TILLAGE, CROPPING SEQUENCE, AND NITROGEN FERTILIZATION EFFECTS ON DRYLAND SOIL NITROGEN AND MALT BARLEY YIELD

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ABSTRACT

Information on management practices is needed to reduce N fertilization rate and soil erosion and sustain dryland malt barley yield and quality in the northern Great Plains. The effects of combinations of tillage and cropping sequences [continuous no-tilled malt barley (*Hordeum vulgaris* L.)(CNTB), no-tilled malt barley-pea (*Pisum sativum* L.) (NTB-P), no-tilled malt barley-fallow (NTB-F), and conventional-tilled malt barley-fallow (CTB-F)] and N fertilization rates (0, 40, 80, and 120 kg N ha^{-1}) were studied on dryland soil NO_3-N content and malt barley yield and quality from 2005 to 2007 in eastern Montana. Soil NO_3-N content at the 0-120 cm depth after crop harvest in the fall were greater in CTB-F than in CNTB and NTB-F and greater with 120 than with 0 and 40 kg N ha^{-1}. Malt barley grain yield was greater in CTB-F than in CNTB and NTB-P in 2006 and greater with N fertilization than without in 2006 and 2007. Grain protein content and N uptake increased but test weight and kernel plumpness decreased with increased N rates in 2007. Plant stand and biomass (stems + leaves) yields were not influenced by treatments in 2006 but were greater with 120 than with 0 and 40 kg N ha^{-1} in 2007. Similarly, biomass N concentration was not influenced by treatments but N uptake was greater with 40 than with 0 kg N ha^{-1} in 2007. Results suggests that no-tilled continuous cropping and 40 kg N ha^{-1} can be used to sustain dryland malt barley yield and quality and reduce the costs of N fertilization and fuel for tillage and potentials for N leaching and soil erosion compared with the conventional CTB-F and 80 kg N ha^{-1} in the MonDak (eastern Montana and western North Dakota) region of the northern Great Plains.

INTRODUCTION

The conventional CTB-F is the most commonly used practice to grow dryland malt barley in the northern Great Plains. Although irrigated malt barley production is getting popular where irrigation facilities are available, most of the production still occurs in drylands that constitute about 90% of area in the Mondak region. While conventional tillage can increase soil NO_3-N content due to increased organic matter mineralization (Halvorson et al., 1999), no-tillage can reduce soil erosion and increase organic matter content (Halvorson et al., 2006) and water storage (Lenssen et al., 2007) compared with conventional tillage. Although fallowing can increase soil water storage and successive crop yields (Lenssen et al., 2007), reduced crop input and increased soil water content and temperature during fallow can further reduce organic matter (Haas et al., 1974). The use of no-tillage has allowed producers to increase cropping intensity due to increased precipitation storage efficiency (Peterson et al., 1996).

The 80 kg N ha^{-1} is the recommended rate of N fertilization for dryland malt barley production in the MonDak region (MSU, 1997). Because of increased protein content with increased N fertilization that reduce the quality of malt barley for malting purpose (Clancy et al., 1991), N fertilization rate needs to be adjusted especially for dryland malt barley production. Similarly, high cost of N fertilization necessitated that N fertilization rate be reduced to sustain malt barley yield and quality and reduce the potential for N leaching. One of the ways to reduce N fertilization rate is to include legume in the crop rotation. The objective of this study was to evaluate the effects of the combinations of tillage, cropping sequence, and N fertilization rate on soil NO_3-N content at the 0-120 cm depth and malt barley yield and quality from 2006 to 2007 in the Mondak region of the northern Great Plains.

MATERIALS AND METHODS

Experiments were conducted at two separate locations, 500 m apart, from 2005 to 2007 on a dryland farm, 15 km north of Sidney, eastern Montana. At both locations, soil was Williams loam (fine-loamy, mixed, Typic Argiborolls) with 350 g kg^{-1} sand, 325 g kg^{-1} silt, 325 g kg^{-1} clay, 7.2 to 7.4 pH, 53.7 to 55.8 Mg ha^{-1} total C content, and 2.1 to 2.5 Mg ha^{-1} total N contents at the 0 to 30 cm depth. Previous crops were spring wheat (*Triticum aestivum* L.) and safflower (*Carthamus tinctorius* L.).

Treatments included combinations of four tillage and cropping sequences [continuous no-tilled malt barley (CNTB), no-tilled malt barley-pea (NTB-P), no-tilled malt barley-fallow (NTB-F), and conventional-tilled malt barley-fallow (CTB-F)] and four N fertilization rates (0, 40, 80, and 120 kg N ha^{-1}). All treatments, except CTB-F, were applied with glyphosate at 1.8 kg a.i. ha^{-1} to control weeds before planting and after harvest, while CTB-F was plowed with sweeps and rods to a depth of 10 cm as needed during crop growth and fallow. Appropriate types and amounts of herbicides and pesticides were also applied to control weeds and pests during growth of malt barley and pea. Treatments were arranged in a randomized complete block with three replications. The subplot size was 12.0 m by 3.0 m.

Six-row malt barley (cv. Certified Tradition) was planted at 45 kg ha^{-1} and pea (cv. Majorette) at 101 kg ha^{-1} with a no-till drill in April of each year from 2005 to 2007. In the first phase of the crop rotation, N fertilizer as urea and mono-ammonium phosphate at 80 kg N ha^{-1}, P fertilizer as mono-ammonium phosphate at 29 kg P ha^{-1}, and K fertilizer as muriate of potash at 27 kg K ha^{-1} were banded to malt barley. Similar rates of P and K fertilizers were banded to pea, along with 5 kg N ha^{-1} while applying mono-ammonium phosphate. In the second phase of the rotation, P as triple super phosphate and K as muriate of potash were banded to malt barley as above but N as urea was broadcast at four rates (0, 40, 80, and 120 kg N ha^{-1}). No fertilizers were applied during the fallow phase of the rotation. In July and August of each year, malt barley and pea grain yields were determined from an area of 10.0×1.5 m^2 with a combine harvester and biomass (stems + leaves) production from an area of 1.0 m^2, after which the residue was returned to the soil.

Soil samples were collected from the 0-120 cm depth from five places within the plot with a hydraulic probe (5 cm i.d.) after crop harvest in August-September of each year. These were divided into six depths (0-5, 5-10, 10-30, 30-60, 60-90, and 90-120 cm), composited by depth, air-dried, ground to 2 mm, and analyzed for NO_3-N content by using auto-analyzer (Lachat Instrument, Loveland, CO). A separate soil core from above depths was also collected at the same time to determine bulk density and to convert soil NO_3-N concentration (mg kg^{-1}) to content (kg ha^{-1}).

Data were analyzed using the MIXED model of SAS (Littell et al., 1996). Tillage and cropping sequence combination was considered as the main plot and N fertilization rate as the subplot treatment. Means were separated by using the least square means test when treatments and interactions were significant. Statistical significance was evaluated at $P \leq 0.05$, unless otherwise mentioned. Regression analysis was done to determine the relationship between N fertilization rate and malt barley yield.

RESULTS AND DISCUSSION

Soil Nitrate-Nitrogen

In 2006, soil NO_3-N contents at 0-5, 5-10, and 0-30 cm depths were greater in CTB-F than in CNTB, NTB-P, and NTB-F (Fig. 1). Similarly, NO_3-N contents were greater with 120 than with 0 and 40 kg N ha^{-1}. In 2007, NO_3-N contents at 0-120 cm were greater in NTB-F and CTB-F than in CNT-B and NTB-P and greater with 80 and 120 than with 0 and 40 kg N ha^{-1}. Tillage, followed by fallow could have increased mineralization of soil organic N (Halvorson et al., 1999), thereby resulting in increased NO_3-N content in CTB-F compared with CNTB and NTB-P. Inclusion of pea in NTB-P did not increase NO_3-N, probably because it may take long time to decompose pea residue in the dryland agroecosystem in the northern Great Plains due to cold weather and limited precipitation (Table 1). Greater NO_3-N content with 80 and 120 than with 0 and 40 kg N ha^{-1} indicates that these N rates were probably higher for dryland malt barley production. Increased NO_3-N accumulation in the soil profile probably results in greater potential for N leaching. Interaction of tillage and cropping sequence with N rate was not significant for NO_3-N content.

Malt Barley Yield and Quality

Malt barley grain yield was greater in CTB-F than in CNTB and NTB-P in 2006 but was not influenced by tillage and cropping sequence in 2007 (Table 2). Grain yield was greater with N fertilization than without in both years. In 2007, grain protein content and N uptake were greater with 80 and 120 than with 0 and 40 kg N ha^{-1}. In contrast, grain test weight and plumpness decreased with increased N fertilization rate. Plant stand and biomass yield were not influenced by treatments in 2006 but were greater with 120 than with 0 and 40 kg N ha^{-1} in 2007 (Table 3). Similarly, biomass N concentration was not influenced by treatments but N uptake was greater with 40 and 80 than with 0 kg N ha^{-1} in 2007. Similar to soil NO_3-N, interaction of tillage and cropping sequence with N fertilization for all plant parameters was not significant. Both grain and biomass yields responded in a second order polynomial with N fertilization (Fig. 2).

Variations in the trend of malt barley grain and biomass yields between CNTB, NTB-P, NTB-F, and CTB-F in 2006 and 2007 suggests that tillage and cropping sequence have variable effects, although soil NO_3-N content was greater in CTB-F than in CNTB and NTB-P (Fig. 1). These differences between tillage and cropping sequence treatments in 2006 and 2007 partly results from variations in climatic conditions between years (Ullrich and Muir, 1986). Although growing season (April-August) precipitations were normal, 86 mm more precipitation occurred in May in 2007 than in 2006 (Table 1). Greater water availability during the active growing period of barley in May probably produced higher plant stand and grain and biomass yields in 2007 than in 2006 (Tables 2 and 3). Although N fertilization increased grain and biomass yields compared with no N fertilization in both years, similar grain yields among N rates suggests that 80 and 120 kg N ha^{-1} may be too high for dryland malt barley production in the MonDak region. These N rates also increased grain protein content but decreased kernel plumpness compared with 0 and 40 kg N ha^{-1}. Since protein content of malt barley should be <130 g kg^{-1} and kernel plumpness >750 g kg^{-1} for malting quality (AMBA, 2005), N fertilization rate of 40 kg N ha^{-1} could be used for sustaining malt barley yield and quality and reduce the cost of N fertilization and the potential for N leaching. This rate, however, could be altered depending on soil NO_3-N content before planting. Soil NO_3-N contents at the 0-30 cm depth before planting in the spring of 2006 and 2007, averaged across tillage and cropping sequence treatments, were 21 and 36 kg ha^{-1}, respectively. This suggests that available N (soil NO_3-N at 0-30 cm + fertilizer N) should range from 61 to 76 kg ha^{-1} for optimum dryland malt barley production. As a result, annual soil testing before planting needs to be done to adjust the rate of N fertilization. Long-term studies that account for malt barley yield and quality for a number of years and recommended soil NO_3-N content at 0-60 cm depth to determine available N are needed to determine the actual management practices required for dryland malt barley production.

CONCLUSIONS

Results of this study suggests that tillage and cropping sequence have variable effects on dryland malt barley grain yield but N fertilization increased grain yield, protein content and soil NO_3-N content and decreased kernel plumpness. To determine the proper crop and N management practices for dryland malt barley production, long-term studies are needed that account for malt barley yields and quality for a number of years and soil NO_3-N content to a depth of at 0-60 cm in the Mondak region of the northern Great Plains.

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Table 1. Monthly average, crop growing season (April-August), and annual precipitation in 2006 and 2007 at the experimental site, 15 km north of Sidney, MT.

Month	2006	2007	105-yr average†
	----------	mm	----------
April	75	73	28
May	43	129	50
June	55	51	72
July	31	22	54
August	37	9	37
April-August	241	234	241
January-December	341	303	353

† Data were taken from Sidney, MT which is 15 km south of the study site.

Table 2. Effects of cropping system and N fertilization on malt barley grain yield and N uptake in 2006 and 2007.

Cropping system†	N rate	Grain yield		2007 Grain					
		2006	2007	Protein content	N uptake	Test wt.	Plump	Normal	Thin
	kg N ha^{-1}	----Mg ha^{-1}-----		g kg^{-1}	-----kg ha^{-1}-----		----------g kg^{-1}------------		
CNTB		1.83c‡	2.50a	123a	49.6a	52.9a	701a	265a	33a
NTB-P		2.27b	2.78a	118a	50.9a	54.2a	784a	194a	21a
NTB-F		2.32ab	2.59a	120a	50.0a	53.7a	715a	256a	28a
CTB-F		2.52a	2.63a	124a	52.6a	52.5a	639a	319a	41a
	0	1.96b	1.99b	106d	33.6c	55.1a	836a	149d	14b
	40	2.30a	2.80a	114c	51.1b	54.0b	757b	220c	22b
	80	2.26a	2.92a	129b	60.1a	52.3c	662c	299b	39a
	120	2.41a	2.80a	136a	60.4a	51.9c	584c	366a	49a

† Cropping systems are CNTB, continuous no-tilled malt barley; CTB-F, conventional-tilled malt barley-fallow; NTB-F, no-tilled malt barley fallow; and NTB-P, no-tilled malt barley-pea.
‡ Numbers followed by different letters within a set are significantly different at $P \leq 0.05$ by the least square means test.

Table 3. Effects of cropping system and N fertilization on malt barley biomass (stems + leaves) yield and N uptake in 2006 and 2007.

Cropping system†	N rate	Plant stand		Biomass yield		2007 Biomass	
		2006	2007	2006	2007	N conc.	N uptake
	kg N ha^{-1}	--millions ha^{-1}---		-----Mg ha^{-1}------		g kg^{-1}	kg ha^{-1}
CNTB		4.97a‡	6.87a	2.37a	3.23a	5.3a	17.9a
NTB-P		5.45a	7.18a	2.63a	3.88a	2.9a	10.5a
NTB-F		5.23a	6.77a	2.86a	3.20a	5.3a	17.5a
CTB-F		5.18a	6.75a	2.54a	3.92a	4.9a	20.7a
	0	4.61a	5.98c	2.38a	2.35c	4.2a	9.7b
	40	5.54a	6.70b	2.65a	3.68b	5.3a	20.6a
	80	5.22a	7.22a	2.64a	4.05ab	4.9a	19.9a
	120	5.47a	7.65a	2.73a	4.25a	4.2a	16.2ab

† Cropping systems are CNTB, continuous no-tilled malt barley; CTB-F, conventional-tilled malt barley-fallow; NTB-F, no-tilled malt barley fallow; and NTB-P, no-tilled malt barley-pea.
‡ Numbers followed by different letters within a set are significantly different at $P \leq 0.05$ by the least square means test.

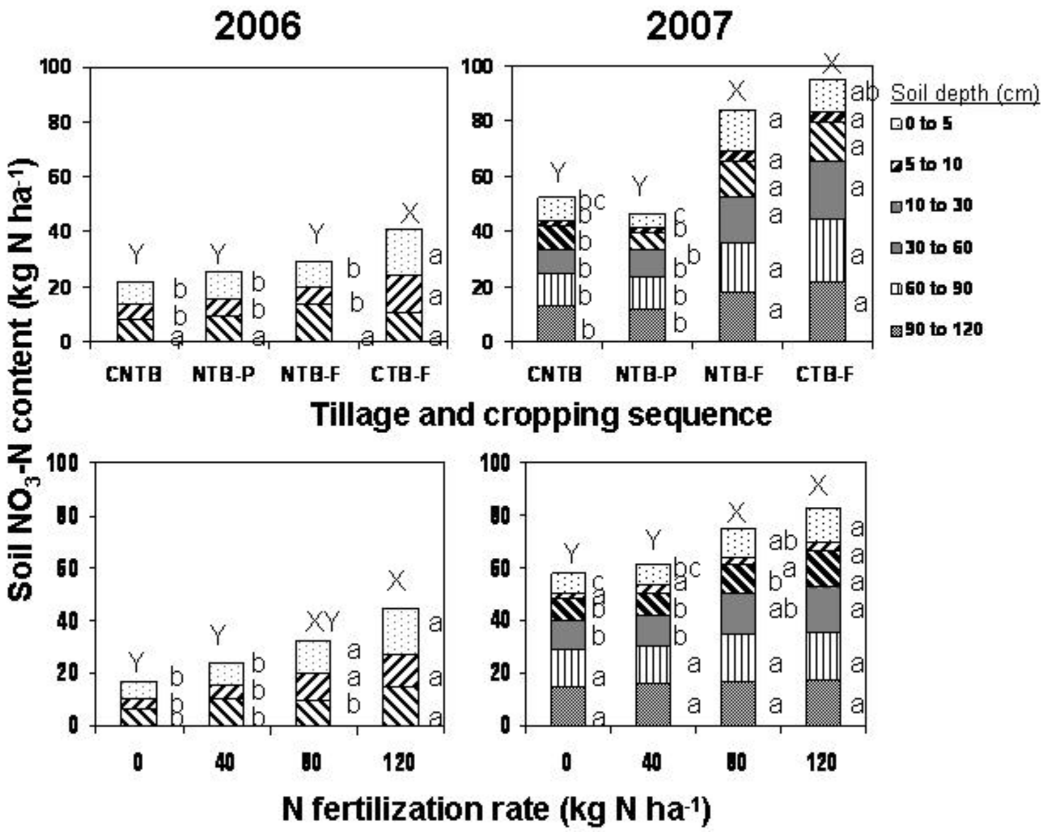

Fig. 1. Effects of tillage and cropping sequence combinations and N fertilization rates on soil NO_3-N content at the 0-120 cm depth after crop harvest in the fall, 2006 and 2007. Tillage and cropping sequences are CNTB, continuous no-tilled malt barley; CTB-F, conventional-tilled malt barley-fallow; NTB-F, no-tilled malt barley-fallow; and NTB-P, no-tilled malt barley-pea. Bars followed by different letter at the right are significantly different at $P < 0.05$ by the least significant difference test.

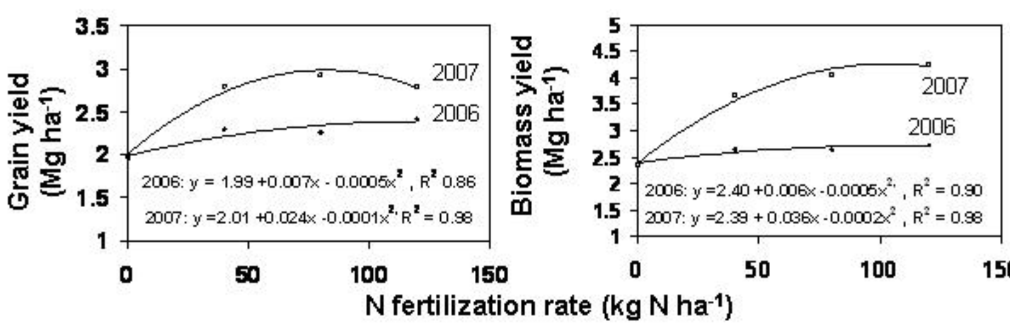

Fig. 2. Response of malt barley grain and biomass yields to N fertilization in 2006 and 2007.