter wheat check plots, which were fully headed by this time, suffered 30-35% hail damage. The early reseeded spring wheat plots suffered 20% damage as they were just in the process of heading. The late reseeding plots only had 5-10% damage as they were more immature and had not headed yet. Subsequently the weather turned hot and dry with constant wind, severely stressing the plants. In July only 0.41 inches of precipitation was received, which is 28% of normal. The average July temperature was also 5.2 °F higher than the long term average of 69.8°F. The yield of 'Fortuna' spring wheat in the variety testing trials at Havre was only 9.5 bu/ac, 34% of the average of the previous nine years. At the end of July a grasshopper infestation infected the plotfield. As the late reseeded spring wheat was the only green plant material in the plot area at the time, those plots were severely damaged, with single stems remaining on most plants in a plot. Also rabbits left evidence that they were feeding in these plots. All of these conditions led to severely reduced yields in this trial.

At Havre in 2003, all winter wheat treatments yielded more and resulted in higher gross income than spring wheat which was damaged by severe late season stress (Table 11). Contrasts statements were used to compare specific treatments within the trial (Table 12). The 20% and 60%winter wheat check treatments yielded less than the 100% winter wheat check treatment, but significantly more than the early planted spring wheat check treatment. There was also a significant difference between the early and late reseeding treatments for yield and gross return. Yield and gross return from early reseeded spring wheat treatments was equivalent to spring wheat on fallow check. There was statistical difference between chemical (635 kg/ha) and mechanical (502 kg/ha) methods of termination before reseeding.

Soil Moisture and Nitrogen

The needs of the crop were met by the 3.38 inches of precipitation that occurred between the two sampling dates for soil moisture and soil nitrogen. All treatments gained soil moisture and there were no significant differences between treatments except in one treatment at the 6-24 inch level (Table 13). Soil nitrogen data is very variable. All treatments lost nitrogen from the top layer of soil as it was moved down the soil profile with rainfall (Table 14). In the 0-6 inch profile the reseeded treatments used significantly more soil nitrogen the fallow check treatment. There were no significant differences in the total amount of soil nitrogen used among the treatments.

Contrasts were performed to compare specific treatments in the trial (Table 15). There were no significant differences between the fallow check treatment and any of the reseeded treatments for total soil moisture or nitrogen use.

Table 11. Means for 18 spring and winter wheat planting treatments grown at Havre, MT
2003.

Treatment	Yield kg/ha	Test Wt kg/m^3	Protein %	Gross Return $/ha
100% Winter Wheat Check	1728	776	16.5	207.71
40% Winter Wheat Check	1559	777	16.8	187.40
60% Winter Wheat Check	1359	773	17.2	163.39
20% Winter Wheat Check	1345	781	17.2	161.62
60% Reseeded Early- Mechanical	1048	748	18.5	134.03
20% Reseeded Early- Mechanical	919	755	18.8	117.50
60% Reseeded Early- Chemical	893	751	18.6	114.25
40% Reseeded Early- Chemical	831	745	18.9	106.27
40% Reseeded Early- Mechanical	827	747	18.5	105.77
100% Spring Wheat Early	825	739	17.6	105.57
20% Reseeded Early- Chemical	775	750	18.8	99.15
100% Spring Wheat Late	547	727	16.4	69.99
20% Reseeded Late- Mechanical	437	728	16.5	55.93
40% Reseeded Late- Mechanical	347	730	16.5	29.48
60% Reseeded Late- Mechanical	231	735	16.5	29.48
20% Reseeded Late- Chemical	188	727	16.7	24.02
60% Reseeded Late- Chemical	170	733	17.6	21.77
40% Reseeded Late-Chemical	157	731	17.3	20.07
LSD (0.05)	304	12.3	0.7	37.39
C.V. (%)	27.2	0.5	3.0	26.9

Table 12. Probability values for treatment contrasts among selected spring and winter wheat treatments grown in 2003 at Havre, MT for yield and gross return per acre.

Contrast	Yield	Gross Return
Early vs late seeding	<.0001	<.0001
Mechanical vs chemical reseed	0.03	0.03
100% WW vs 60% WW	0.02	0.02
100% WW vs 40% WW	0.25	0.27
100% WW vs 20% WW	0.01	0.01
20% WW vs early reseed	<.0001	<.0003

Table 13. Average change in soil moisture used between the early and late planting dates of seven treatments grown in Havre, Montana, 2003.

Treatment	0-6 inch†	6-24 inch	24-36 inch	36-48 inch	total
Spring wheat – fallow	-0.13	-0.26	-0.48	-0.33	-1.20
60% Reseed-mech	-0.05	-0.40	-0.21	-0.33	-0.99
40% Reseed-mech	-0.11	-0.18	-0.35	-0.42	-1.05
20% Reseed-mech	-0.14	-0.14	-0.33	-0.21	-0.82
60% Reseed-chem	-0.10	-0.46	-0.42	-0.22	-1.20
40% Reseed-chem	-0.04	0.02	-0.39	-0.26	-0.67
20% Reseed-chem	-0.14	-0.39	-0.21	-0.45	-1.18
LSD	NS‡	0.43	NS‡	NS‡	NS‡
C.V.	64.64	70.84	63.92	53.13	37.10

†Inches of water used, a (-) symbol represents a gain in soil moisture.
‡Nonsignificant at the P<0.05 level.

Table 14. Average change in soil nitrogen used between the early and late planting dates of seven treatments grown Havre, Montana, 2003.

Treatment	0-6 inch†	6-24 inch	24-36 inch	36-48 inch	total
Spring wheat – fallow	14.8±	-16.8±	-13.8	-29.2	-45.0
60% Reseed-mech	72.1	8.1	-2.6	-49.6	28.0
40% Reseed-mech	84.7	-36.0	21.6	-34.6	35.7
20% Reseed-mech	78.3	-64.5	17.8	7.8	39.4
60% Reseed-chem	97.9	100.5	-87.2	-11.4	99.8
40% Reseed-chem	81.4	-6.9	-68.4	-22.2	-16.1
20% Reseed-chem	83.1	-20.1	5.8	-39.2	29.6
LSD	26.5	114.3	NS‡	NS‡	NS‡
C.V.	15.33	947.8	332.9	193.2	346.5

†Pounds of nitrogen used, a (-) symbol represents a gain in soil nitrogen.
‡Nonsignificant at the P<0.05 level

Table 15. Probability values for treatment contrasts for the amount of total water and nitrogen used between the early and late planting dates in Havre Montana, 2003.

	Soil moisture	Soil nitrogen
Fallow vs mechanical	0.48	0.20
Fallow vs chemical	0.60	0.18
Fallow vs all reseed	0.51	0.16

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Bozeman 2003

The 2003 crop year in Bozeman was very good. Stands were well established in the fall of 2002 and snow cover was maintained during the winter. Due to this snow cover, much of the spring wheat that was interseeded with the winter wheat to achieve our differential stand reductions actually survived the winter. Determination of which plants were winter wheat and which were spring wheat could not be determined until the plants had headed. After heading, the heads of the spring wheat plants were removed, but because they were present during the growing season they prevented plant compensation by the winter wheat plants by using moisture and nutrients that the winter wheat could have used. This resulted in reduced yields for the check winter wheat entries, especially in the 20% winter wheat stands. An example of the surviving spring wheat can be seen in Figure 1.

The data shown are for the winter wheat after the spring wheat heads have been removed. In this environment all the reseeded treatments were significantly lower than the 100% winter wheat check for yield, test weight and gross return (Table 16).

Survival of the spring wheat in treatments designed to simulate reduced winter wheat survival invalidated any meaningful comparisons of the 60%, 40%, and 20% winter wheat checks to any other treatments. The contrast analysis shows that early spring wheat reseeding was superior to late spring wheat reseeding, and that there was no difference between the chemical and mechanical reseed treatments (Table 17).

With the spring wheat surviving the winter it is hard to draw any definite conclusions in this environment. If the spring wheat had died during the winter as planned I would assume that the winter wheat would have performed much better due to plant compensation.

Soil Moisture and Nitrogen:

The early soil samples were taken on April 21 and the late reseeded plots were resampled on May 20 to determine soil water and nitrogen use. There was 2.08 inches of precipitation between the two sampling dates.

Table 16. Means for 18 spring and winter wheat planting treatments grown at Bozeman, MT in 2003.

Entry	Yield kg/ha	Test Wt kg/m^3	Protein %	Gross Return $/ha
100% Winter Wheat Check	5593	777	13.8	672.33
100% Spring Wheat Early	3827	728	17.4	489.53
40% Reseeded Early- Mechanical	3515	736	17.0	449.66
40% Reseeded Early- Chemical	3510	736	16.9	449.02
20% Reseeded Early- Mechanical	3392	731	17.2	433.98
20% Reseeded Early- Chemical	3307	730	17.2	423.11
60% Reseeded Early- Mechanical	3270	728	17.6	418.27
60% Reseeded Early- Chemical	3209	727	17.2	410.21
100% Spring Wheat Late	2245	747	16.7	287.21
60% Reseeded Late- Chemical	1957	753	16.3	250.38
40% Reseeded Late-Chemical	1939	751	16.2	248.04
40% Reseeded Late- Mechanical	1903	750	16.3	243.42
20% Reseeded Late- Mechanical	1895	756	16.7	242.43
60% Reseeded Late- Mechanical	1838	756	16.7	235.17
20% Reseeded Late- Chemical	1733	743	16.5	221.76
LSD (0.05)	672	23	0.9	83.35
C.V. (%)	11.06	2.24	4.09	15.66

Table 17. Probability values for treatment contrasts among selected spring and winter wheat treatments grown in 2003 at Bozeman, MT for yield and gross return per acre.

	Yield	Gross Return
Early Reseed vs. Late reseed	<.001	<.001
Mechanical vs. Chemical	0.84	0.83

Figure 1. Spring wheat mixed with winter wheat, Bozeman 2003.

There was no significant difference in the total amount of soil moisture used among the treatments (Tables 18 and 20). All treatments gained moisture at the deepest level as water moved down in the profile. Once again, due to the spring wheat survival in the winter wheat treatments it is not valid to compare individual treatments in this environment.

The contrast analysis shows that the reseeded treatments used significantly more nitrogen than the fallow spring wheat as would be expected (Table 20). The amount of nitrogen used in reseeded treatments (86.5 lb/ac) is much higher than would be expected and further investigation is needed to determine if this is the actual amount of nitrogen that is being lost in that time period (Table 19).

Table 18. Average change in soil moisture used between the early and late planting dates of seven treatments grown in Bozeman, Montana, 2003.

Treatment	0-6 inch†	6-24 inch	24-36 inch	36-48 inch	total
Spring wheat – fallow	-0.06	0.23	-0.00	-0.07	0.11
60% Reseed-mech	-0.01	0.37	0.22	-0.07	0.52
40% Reseed-mech	0.12	0.32	0.16	-0.07	0.52
20% Reseed-mech	0.19	0.29	0.20	-0.16	0.43
60% Reseed-chem	-0.14	0.33	-0.02	-0.17	0.10
40% Reseed-chem	0.05	0.33	-0.05	-0.12	0.20
20% Reseed-chem	0.04	0.37	0.12	-0.18	0.35
LSD	0.15	NS‡	0.27	NS‡	NS‡
C.V.	215.6	68.68	127.6	97.5	86.99

†Inches of water used, a (-) symbol represents a gain in soil moisture.
‡Nonsignificant at the $P<0.05$ level.

Table 19. Average change in soil nitrogen used between the early and late planting dates of seven treatments grown in Bozeman, Montana, 2003.

Treatment	0-6 inch†	6-24 inch	24-36 inch	36-48 inch	total
Spring wheat – fallow	-12.4	13.8	-3.80	4.60	2.20
60% Reseed-mech	19.4	62.1	1.40	-2.40	80.5
40% Reseed-mech	16.2	14.4	0.80	22.0	53.4
20% Reseed-mech	36.0	83.7	1.40	-1.20	119.9
60% Reseed-chem	8.80	65.7	6.00	1.00	81.5
40% Reseed-chem	22.5	53.7	-1.40	-5.00	69.8
20% Reseed-chem	10.6	96.3	8.60	-1.80	113.7
LSD	26.9	NS‡	NS‡	NS‡	77.0
C.V.	78.75	68.42	530.6	465.1	43.8

†Pounds of nitrogen used, a (-) symbol represents a gain in soil nitrogen.
‡Nonsignificant at the $P<0.05$ level

Table 20. Probability values for treatment contrasts for the amount of total water and nitrogen used between the early and late planting dates in Bozeman Montana, 2003.

	Soil Moisture	Nitrogen
Fallow vs mechanical	0.15	0.03
Fallow vs chemical	0.65	0.02
Fallow vs all reseed	0.30	0.02

<u>Bozeman 2004</u>

To avoid the problem of spring wheat surviving over the winter, new technology was used to alleviate the problem. A winter wheat variety, Above, which is resistant to the imidazolinone herbicides was used. This was mixed with Fortuna spring wheat and seeded in the fall of 2003 to produce differential winter wheat stands. Early in the spring of 2004 'Beyond' herbicide, was sprayed on the plots to eliminate any surviving spring wheat. This process worked to achieve our desired spring survival rates.

Precipitation was down slightly for the 2004 crop year. Between September 2003 and August 2004, 13.36 inches of rain was recorded compared to a long term average of 15.96 inches. Between April 1 and July 31 there was 7.82 inches of growing season precipitation. The average temperature was also slightly above normal at 44.5°F compared to the average of 43.4°F.

The 20% winter wheat check produced the highest yield in this environment, showing how winter wheat has the ability to compensate for reduced stands (Table 21). All the winter wheat check treatments were significantly superior to the early reseed spring wheat treatments for yield and gross return. The early reseeded treatments performed significantly better than the late reseeded treatments. There was no difference between the method of termination before reseeding, chemical or mechanical (Table 22).

<u>Soil Moisture and Nitrogen</u>

This trial was seeded into a dry seed bed in the fall of 2003 and was irrigated before seeding to assure moisture for germination. Winter snow cover was adequate along with spring moisture. The treatments were soil sampled on April 14 and resampled on May 21. There was 1.57 inches of precipitation between the sampling dates.

The mechanically terminated treatments averaged about 1.67 inches less moisture in the profile than the fallow treatments, while the chemically terminated treatments averaged 1.25 inches less (Table 23). Contrasts (Table 25), indicated this was significant for the mechanically terminated treatments. There was no difference in the total amount of nitrogen used among any of the treatments (Tables 24 and 25). The terminated winter wheat treatments used an average of 50 lbs/ac of nitrogen compared to 38 lbs/ac for the fallow check treatment.

Table 21. Means for 18 spring and winter wheat planting treatments grown at Bozeman, MT in 2004.

Entry	Yield kg/ha	Test Wt kg/m^3	Protein %	Gross Return $/ha
20% Winter Wheat Check	6334	811	13.7	768.36
40% Winter Wheat Check	6109	810	14.3	741.06
100% Winter Wheat Check	5568	797	14.2	675.50
60% Winter Wheat Check	5289	801	14.3	641.67
40% Reseeded Early- Mechanical	4269	777	16.8	546.13
100% Spring Wheat Early	4154	777	17.9	531.42
20% Reseeded Early- Mechanical	3867	778	18.1	494.79
40% Reseeded Early- Chemical	3796	784	17.9	485.63
20% Reseeded Early- Chemical	3745	779	18.2	479.21
60% Reseeded Early- Chemical	3581	784	18.2	458.14
60% Reseeded Early- Mechanical	3510	776	17.9	449.05
20% Reseeded Late- Chemical	3046	803	17.3	389.68
60% Reseeded Late- Chemical	2835	806	17.4	362.74
40% Reseeded Late- Mechanical	2820	801	17.2	360.79
20% Reseeded Late- Mechanical	2791	797	17.5	357.05
100% Spring Wheat Late	2712	798	17.9	346.91
60% Reseeded Late- Mechanical	2570	802	17.6	328.76
40% Reseeded Late-Chemical	2486	805	17.5	318.14
LSD (0.05)	739	9	1.1	92.88
C.V. (%)	13.5	0.78	4.38	13.5

Table 22. Probability values for treatment contrasts among selected spring and winter wheat treatments grown in 2004 at Bozeman, MT for yield and gross return per acre.

	Yield	Gross Return
Early Reseed vs. Late reseed	<.001	<.001
Mechanical vs. Chemical	0.72	0.71
100%WW vs 60%WW	0.47	0.48
100%WW vs 40%WW	0.16	0.17
100%WW vs 20%WW	0.05	0.06
20% WW vs. early reseed	<.001	<.001

Table 23. Average change in soil moisture between the early and late planting dates of seven treatments grown in Bozeman, Montana, 2004.

Treatment	0-6 inch†	6-24 inch	24-36 inch	36-48 inch	total
Spring wheat – fallow	0.05	0.05	-0.18	-0.12	-0.20
60% Reseed-mech	0.27	0.94	0.15	-0.01	1.35
40% Reseed-mech	0.37	0.90	0.32	0.26	1.85
20% Reseed-mech	0.27	0.76	0.07	0.12	1.23
60% Reseed-chem	0.27	0.67	0.18	0.16	1.28
40% Reseed-chem	0.27	0.30	0.02	-0.05	0.55
20% Reseed-chem	0.46	0.73	0.05	0.09	1.33
LSD	0.35	NS‡	0.40	0.28	1.56
C.V.	52.5	73.5	194.7	177.2	62.4

†Inches of water used, a (-) symbol represents a gain in soil moisture.
‡Nonsignificant at the P<0.05 level.

Table 24. Average change in soil nitrogen between the early and late planting dates of seven treatments grown in Bozeman, Montana, 2004.

Treatment	0-6 inch†	6-24 inch	24-36 inch	36-48 inch	total
Spring wheat – fallow	-2.8	37.8	7.8	-4.8	38.0
60% Reseed-mech	10.2	54.6	31.8	12.6	109.2
40% Reseed-mech	34.4	44.4	19.0	7.6	105.4
20% Reseed-mech	13.7	19.8	-22.8	-27.0	-16.3
60% Reseed-chem	-14.8	3.9	3.6	12.2	4.9
40% Reseed-chem	29.6	-5.4	12.8	2.0	39.0
20% Reseed-chem	25.2	39.9	0.4	-6.8	58.7
LSD	NS‡	34.2	NS‡	NS‡	NS‡
C.V.	218.0	52.0	336.2	5267.1	160.6

†Pounds of nitrogen used, a (-) symbol represents a gain in soil nitrogen.
‡Nonsignificant at the P<0.05 level

Table 25. Probability values for treatment contrasts for the amount of total water and nitrogen used between the early and late planting dates in Bozeman Montana, 2004.

	Soil Moisture	Nitrogen
Fallow vs mechanical	0.03	0.40
Fallow vs chemical	0.07	0.91
Fallow vs all reseed	0.04	0.69

Havre 2004

Havre in 2004 was characterized by a very wet spring. The month of May had 4.36 inches of precipitation, compared to the long term average of 1.81inches. The early reseeding was done on April 27th. The appropriate time to seed the late reseeding portion of the trial was May 27th. Due to the wet conditions we would not have been able to seed until at least the second week of June, which is not a realistic seeding date in north central Montana. Late reseeding treatments were consequently not implemented in this environment.

All winter wheat check treatments were similar and statistically superior to early reseeded treatments (Table 26). Contrast statements show a difference between the 100% winter wheat check and the 20% check (Table 27) for yield and gross return. The 20% winter wheat check performed better than any of the reseeded treatments. There was also no difference between the fallow spring wheat treatment and any of the reseeded treatments. There was no statistical difference between the mechanical and chemical treatments.

Soil Moisture and Nitrogen

Since there were no late reseeding treatments in 2004 at Havre we will look at the amount of soil moisture and nitrogen removed from early planting to post harvest. This data shows how variable soil sampling can be, with nitrogen use ranging from 195 lbs/ ac used to almost 42 lbs/ac (Table 28). Statistically there were no differences among treatments for soil water or nitrogen utilization (Tables 28 and 29).

Table 26. Means for 11 spring and winter wheat planting treatments grown at Havre, MT
2004.

Treatment	Yield kg/ha	Test Wt kg/m^3	Protein %	Gross Return $/ha
100% Winter Wheat Check	4195	779	14.3	461.61
60% Winter Wheat Check	3993	782	13.7	439.37
40% Winter Wheat Check	3825	781	14.2	420.92
20% Winter Wheat Check	3667	773	14.6	403.53
40% Reseeded Early- Mechanical	2854	740	16.1	329.09
20% Reseeded Early- Mechanical	2838	739	16.0	327.33
100% Spring Wheat Early	2832	726	16.4	326.64
20% Reseeded Early- Chemical	2825	753	15.2	325.80
40% Reseeded Early- Chemical	2710	729	16.2	312.55
60% Reseeded Early- Chemical	2666	733	16.0	307.40
60% Reseeded Early- Mechanical	2630	740	15.9	303.31
LSD (0.05)	643	31	1.4	72.42
C.V. (%)	14.0	2.9	6.4	14.0

Table 27. Probability values for treatment contrasts among selected spring and winter wheat treatments grown in 2004 at Havre, MT for yield and gross return per acre.

Contrast	Yield	Gross Return
Mechanical vs chemical reseed	0.73	0.73
100% WW vs 60% WW	0.33	0.34
100% WW vs 40% WW	0.08	0.09
100% WW vs 20% WW	0.02	0.02
20% WW vs early reseed	<.001	<.001

Table 28. Total soil moisture and nitrogen used between spring planting and post harvest for 11 spring and winter wheat treatments grown in Havre, MT. 2004.

Treatment	Soil Moisture used Inches	Soil nitrogen used lbs/ac
100% Winter Wheat Check	4.62	136.8
60% Winter Wheat Check	4.64	115.1
40% Winter Wheat Check	4.34	122.0
20% Winter Wheat Check	3.16	171.6
100% Spring Wheat Early	3.73	195.2
60% Reseeded Early- Mechanical	3.16	41.9
40% Reseeded Early- Mechanical	4.07	143.6
20% Reseeded Early- Mechanical	4.28	114.2
60% Reseeded Early- Chemical	3.53	151.1
40% Reseeded Early- Chemical	4.13	188.4
20% Reseeded Early- Chemical	3.71	80.8
LSD (0.05)	NS‡	NS‡
C.V. (%)	23.2	67.6

‡Non significant at the P<0.05 level

You would not expect the 20% winter wheat check to use 35 lbs/ac more than the 100% winter wheat check. The soil moisture also shows variation, but we do see downward trend in the amount of soil water used as the stand decreases in the winter wheat checks.

Table 29. Probability values for treatment contrasts for the amount of total water and nitrogen used between the early planting date and post harvest in Havre, Montana, 2004.

	Soil Moisture	Nitrogen
Fallow vs mechanical	0.83	0.64
Fallow vs chemical	0.90	0.97
Fallow vs all reseed	0.86	0.82

CONCLUSIONS

Environments used in this study were extremely variable in nature. There was severe late growing season stress in the 2003 Havre trial and the spring wheat survival in the 2003 Bozeman trial invalidated the winter wheat data in that trial. The significant environment X treatment interaction indicates treatment response was not consistent across environments.

Older producers have a saying that 50% of a winter wheat crop is still better than a full spring wheat crop. Data from Holen et.al., 2001, shows that this may be reduced to a figure of 35%. This is based on the capacity of a reduced stand of winter wheat to compensate for yield loss through increased tillering, larger heads, and heavier kernels to achieve yields similar to winter wheat without significant stand loss.

A critical management input when considering reseeding, is knowing how a replanted spring wheat crop compares to a winter wheat stand reduced to below this critical 35% level.

Winter wheat yields and gross return showed a trend downward corresponding with reduced stands, but showed few statistical differences. This shows that under good conditions we may be able to reduce seeding rates and allow the plant to compensate to achieve optimum yields in favorable environments.

The contrast comparing the 20% winter wheat treatment and the early reseeded treatment showed no statistical differences in the combined 3 and 4 environment analyses. However, in 3 out of 3 (Bozeman 2003 invalid) individual environments the 20% stand of winter wheat performed better than the early planted spring wheat check treatment. If you are able to control the weeds in the reduced stands I feel that it would be profitable to not reseed a reduced stand of less than 35% in certain environments. This study only reports the yield and gross return per acre. If you would add in the cost of reseeding it would increase the probability of making more of a profit by not reseeding. This result showing a 20% winter wheat stand is at least equivalent to an early planted spring wheat stand should be verified in additional environments.

The early reseeded treatments were significantly better than late reseeded treatments in 3 of 3 environments (no late reseed in Havre 2004). Later seeding as a general rule does not fair as well, as the plant does not have as much time to tiller and use the available resources such as moisture and nutrients. As seen in Havre 2003 late planting can also increase susceptibility to summer heat stress. Late reseeding of a failed winter wheat crop is not a viable option. If it gets too late in the year to reseed, the reduced stand of winter wheat winter wheat is the best option.

There may be a yield penalty associated with reseeding. On average, early reseeded spring wheat yielded 93% of the early planted spring wheat check. There may be many reasons. Planting into the untilled chemical termination plots can result in poor seed to soil contact and may lead to residue pathogens such as

Rhizoctonia. There may also be a use of soil water and nutrients which we were unable to quantify.

There was no statistical difference in the spring wheat yields in the method of termination, chemical or mechanical, of the surviving winter wheat stand before reseeding in 3 of 4 environments. Chemical termination was expected to perform better due to the loss of moisture in the soil due to tillage. In 2003 the chemical reseed treatments were seeded directly into the killed row of winter wheat. This resulted in slow germination due to poor seed to soil contact. In 2004 this was avoided planting between the killed rows resulting in improved germination.

There was some evidence for significant utilization of soil water by terminated winter wheat in one of three environments and some evidence for significant nitrogen use by the terminated winter wheat in one of three environments. However, results were inconsistent and no valid conclusions could be made. Since soil data was highly variable more data is needed to draw any conclusions about the amount of soil moisture and nitrogen used by the surviving winter wheat stands before reseeding.

While this study seems to indicate a grain yield and economic return advantage from a 20% winter wheat stand compared to an early reseeded spring wheat, more data are needed to validate any conclusions. More data points and environments need to be sampled to make a solid conclusion. Smaller trials comparing only 20% winter wheat stands to reseeded spring wheat may make this feasible. Using producer fields that have a significant stand reduction may be another option.

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