NITROGEN MANAGEMENT

Nitrogen Fertilization and Rotation Effects on No-Till Dryland Wheat Production

Ardell D. Halvorson,* David C. Nielsen, and Curtis A. Reule

ABSTRACT

No-till (NT) production systems, especially winter wheat (*Triticum aestivum* L.)–summer crop–fallow, have increased in the central Great Plains, but few N fertility studies have been conducted with these systems. Therefore, winter wheat (W) response to N fertilization in two NT dryland crop rotations, wheat–corn (*Zea mays* L.)–fallow (WCF) and wheat–sorghum (*Sorghum bicolor* L.)–fallow (WSF), on a Platner loam (fine, smectitic, mesic Aridic Paleustoll) was evaluated for 9 yr. Five N rates, 0, 28, 56, 84, and 112 kg N ha^{-1}, were applied to each rotation crop. Wheat biomass and grain yield response to N fertilization varied with year but not with crop rotation, increasing with N application each year, with maximum yields being obtained with 84 kg N ha^{-1} over all years. Based on grain N removal, N fertilizer use efficiency (NFUE) varied with N rate and year, averaging 86, 69, 56, and 46% for the 28, 56, 84, and 112 kg ha^{-1} N rates, respectively. Grain protein increased with increasing N rate. Precipitation use efficiency (PUE) increased with N addition, leveling off above 56 kg N ha^{-1}. A soil plus fertilizer N level of 124 to 156 kg N ha^{-1} was sufficient to optimize winter wheat yields in most years in both rotations. Application of more than 84 kg N ha^{-1} on this Platner loam soil, with a gravel layer below 120 cm soil depth, would more than likely increase the amount of NO_3–N available for leaching and ground water contamination. Wheat growers in the central Great Plains need to apply N to optimize dryland wheat yields and improve grain quality, but need to avoid over-fertilization with N to minimize NO_3–N leaching potential.

In the central Great Plains region of the USA, use of reduced tillage and NT systems increased during the 1990s. These tillage systems improved the storage of precipitation in the soil profile compared with mechanical tillage systems, allowing more intensive cropping systems to be developed (Anderson et al., 1999; Halvorson and Reule, 1994; Halvorson et al., 2002; McGee et al., 1997; Nielsen et al., 2002; Peterson et al., 1996). The dominant wheat–fallow system of farming is being slowly replaced with more intensive cropping systems, such as 3-yr WCF and WSF systems, 4-yr systems (crop–crop–crop–fallow), and annual cropping systems with no fallow (Anderson et al., 1999; Halvorson and Reule, 1994; Norwood, 2000; Peterson et al., 1993; Schlegel et al., 2002).

Dhuyvetter et al. (1996) reported that the more intensive cropping systems had higher profit potential than wheat–fallow systems in the Great Plains. This finding was supported by the economic analyses of intensive dryland cropping systems in eastern Colorado (Kaan et al., 2002) and in south-central North Dakota (DeVuyst and Halvorson, 2004). Greater profit potential with increasing cropping intensity and NT production systems has enhanced the adoption of these systems.

Crop water use efficiency is improved with more intensive cropping systems (Halvorson, 1990; Nielsen et al., 2002; Norwood, 1999; Farahani et al., 1998). Nitrogen fertilization can improve water use efficiency, but high N fertilization rates can result in excess biomass production, which uses up stored soil water needed for grain production (Nielsen and Halvorson, 1991). Therefore, it is important to balance N fertilization with available seasonal water supplies.

More intensive cropping systems using NT may require higher rates of N fertilizer to maintain yield potential due to increased crop N removal as well as compensate for N sequestration in crop residue and surface soil due to lack of tillage. Few N fertility rate studies have been conducted in the central Great Plains under NT conditions to evaluate the response of winter wheat to N application in more intensive NT cropping systems (Halvorson and Reule, 1994; Kolberg et al., 1996; Thompson and Whitney, 1998). Halvorson and Reule (1994) reported spring barley (*Hordeum vulgare* L.) yields were optimized with the application of 67 kg N ha^{-1} each crop year in a NT annual cropping system on a Weld silt loam (fine, smectitic, mesic Aridic Argiustoll). Thompson and Whitney (1998) reported that 67 kg N ha^{-1} applied to each crop was sufficient to optimize wheat and sorghum yields on a silt loam soil in Kansas. Kolberg et al. (1996) reported no yield benefits to N applications above 84 kg N ha^{-1} on dryland winter wheat in WCF and WSF rotations on two loam soils in eastern Colorado.

The objective of this study was to evaluate the influence of N fertilization rate and crop rotation (WCF and WSF) on dryland winter wheat yields, NFUE, PUE, and residual soil NO_3–N using a NT production system on a Platner loam soil with a gravelly layer below the 120-cm depth.

A.D. Halvorson, USDA-ARS, 2150 Centre Ave., Bldg. D, Suite 100, Fort Collins, CO 80526; D.C. Nielsen, USDA-ARS, Central Great Plains Res. Stn., 40335 County Road GG, Akron, CO 80720; and C.A. Reule, USDA-ARS, 2150 Centre Ave., Bldg. D, Suite 100, Fort Collins, CO 80526. Contribution from USDA-ARS. The U.S. Department of Agriculture offers its programs to all eligible persons regardless of race, color, age, sex, or national origin, and is an equal opportunity employer. Received 18 Dec. 2003. *Corresponding author (ardell.halvorson@ars.usda.gov).

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677 S. Segoe Rd., Madison, WI 53711 USA

Abbreviations: NFUE, nitrogen fertilizer use efficiency; NT, no-till; PUE, precipitation use efficiency; WCF, wheat–corn–fallow; WSF, wheat–sorghum–fallow.

Table 6. Growing season precipitation use efficiency (PUE) by winter wheat each year as a function of N fertilization rate, averaged over wheat–corn–fallow and wheat–sorghum–fallow rotations.

	N rate, kg N ha^{-1}					†Equation: $y = a + bx + cx^2$			
Year	0	28	56	84	112	a	b	c	r^2
	PUE, kg grain ha^{-1} mm precipitation^{-1}								
1985	15.8	17.0	19.9	23.1	22.5	15.3	0.104	−0.0003	0.93
1986	12.7	18.0	21.0	22.6	23.6	12.9	0.196	−0.0009	1.00
1987	15.3	20.6	19.0	19.2	20.3	16.2	0.098	−0.0006	0.59
1988	9.2	10.8	13.6	14.3	12.1	8.8	0.131	−0.0009	0.89
1989	15.7	19.9	19.5	20.1	18.9	16.1	0.123	−0.0009	0.87
1990	8.6	15.7	18.6	16.9	17.6	9.2	0.246	−0.0016	0.92
1991	14.9	21.1	24.8	28.7	27.4	14.7	0.268	−0.0014	0.99
1992	16.7	24.2	25.0	23.0	22.2	17.5	0.234	−0.0018	0.86
1993	18.5	30.9	36.1	34.5	35.3	19.3	0.439	−0.0027	0.95
Avg.	14.1	19.8	21.9	22.5	22.2	14.4	0.204	−0.0012	0.99

† y = Precipitation use efficiency (PUE), kg grain ha^{-1} mm precipitation^{-1}; x = N rate, kg N ha^{-1}.

SUMMARY

This study shows that N fertilization of winter wheat in a WCF or WSF system is essential to optimize grain yield potential. On this Platner loam soil with gravel layer below the 120-cm depth, application of 112 kg N ha^{-1} appears to be an excessive rate for the amount of water available to the wheat crop. Grain protein was increased by increasing N fertilizer rate, but this varied with year. Nitrogen fertilizer use efficiency generally decreased with increasing N rate, varying with year. Precipitation use efficiency was lowest with no N fertilizer applied, and generally increased with increasing N rate up to 56 kg N ha^{-1}, then leveled off with increasing N rate. The results indicate that a soil plus fertilizer N level of between 124 and 156 kg N ha^{-1} would be sufficient to produce a 95% yield potential. The study shows that wheat grain yields and protein content will be improved by N fertilization, but soil testing to monitor residual soil NO_3-N levels is needed to prevent overfertilization with N.

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Table 2. Total soil water and NO_3–N at winter wheat planting in the 0- to 120-cm soil depth, averaged over wheat–corn–fallow and wheat–sorghum–fallow rotations.

	N rate, kg N ha^{-1}					
Year	0	28	56	84	112	Yearly avg.
	soil water, mm (0- to 120-cm depth)					
1985	299a†	299a	299a	299a	299a	299cd‡
1986	292a	292a	292a	292a	292a	292cd
1987	269a	284a	258a	251a	268a	266b
1988	299a	259a	280a	325a	314a	295cd
1989	283a	315a	345a	298a	296a	307d
1990	258ab	264a	232bc	227c	253abc	247a
1991	300a	245a	280a	297a	292a	282bc
1992	277a	298a	320a	269a	258a	284bc
1993	304a	310a	293a	287a	300a	299cd
Avg.	287a	285a	289a	283a	286a	
	soil NO_3–N, kg N ha^{-1} (0- to 120-cm depth)					
1985	50a†	50a	50a	50a	50a	50ab‡
1986	36a	36a	36a	36a	36a	36a
1987	95a	185a	164a	215a	377b	207f
1988	49a	60ab	59ab	113c	96bc	75c
1989	91a	87a	93a	83a	102a	91cd
1990	92a	92a	182ab	201ab	267b	167e
1991	59a	96a	92a	100a	113a	92cd
1992	43a	53ab	77b	59ab	126c	71bc
1993	65a	67a	108ab	145b	155b	108d
Avg.	64a	81ab	95ab	111b	147c	

† Values within a row followed by the same letter are not significantly different for N rates.

‡ Values within the yearly average column followed by the same letter are not significantly different.

RESULTS AND DISCUSSION

Annual precipitation during the study period varied considerably with year (Table 1). Above average annual precipitation occurred in 1985, 1987, 1990, and 1993, about average in 1988 and 1992, and below average in 1986, 1989, and 1991. Growing season (April–June) precipitation, however, did not follow the same pattern as for annual precipitation (Table 1). Growing season precipitation was below the long-term average in 1989, 1990, 1992, and 1993, near average in 1985, 1987, and 1991, and above average in 1986 and 1988. Soil water in the 0- to 120-cm root zone at wheat planting was probably near field capacity most years, with 1987 and 1990 having slightly lower water contents than the other years (Table 2). Thus, growing season precipitation and climatic conditions, such as temperature, evapotranspiration, frost, and hail, were the elements other than N fertilization having the greatest impact on wheat yields during the study period.

Total biomass production was not significantly affected by crop rotation, with average wheat biomass production of 7596 and 7666 kg ha^{-1} for the WCF and WSF rotations, respectively. Biomass production varied with year and N rate (Fig. 1, with yields for each crop sequence shown separately for easier reader interpretation). Biomass was increased by N application each year, but the N rate resulting in maximum biomass yield varied with year (Table 3). The highest level of biomass production occurred in 1986, 1991, and 1993 with the 84 or 112 kg N ha^{-1} N rates resulting in maximum yield. In 1985, 1987, and 1988, biomass yields were slightly lower but were still near maximum with the two highest N rates. Biomass yields tended to be lowest in 1989, 1990,

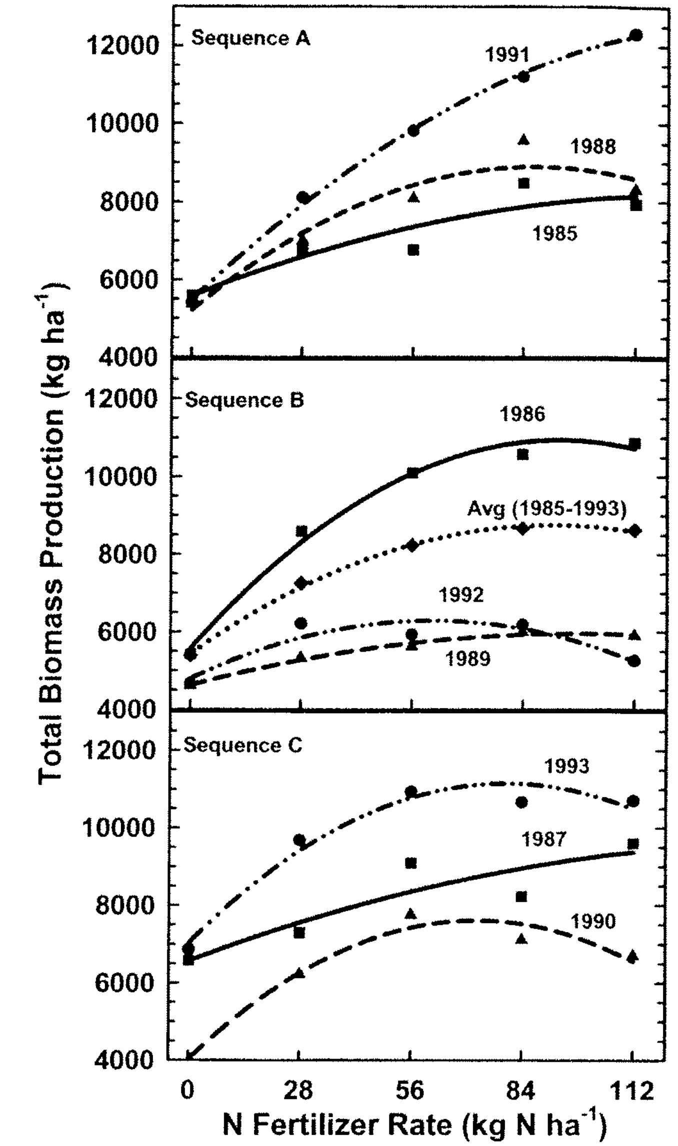

Fig. 1. Total winter wheat biomass production each year at crop maturity for each of the three cropping sequences as a function of N fertilizer rate, averaged over wheat–corn–fallow and wheat–sorghum–fallow rotations.

and 1992, with biomass production being near maximum with the 28 or 56 kg ha^{-1} N rates.

Grain yields varied significantly with year and N application rate (Fig. 2 and Table 3), but not with crop rotation. Grain yields averaged 3281 and 3275 kg ha^{-1} for the WCF and WSF, respectively. Norwood (2000) also found no differences in wheat grain yields between WCF and WSF rotations. Grain yield in 1985, 1986, and 1991 increased with increasing N rate, maximizing at the 84 and 112 kg ha^{-1} N rates. In 1988, 1990, and 1993, grain yields were near maximum at the 56 and 84 kg ha^{-1} N rates. Low grain yield in 1988 probably resulted due to low rainfall during April through mid-May, high evaporative demands, and a large number of days with high air temperatures, even with slightly better than average growing season precipitation. Butler et al. (2001) showed a strong decline in winter wheat yields with daily maximum temperatures >25°C between 21 May