Dickinson Research Extension Center
1089 State Avenue
Dickinson, ND 58601

1999 Diagnosis and Management of Root Disease in Dryland Wheat in Western North Dakota

[(1)]R.O. Ashley, M.P. McMullen, J.A. Staricka, E.D. Eriksmoen, P.M. Carr,
B. Schmidt, M. Whitney, P. Carpentier, R. Schmidt, M. Claymore, H. Peterson

Summary

Western North Dakota spring wheat (*Triticum aestivum* L.),and durum (*Triticum turgidum* L. Durum Group), producers commonly plant into ground previously planted to wheat, durum, or barley (*Hordeum vulgare* L.) The objective of this project was to demonstrate the extent that root disease affects yield and quality of wheat in continuous wheat sequences and the effect that crop rotations have on reducing root disease. Field demonstrations were initiated at seven locations in western North Dakota in 1999. Methyl bromide fumigant was used in plots to control fungal root diseases. Root disease ratings were consistently lower in fumigated plots than in natural (non-fumigated) soil plots. Under continuous wheat sequences, yields from fumigated plots were 37% to 78% greater than from wheat grown in natural soil plots. Grain protein and test weight tended to be higher than natural soil plots. When wheat was grown in a wheat-fallow rotation, grain yield from fumigated plots was 23% greater than from natural soil plots.

Introduction

The flexibility allowed producers by the Federal Agriculture Improvement and Reform (FAIR) Act of 1996 and favorable prices for hard red spring wheat, durum, and barley in 1995 and 1996 prompted many western North Dakota producers to abandon summer fallow and initiate continuous cropping of these cereal grains. Statewide, North Dakota producers in 1997 seeded nearly 62% of their wheat acres on fields that were either in wheat or barley the previous year (McMullen, 1998). In western North Dakota, of the known previous crops reported in this study, 75% of the wheat grown had been in fields where wheat or barley was grown the previous year. In 1998 and 1999 prices fell, prompting some producers to either go back to the wheat-fallow system or consider abandoning the use of non-host crops in rotation with wheat.

Research conducted by North Dakota State University (NDSU) (Stack and McMullen, 1995) and Canadian scientists (Ledingham, et. al., 1973; Mathieson, 1943; Butler, 1961) suggests that root and crown diseases reduce yields an average of from five to ten percent. In continuous cereal and cereal fallow rotations, yields are commonly lower than expected based on available soil moisture and growing season precipitation. Cook (1990) over a 15-year period found that when root and crown diseases were controlled with fumigation in continuous winter wheat rotations, an average 70% yield increase could be expected. A one-year break and two-year break between wheat crops produced a 22% and 7% yield increase, respectively, for fumigated compared to non-fumigated plots. Producers are encouraged to incorporate crop rotations into their farming practices. Crop rotations have been shown to reduce pest problems while improving yields and quality of subsequent crops (Black and Siddoway, 1975). Many producers do not fully realize the extent of yield and quality losses that result from root and crown disease problems. This demonstration provided producers the opportunity to see the impact of root diseases on dryland wheat and durum wheat in western North Dakota and the role that crop rotation can play in disease control.

Materials and Methods

Seven locations with a history (Table 1) of either continuous cereal grain or cereal grain - fallow rotation were selected. Agronomic practices and estimated stored soil water and precipitation were recorded (Table 2). Stored soil water was estimated at the time of fumigation with the use of a Paul Brown Soil Moisture Probe (Brown and Carlson, 1990). Producers for the on-farm locations at Amidon and Garrison recorded precipitation. The North Dakota Agricultural Weather Network (NDAWN) at Beach, Hazen and the Williston Research Extension Center provided precipitation data for their respective sites. The National Oceanic and Atmospheric Administration weather observation sites at Center 4SE and Shields provided precipitation information for the Center and Selfridge locations respectively (Kail, 1999).

A randomized complete block design with four replications was used at all locations except the Williston Research Extension Center, where six replications were utilized. Plots at Williston and Beach were fumigated in the fall of 1998. Also, a set of plots at the Beach location was fumigated in the spring of 1999. At all other locations the fumigant was applied in the spring of 1999. Each plot was 300 ft^2 (28 m^2). Plots to be fumigated were covered with a six mil plastic sheet, edges buried in trenches four to six inches deep to seal the covered area, and methyl bromide was metered through plastic hoses at the rate of one pound per 100 ft^2 (50g m^{-2}). Fumigated plots remained covered for 48 to 120 hours after which time the plastic was removed. Non-fumigated or natural soil plots served as checks. After the plastic was removed, producers farmed through the fumigated and natural soil plots with their normal management practices. After planting but prior to emergence, metalaxyl, a fungicide, was applied to the soil surface at the rate of five pounds active ingredient per acre at the Beach location. Metalaxyl has activity against *Pythium*, a potential root pathogen of wheat and other crops. Rainfall did not occur at that location until five days after application.

Root samples were collected from plots between Haun stage 5 and 11 at all locations except Williston and then again at Haun stage 14.5 (soft dough stage) from all locations. Samples were carefully washed by hand. An evaluation of the first group of samples was completed at the Dickinson Research Extension Center. Plant length, plant development, root counts, and evaluation of the subcrown internode were noted. The second group of root samples was sent to the NDSU Plant Pathology Department for agar plate culture evaluation and a visual evaluation of root mass, root color, and extent of root rot lesions on the subcrown internode.

Soil samples collected at Haun stage 14.5 from the four to six inch depth at the Amdion and Williston locations were submitted to Eden Bioscience, Bothell, WA for a biological soil assay for *Pythium* spp., *Fusarium* spp. and *Rhizoctonia* spp. *Pythium* presence and levels were determined using a modification of J. Michell’s selective antibiotic medium (1981); *Fusarium* presence and levels were determined using Komada’s medium (Komada, 1975); and *Rhizoctonia* presence and levels were determined using a MKH at 1:1000 dilution (Sneh, 1991).

Early crop water-use from planting on April 28 to May 20 was calculated using the procedure outlined by Doorenbos and Pruitt, (1984) and the reference crop evapotranspiration factor (ETo) calculated by NDAWN at Williston. Soil moisture was measured in fumigated and natural soil plots at the Williston Research Extension Center location with a neutron probe once a week. Water-use was calculated using differences in soil moisture content and adjusted to include rainfall. Cumulative water use was calculated by summing estimated early crop water use and water use determined from differences in soil moisture content adjusted for rainfall. Water-use efficiency (WUE) for the two treatments was calculated using the following equation: WUE = Grain yield (bu/A)/Cumulative water-use.

Head density, mature plant height, and total above ground biomass were measured at harvest. At all locations but Williston, yield samples were harvested from each plot by hand from an area four rows wide by 8 ft (2.4 m) long, bagged, hung up to dry, threshed, and yield and quality factors measured. At Williston, samples were machine harvested from an area 4 ft (1.2 m) wide by 18 ft (5.4 m) long. Protein was analyzed with an NIR analyzer at Southwest Grain Inc., Dickinson, ND for all samples except Williston.

All data was statistically analyzed using SAS Statistical software version 6.12 (SAS Institute Inc., 1996).

Results and Discussion

Yield and Quality

Significant differences in grain yield were detected between fumigated and natural soil plots at all locations except Hazen (Table 3). Wet soil conditions prevented planting durum in the Hazen field until June 14, 1999, two weeks later than Selfridge, the next latest location. Extremely high levels of septoria, and tan spot infections were noted at the Hazen location. Roviara and Ridge (1979) found that when rust infection occurred late in the season, grain yields of wheat grown on fumigated soils were not increased to the extent that they were when rust was not a yield-limiting factor. Foliar disease infection occurred early in the development of the crop and the severity worsened as the season progressed. When compared to natural soil plots, wheat and durum grain yields were 78% greater at Beach; 75% greater at Center; 38% greater at Garrison; 63% greater at Selfridge; and 37% greater at Williston from fumigated plots when grown in continuous wheat rotations. Yield differences seen at Beach and Center were probably due to the effect of both weeds and diseases. High populations of weeds were present at these two locations. Weeds were not a yield limiting problem at Amidon, Garrison, Selfridge, and Williston. In the wheat-fallow rotation at Amidon, grain yields were 23% greater from the fumigated plots than from the natural soil plots.

There were no observed differences in weed populations between fall fumigated and spring-fumigated plots at Beach yet grain yields were significantly lower for fall-fumigated plots. Soil conditions during fumigation in the fall were very dry while spring soil conditions were moist. Since effectiveness of fumigant on various fungi in the soil is dependent on contact time of the fumigant with fungi and fungi in a susceptible state, the control of soil-borne pathogens was incomplete in the fall compared to the spring when soils were moist (Vanachter, 1979).

In continuous wheat rotations where weeds were not considered a contributing factor in yield differences, total biomass production was 29% to 49% greater from the fumigated plots compared to the natural soil plots. In the wheat-fallow rotation, total bio-mass production was 16% greater from the fumigated plots than the natural soil plots.

Grain protein content was significantly higher at the Amidon and Beach sites. At these locations grain from the fumigated plots had one to one and a half percent more protein than grain from natural soil plots. Test weight was two pounds heavier for grain from the fumigated plot. However, at Williston, grain from fumigated plots was a pound lighter compared to the natural soil plots.

Plant Length, Mature Plant Height, and Head Density

The initial length of plants (Table 4) growing on fumigated plots at Beach and Selfridge was significantly longer than plants grown on natural soil plots. At the other locations analyzed, plant length tended to be longer from fumigated plots compared to natural soil plots. Differences in plant length among treatments tended to be maintained to maturity but the only site showing significant differences of plant height (Table 3) at maturity was at Beach.

Plant population counts at emergence were made only at Williston (580,000 plants/acre fumigated vs. 520,000 plants/acre natural soil plots: not significant). Head density (Table 3) was significantly greater at all locations except at Garrison. Variability in soils likely caused a large amount of variability in head density counts.

Root Assessments

Initial root evaluations (Table 4) indicated that plants growing on fumigated plots had greater seminal root and crown root numbers than plants growing on natural soil plots at Center and Garrison. At other locations seminal root counts tended to be higher for plants grown on fumigated plots than from natural soil plots. Hazen, at the second root evaluation (Table 5) had significantly greater portion of the subcrown internode of plants growing on natural soil plots was covered by lesions than plants growing on fumigated plots. At other locations a similar tendency was observed but was not statistically significant.

Crown root counts for fumigated plots at Amidon, Beach, Center, and Selfridge were significantly greater than crown root counts for natural soil plots. At Beach, where metalaxyl was applied as a post plant soil treatment, crown root counts were significantly greater than in natural soil plots although there was no difference of crown root counts between the fumigated and metalaxyl treatments. As noted earlier there was no significant difference in grain yield between the metalaxyl treatment and natural soil plot, but there were differences between fumigated and natural soil plots. A portion of this grain yield difference between fumigated and natural soil plots can be attributed to high weed populations growing in the natural and metalaxyl treated plots. *Pythium* is known to be very sensitive to metalaxyl (Cook et. al. 1987; McMullen and Lamey, 2000). *Pythium* is known to "destroy" root hairs of plants, reducing the number and size of crown roots (Cook, 1990). When metalaxyl removed the competition of *Pythium* for plant resources, normal root development similar to that in fumigated plots occurred. Though competition from *Pythium* was removed, the weed competition in the metalaxyl treated plot overwhelmed the ability of the plant to out compete the wild oat problem.

Pythium was found in tissue samples from Beach, Center, and Garrison. Tissue samples were not cultured from the other locations in this demonstration. Though not cultured from samples submitted from this demonstration, *Bipolaris sorokiniana* (syn. *Helminthosporium sativum*) was detected in samples submitted for a seed treatment demonstration conducted at Regent. Symptoms of Common root rot (*Bipolaris sorokiniana*) were noted during subcrown internode examinations.

Soils were sampled at the Amidon and Williston sites. Soil biological assays were conducted for *Pythium* spp., *Fusarium* spp., and *Rhizoctonia* spp. At Amidon, where the field had been in a wheat-fallow rotation for at least 20 years, *Fusarium* and *Pythium* was detected at a level of 139 propagules per gram (ppg) of soil for each of the fungi species found. Of these three fungi species assayed for only *Pythium* was detected at Williston at a level of 70 ppg.

Water-use Efficiency -Williston

Crop evapotranspiration on both fumigated and natural soil plots for the period of April 28 to May 20 was estimated to be 1.92 inches. From May 20 and for the rest of the growing season, water content of soils at the Williston Research Extension Center location was measured weekly with a neutron moisture gauge and water-use calculated (Table 6). Wheat grown on the fumigated plots extracted 0.60 inches more water from the soil than wheat grown on natural soil plots. Water extracted from specific soil depths in the fumigated plots occurred earlier in the growing season compared to natural soil plots. The pattern of water removal from soil is similar to root development and profile of root distribution (Briggs, 1978). The water-use pattern in this experiment suggests that roots of plants growing on the fumigated plots penetrated the soil profile at a faster rate earlier in the season than plants growing on the natural soil plots.

Water-use efficiency in terms of grain yield was 4.45 bushel per inch of water from fumigated plots while natural soil plots was 3.40 bushel per inch of water. Passioura (1977) suggested that an increase in evapotranspiration or water-use efficiency or harvest index should increase grain yield. This was based on the assumption that there would not be any significant negative relationships among these three variables. Aggarwal et. al. (1986) demonstrated under field conditions that an increase in evapotranspiration resulted in lower water-use efficiency. However, Aggarwal increased the amount of water available to the plant through irrigation. In the dryland situation at Williston, where evapotranspiration increased due to greater exploration of the soil volume by increased root activity, this negative relationship did not hold.

Implications of Demonstration

Root disease ratings were consistently lower in fumigated plots than natural soil plots with a field history of continuous wheat and wheat-fallow. In previous demonstrations (Ashley et. al. 1998 and Ashley et. al. 1997) root disease ratings were consistently lower in fumigated plots than in natural soil plots with a field history of continuous wheat but were the same when crop rotations included crops that were poor hosts to wheat root disease. Plants with healthier root systems can extract more water from the soil and are more efficient in utilizing the moisture and nutrients absorbed in the production of grain. This and previous demonstrations indicate that when wheat is grown in a continuous wheat rotation, there is approximately a 40% difference in yield between fumigated and natural soil plots. When a one-year break in the wheat rotation occurs, such as a non-host crop or summer fallow, there was about a 24% difference between fumigated and natural soil plots. When a two-year break in the crop rotation utilizes non-host crops, there was no difference between fumigated and natural soil plots.

Cooperating Producers

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(1) R.O. Ashley, Area Extension Specialist/Cropping Systems, Dickinson, Research Extension Center, Dickinson, ND; M.P. McMullen, Extension Plant Pathologist, NDSU, Fargo, ND; J.A. Staricka, Soil Scientist, Williston, Research Extension Center, Williston, ND; E.D. Eriksmoen, Agronomist, Hettinger Research Extension Center, Hettinger, ND; P.M. Carr, Agronomist, Dickinson Research Extension Center, Dickinson, ND; B. Schmidt, Mercer County Agent, Beulah, ND; M. Whitney, Slope County Agent, Amidon, ND; P.Carpentier, McLean County Agent, Washburn, ND; R. Schmidt, Oliver County Agent, Center, ND; H. Peterson, Golden Valley County Agent, Beach, ND.

Table 1. Cropping history[1] of selected fields in western North Dakota.

Location	1998	1997	1996	1995	1994	1993
Amidon	sf	hrsw	sf	hrsw	sf	hrsw
Beach	hrsw	hrsw	hrsw	hrsw	hrsw	hrsw
Center	hrsw	barley	hrsw	hrsw	oat	na
Garrison	durum	barley	durum	sf	oat	durum
Hazen	barley	sf	durum	sf	durum	durum
Selfridge	hrsw	sf	hrsw	hrsw	hrsw	hrsw
Williston	hrsw	hrsw	hrsw	hrsw	hrsw	hrsw

1 Cropping history: hrsw = hard red spring wheat; durum = durum wheat; sf = summer fallow; and na = not available.

Table 2. Agronomic practices and water, 1999.

Location	Cultivar	Tillage system	Weed severity rating	Seed treatment	Estimated stored soil water[1]	Growing season precipitation[2]	Total water
					inches	inches	inches
Amidon	Trenton hrsw	conventional	none	Vitavax Extra (carboxin + imazalil + thiabendazole	6.8	6.53	13.3
Beach	Ernest hrsw	minimum	high	RTU Vitavax (carboxin)	7.0	5.38	12.4
Center	Russ Hrsw	minimum	high	none	8.0	9.34	17.3
Garrison	Ben Durum	conventional	low	none	6.6	4.35	11.0
Hazen	Renville durum	no-till	none	DB Green L + RR (mancozeb + lindane + imazalil)	8.8	8.05	16.9
Selfridge	Kulm Hrsw	minimum	none	none	8.0	11.26	19.3
Williston	Keene hrsw	no-till	none	none	8.6	4.45	13.1

1 Williston stored soil water estimate made using neutron probe. All remaining stored soil water estimates were made using the Brown probe.

2 Growing season precipitation at Beach, Hazen, and Williston was provided by NDAWN. Growing season precipitation at Amidon and

Garrison was recorded by participating producers. Growing season precipitation values used for Selfridge and Center were from National Oceanic and Atmospheric Administration weather sites at Shields and Center 4SE respectively.

Click on the Table numbers below to view tables.

Table 3. Yield, test weight, protein, height, head density, and total biomass of wheat at selected locations in North Dakota, 1999.

Table 4. Initial root and plant evaluations of wheat in various rotations in selected fields in North Dakota, 1999.

Table 5. Visual root scores for wheat at soft dough stage grown at selected locations in North Dakota, 1999.

Table 6. Water-use at various soil depths over specific time periods for hard red spring wheat grown on fumigated and natural soil plots at Williston Research Extension Center, 1999.

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