Evaluation of management practices for converting grassland back to cropland

A.D. Halvorson, C.A. Reule, and R.L. Anderson

ABSTRACT: Minimum-till (MT) and no-till (NT) systems were evaluated for converting seeded grassland back to cropland. Nitrogen fertilization needs to optimize grain yields following grass and to optimize hay yields from the grassland were also evaluated. Tillage treatments — conventional till (CT), MT, and NT — were established on a Weld silt loam soil that had been seeded to grass about 30 yr following more than 30 yr of crop-fallow. Nitrogen treatments were 0, 45, and 90 kg N/ha (0, 40, and 80 lb N/a) applied to each crop in a winter wheat (Triticum aestivum *L.)-corn* (Zea mays *L.)-fallow rotation or annually to grass plots. Residue cover at wheat planting averaged 18, 44, and 73% for CT, MT, and NT, respectively. Soil water recharge was minimal between grass kill and wheat planting; however, soil NO_3-N increased 115, 69, and 54 kg N/ha (103, 62, and 48 lb N/ac) for CT, MT, and NT, respectively. Wheat grain yields were greater with CT 2,685 kg/ha (40 bu/ac) and MT 2,558 kg/ha (38 bu/ac) than with NT 2,052 kg/ha (30.5 bu/ac). Lower wheat yields with NT resulted from lack of grass control. Wheat yield responses to N varied with year and were dependent on available water supplies. Corn grain yields were low [1,233, 2,063, and 1,564 kg/ha (19.7, 32.9, and 24.9 bu/ac) for CT, MT, and NT, respectively] due to limited growing season water. Average wheat 6,298 kg/ha (5,623 lb/ac) and corn 5,040 kg/ha (4,500 lb/ac) phytomass production exceeded that of the fertilized grass [1,529 kg/ha with 90 kg N/ha (1,365 lb/ac with 80 lb N/ac)]. Producers converting CRP grass to crop production can use MT and NT practices to maintain soil erosion control.*

Key words: CRP conversion, cropland, crop rotation, corn, dryland, grassland, hay, nitrogen, tillage system, wheat.

The 1985 Food Security Act (U.S. Congress 1985) established the Conservation Reserve Program (CRP), which resulted in extensive areas of highly-erodible cropland being seeded primarily to native and introduced grass species. The primary purpose of CRP was to reduce soil loss by wind and water erosion. Other CRP objectives included reduced production of major crops, farm income enhancement, improved water quality, improved fish and wildlife habitat, and enhanced ecological diversity (CAST 1990).

In March 1986, farmers began to submit bids for CRP enrollment, and about 13.7 million ha (33.9 million ac) were enrolled by January 1990. The CRP program was funded for a 10-yr period, after which producers had the option of keeping their CRP fields in grass or converting their fields into cropland. Schertz (1995) reported that a 1993 Soil and Water Conservation Society survey of post-CRP land use indicated that 63% of the CRP acres would be converted back to cropland. If CRP fields are converted back to cropland, then conservation management systems should be used to retain the soil conservation benefits gained during the 10-yr CRP period (Aase et al. 1997; CAST 1990; Schertz 1995). Schertz (1995) indicated that research data are needed on the best methods for bringing CRP land back into crop production. In the central Great Plains after the ninth sign-up period, Colorado had 0.79 million ha (1.95 million ac) of CRP contracted, Kansas had 1.16 million ha (2.86 million ac), and Nebraska had 0.55 million ha (1.35 million ac) contracted for CRP (USDA 1990).

Land enrolled in CRP is now eligible to be removed from the program and put back into crop production. Because CRP fields were highly erodible when placed in the conservation program, the 1985 Food Security Act required producers to maintain erosion control on these lands following CRP to be eligible to participate in other government farm programs. Many questions arose as to how to best convert CRP to cropland while maintaining soil erosion control. Information is needed on: 1) how to effectively convert CRP grassland back to cropland while maintaining soil erosion protection; 2) fertility needs following CRP (Fixen 1996); 3) tillage and herbicide needs to effectively convert grassland back to cropland; 4) use of more intensive cropping systems than crop fallow; and 5) improving productivity of CRP grassland to encourage farmers to keep the land in grass. Based on these needs, research was initiated in 1990 with the following objectives: 1) determine whether CRP-type grassland can be converted to cropland using MT or NT systems; 2) determine N fertility needs to optimize crop yields; and 3) determine if forage production on CRP-type grassland can be increased by N fertilization.

Methods and materials

To simulate CRP conditions at the end of 10 or more years of continuous grass, a research site representative of surrounding CRP land was located at the U.S. Department of Agriculture's Agricultural Research Service (USDA-ARS) Central Great Plains Research Station at Akron, Colo. The site was predominantly Weld silt loam soil (fine montmorillonitic, mesic Aridic Paleustoll), and had been in crop fallow more than 30 yr before being planted back to grass in about 1960.

The grass was occasionally hayed (possibly 30 to 40% of the time), but not fertilized to anyone's knowledge during the period prior to conversion back to cropland in 1990. This is similar to the occasional haying of CRP grassland during periods of drought to provide needed forage for livestock producers. Average grass composition in 1990 before application of treatments was 80% crested wheatgrass (*Agropyron cristatum* L.), 13% blue grama (*Bouteloua gracilis*), 2% sand dropseed (*Sporobolus cryptandrus*), and 5% alfalfa (*Medicago sativa* L.).

New sets of tillage and N plots were established each of three consecutive years. A split-plot, randomized, complete block design was used with three replications. CT, MT, and NT tillage treatments were compared on main plots (each 9.1 x 12.2 m, or 30 x 40 ft), with N rates as subplots (3.0 x 12.2 m, or 10 x 40 ft). Existing old grass litter was not mowed or removed before applying tillage treatments. Nitrogen treatments included 0,

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45, and 90 kg N/ha (0, 40, and 80 lb N/a) applied broadcast at or just prior to planting with ammonium nitrate as the N source.

The first set of CT treatments received initial sweep plow tillage to kill the grass/legume mixture on May 7, 1990, and the second set on April 4, 1991, and the third set on October 21, 1991. Tillage was repeated as needed until wheat planting the following September.

The first set of MT plots were initially sprayed with glyphosate (N-phosphonomethyl glycine) on May 7, 1990, at a rate of 2.2 kg ai/ha (2 lb ai/a) to kill the grass/legume mixture, followed by a sweep plow tillage operation about 4 wk later. The second and third sets of MT plots first received an initial sweep plow tillage on April 4, 1991, and October 21, 1991, respectively. The tillage operations were followed with an application of glyphosate (1.1 kg ai/ha, or 1 lb ai/a) on May 22, 1991, and glyphosate (1.1 kg ai/ha, or 1 lb ai/a) plus 2,4-D (2,4-dichlorophenoxyacetic acid, 0.56 kg ai/ha, or 0.5 lb ai/a) May 4, 1992, for the second and third sets of MT plots, respectively.

The first set of NT plots were initially treated with glyphosate (2.2 kg ai/ha, or 2 lb ai/a) on May 7, 1990; the second set was treated with glyphosate (1.1 kg ai/ha, or 1 lb ai/a) on May 6, 1991, and the third set were treated with glyphosate (1.1 kg ai/ha, or 1 lb ai/a) plus 2,4-D (0.56 kg ai/ha, or 0.5 lb ai/a) on May 4, 1992, after the grass greened up in the spring and was actively growing. Unlike the third set of CT and MT plots, grass kill in the third set of NT plots was delayed until the spring of 1992 because grass was under water stress in October 1991, and not actively growing. (This would have resulted in poor herbicide performance and grass kill).

After initial operations, CT plots were tilled (undercutter), and the MT and NT plots were chemically fallowed [glyphosate (1.1 kg ai/ha, or 1 lb ai/a) plus 2,4-D (0.56 kg ai/ha, or 0.5 lb ai/a)], generally 3 to 4 times, until winter wheat planting.

A winter wheat-corn-fallow (W-C-F) rotation was followed with the first crop being wheat. Winter wheat (TAM 107) was planted (approximately 2.2 million seeds/ha, or 900,000 seeds/ac) with a Haybuster 1000 series disk drill about Sept. 20 each year with 22 kg P/ha (20 lb P/a) placed with the seed. The wheat plots were harvested in early July each year by making a 1.5-m (5-ft) wide pass through the length (12.2 m, or 40 ft) of each plot with a plot combine. The grain samples were cleaned before determining grain yield (12% moisture content).

Corn (Pioneer 3732) was planted in early May 1992 with a Buffalo planter equipped with a disc opener. The seeding rate was about 37,000 seeds/ha (15,000 seeds/ac) and row spacing of 0.76 m (30 in). Corn was planted on the second (1993) and third (1994) sets of plots with a JD Maximerge planter. The corn was generally harvested in late September to mid-October. Weed control for the corn crop was provided with a preplant application of glyphosate (1.1 kg ai/ha, or 1 lb ai/a) and atrazine (1.1 kg ai/ha, or 1 lb ai/a). Corn grain yields (15.5% moisture) were determined by harvesting two corn rows the length (12.2 m, or 40 ft) of the plot area with a plot combine. Grain samples were cleaned before determination of grain yields.

Phytomass production (oven dry basis) was determined at wheat harvest by cutting whole-plant samples from a minimum area of 1 m^2 from an unharvested area of each wheat plot with a bundle cutter. Wheat residue (straw) production was estimated by subtracting grain weight from total phytomass production. Corn stover produced was estimated by subtracting grain yields from measured total phytomass production. Phytomass production was determined from hand sampling whole corn plants from 2.4 m (8 ft) of corn row in early September that would not be used for grain harvest. Phytomass production was used to estimate corn silage yields at 70% moisture content.

The first set of plots established in 1990 was fallowed after corn harvest in October 1992 until wheat planting in September 1993. Wheat (second cycle of the W-C-F rotation) was planted on the first set of plots in September 1993. Wheat was harvested a second time from the first set of plots in July 1994.

Percent residue cover was estimated on each tillage plot using a line transect method just prior to wheat and corn planting. In addition, surface crop residue was collected from a 1 m^2 area of the soil surface, washed and dry weight determined. Soil samples were collected from each tillage treatment at grass kill, just prior to wheat planting, and from all treatments just prior to corn planting to a depth of 180 cm (6 ft) for determination of gravimetric soil water and soil NO_3-N content. Samples were collected before N fertilization. Soil sampling depths were 0 to 15 cm (0 to 6 in), 15 to 30 cm (6 to 12 in), and in 30-cm (12-in) increments to 180 cm (6 ft) depth. Soil water content measured after the fallow period (October 1992 to September 1993) in the first set of plots was used as an estimate of field capacity for the 180-cm (6-ft) profile.

Nitrogen treatments (0, 45, and 90 kg N/ha or 0, 40, and 80 lb N/ac) were established on grass plots [9.1 x 12.2 m (30 x 40 ft) with 3.0 x 12.2 m (10 x 40 ft) N subplots] in September 1990. The grass plots were randomly located within each block of the cropped plots with three replications. These N treatments were included to determine if the grass forage production could be increased sufficiently to compete economically with crop production. The N source was ammonium nitrate applied broadcast on Sept. 18, 1990, on April 8, 1992, and on Sept. 21, 1992. The grass plots were harvested the first time on June 14, 1991, by hand cutting 7.4 m^2 (8.9 yd^2) from the center of each plot. Because of drought conditions during April and May, 1992, the grass plots were harvested on May 20, 1992, by hand cutting 2 m^2 (2.4 yd^2) from the center of each plot. The grass plots were harvested on June 9, 1993, with a plot forage harvester that cut 11 m^2 (13.2 yd^2) from the center of each plot and again on June 8, 1994. Forage yields are expressed on an oven dry weight basis. Soil samples were collected (same procedure as for cropped area) from the grass plots for water and soil NO_3-N measurements in the spring of 1992, 1993, and 1994.

Statistical analyses of the data were performed using SAS (SAS Institute 1991). All significant differences discussed are at the 0.05 probability level unless otherwise stated. The Least Significant Difference (LSD) method was used to separate treatment differences.

Results

Surface residue cover at planting. Average residue cover at winter wheat planting for the 3 yr, as measured by the line transect method, increased significantly ($P < 0.001$; $LSD_{.05} = 6.6\%$) as tillage intensity decreased with 18, 44, and 73% residue cover for the CT, MT, and NT systems, respectively. Percent residue cover varied with year and tillage treatment ($P = 0.001$; $LSD_{.05} = 8\%$). Residue cover at wheat planting was 26, 45, and 75% in 1990; 17, 25, and 64% in 1991; and 12, 64, and 81% in 1992 for the CT, MT, and NT treatments, re-

Table 1. Changes in soil water at initial grass kill and at wheat planting each year (significant interaction) and soil N levels at grass kill and wheat planting as a function of tillage treatment (significant interaction) in the 0- to 180-cm (0- to 6-ft) soil depth.

	Soil water, cm/180-cm depth			
	Grass	Wheat		
Year	Kill	Planting	$LSD_{.05}$	$LSD_{.10}$
1990	22.2	29.0	2.0	1.7
1991	27.9	26.2	2.0	1.7
1992	32.5	34.2	2.0	1.7

	Soil NO_3-N, kg N/ha/180-cm depth			
Tillage	Grass	Wheat		
Treatment	Kill	Planting	$LSD_{.05}$	$LSD_{.10}$
CT	26	141	21	18
MT	43	112	21	18
NT	34	88	21	18

spectively. Quantity (weight) of residue on the soil surface increased with decreasing tillage intensity with a significant year by tillage treatment interaction ($P = 0.007$; $LSD_{.05} = 304$ kg/ha). Quantity of residue on the soil surface at wheat planting was 358, 809, and 1,780 kg/ha (320, 722, and 1,589 lb/ac) in 1990; 376, 405, and 989 kg/ha (336, 362, and 883 lb/ac) in 1991; and 43, 1,231, and 1,391 kg/ha (38, 1,099, and 1,241 lb/ac) in 1992 for the CT, MT, and NT treatments, respectively. Averaged across three years, quantity of surface residue at wheat planting was significantly ($P < 0.001$; $LSD_{.05} = 248$ kg/ha) increased with a reduction in tillage with residue levels of 259, 815, and 1,388 kg/ha (231, 728, and 1,239 lb/ac) for the CT, MT, and NT treatments, respectively. The residue cover for CT may not meet residue requirements at planting for effective soil erosion control. The MT and NT treatments provided more potential protection from wind and water erosion than CT treatment.

Surface crop residue levels at corn planting in 1992 were 1,480, 1,926, and 3,183 kg/ha (1,321, 1,720, and 2,842 lb/ac) for CT, MT, and NT plots, respectively, with NT having significantly greater ($P = 0.001$; $LSD_{.05} = 393$ kg/ha) residue levels than the CT and MT systems. Estimated residue cover by line transect was also significantly greater ($LSD_{.05} = 14\%$) with NT (88%) compared to CT (51%) and MT (58%). Surface crop residue levels remaining after corn planting in 1993 were 272, 965, and 1,098 kg/ha (243, 862, and 980 lb/ac) for CT, MT, and NT plots, respectively, but were not significantly different ($P = 0.22$). Residue levels estimated by the line transect method showed that NT (45%) and MT (39%) treatments had significantly ($P = 0.02$; $LSD_{.05} = 17\%$) greater residue levels than the CT (17%) treatment.

Table 2. Precipitation (mm) received during study and 87-yr average at Akron, Colo.

Month	Year					87-yr average
	1990	1991	1992	1993	1994	
Jan	19	2	25	6	10	8
Feb	4	4	5	14	5	9
March	43	28	50	12	2	21
April	38	21	5	49	61	43
May	104	104	28	26	22	76
June	24	53	107	44	6	63
July	120	80	51	122	69	69
Aug	112	26	98	23	30	52
Sept	18	3	5	21	11	31
Oct	27	10	20	94	70	23
Nov	20	37	20	26	26	14
Dec	2	11	6	12	13	11
Total	530	378	420	450	325	419

Soil water. Changes in soil water between initial grass kill and wheat planting showed a gain in water for the 1991 crop, a slight loss of soil water for the 1992 crop, and only a small increase for the 1993 wheat crop (Table 1). Tillage treatment had no significant effect ($P = 0.41$) on soil water content at wheat planting, with water contents of 31 (12.2), 30 (11.8), and 28 cm (11.0 in)/180 cm (6 ft) soil depth for the CT, MT, and NT treatments, respectively. Soil water in the 0-to-180 cm (0-to 6-ft) profile at wheat planting was considerably below field capacity in 1991 and 1992. Field capacity was estimated to be about 39 cm (15.4 in) water/180 cm (6 ft) depth based on soil water samples taken in September 1993, following a fallow period.

The 1993 wheat crop started the season with the most soil water, which reflects the fact that the grass was initially tilled in October 1991 in the CT and MT plots, resulting in a longer fallow period before wheat was planted September 1992. The 1992 June-to-August precipitation (Table 2) also was above normal, which influenced the soil water content at wheat planting in September 1992. Soil water at wheat planting was greatest in September 1993, following a 12-mo fallow period in this W-C-F rotation on the first set of plots. Soil water in September 1993 was 39.2, 38.4, and 37.8 cm/180-cm depth (15.4, 15.1, and 14.9 in/6-ft depth) for the NT, MT, and CT treatments, respectively. Soil water in September 1993 was not significantly different among tillage or N treatments.

Soil nitrate-N. Soil NO_3-N levels were generally low at initial grass kill with no significant differences among tillage treatments, but had significant differences across years with 14, 43, and 45 kg N/ha/180-cm soil depth (13, 38, and 40 lb N/ac/6-ft depth) for 1990, 1991, and 1992, respectively. At wheat planting, soil NO_3-N had increased similarly across years (data not shown), but varied significantly with tillage treatment. Differences in soil NO_3-N among tillage treatments are shown in Table 1. Increase in soil NO_3-N during the short fallow period before wheat planting was greatest for CT and lowest with NT. The effects of mechanical tillage on mineralizing N from soil organic matter was very evident in this study. The difference among tillage treatments in soil NO_3-N at initial grass kill and soil NO_3-N at wheat planting indicates that about 115, 69, and 54 kg N/ha (103, 62, and 48 lb N/ac) was mineralized in the 0-to-180

Table 3. Precipitation (mm) received during selected crop and non-crop periods.

Crop year	Grass dormancy (Jan-April)	Grass kill to wheat planting (May-Sept)	Wheat cropping season (Oct-June)	Wheat harvest to corn planting (July-April)	Corn growing season (May-Sept)
1990	105	377	——	——	——
1991	55	265	260	——	——
1992	84	422 (Oct-Sept)	278	251	290
1993	——	——	197	276	236
1994	——	363*	238	376	138
86 yr Avg	81	292	268	280	292

*From 1992 winterwheat harvest (July) to 1993 winter wheat planting (Sept.).

cm (0-to-6 ft) soil depth during the initial fallow period for CT, MT, and NT, respectively.

Soil NO_3-N at corn planting varied by year and N rate (P = 0.004) with soil NO_3-N levels of 66, 91, and 84 kg N/ha/180 cm (59, 81, and 75 lb N/ac/6 ft) in 1992; 66, 98, and 163 kg N/ha/180 cm (59, 88, and 146 lb N/ac/6 ft) in 1993; and 97, 106, and 137 kg N/ha/180 cm (87, 95, and 122 lb N/ac/6 ft) in 1994 for the 0, 45, and 90 kg N/ha (0, 40, and 80 lb N/ac) rates, respectively. Except for 1992, residual soil NO_3-N increased with increasing N rate.

Wheat yields. Wheat grain yields for CT (2,685 kg/ha, or 40 bu/ac) and MT (2,558 kg/ha, or 38 bu/ac) were significantly greater (P = 0.03, $LSD_{.05}$ = 469 kg/ha) than those yields obtained with NT (2,052 kg/ha, or 30.5 bu/ac) when averaged across 3 yr. The lower yield with NT resulted from lack of control of the grass/legume mixture. Averaged across years, visual estimates of ground area still occupied by grass at wheat planting was 0, 1, and 23% for CT, MT, and NT, respectively, with an $LSD_{.05}$ = 5%. The continued water and nutrient use by the grass in the NT plots resulted in less water and nutrients being available to the wheat crop. Ultimately, this reduced the yield of the NT plots. Precipitation for the study period is reported in Table 2 and cumulative precipitation received during selected crop and non-crop periods is shown in Table 3.

When averaged across years, N fertilization did not significantly (P = 0.10) affect wheat grain yields in this study; however, the year x N interaction was significant (P = 0.05). In 1991, wheat yields increased with the application of 45 kg N/ha (40 lb N/ac) and then leveled off at the highest N rate (Figure 1). In 1992, the wheat crop was water-stressed, resulting in low yields and no response to N fertilization. The 1993 wheat yields were greater than in 1992, but there was no significant response to N fertilization. Lack of response to N fertilization might

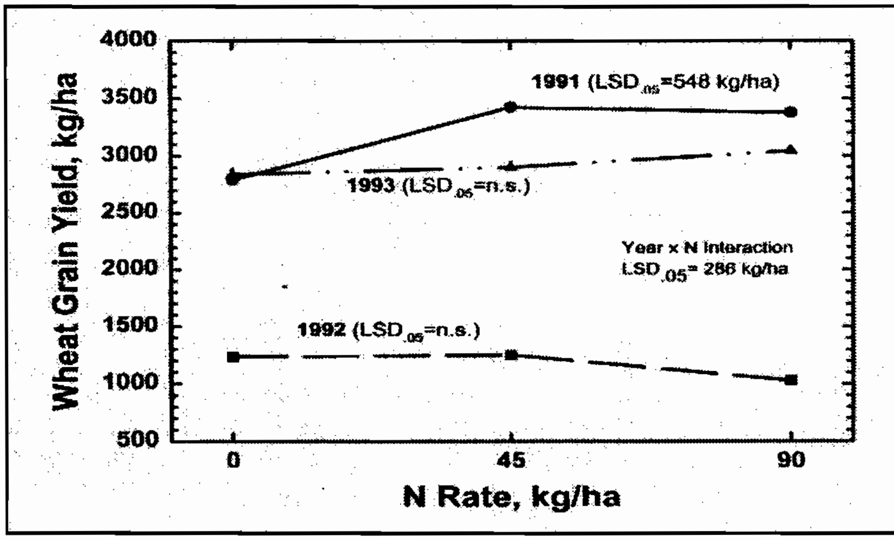

Figure 1. Winter wheat grain yields (12% moisture basis) as a function of N rate and year (significant year x N rate interaction) following grass removal.

be expected due to the large amount of soil N available to the wheat crop at planting (Table 1) and the low yield potential due to limited water supplies (Tables 1, 2, and 3). Wheat grain yields in 1991 (3,196 kg/ha, or 2,854 lb/ac) and 1993 (2,927 kg/ha, or 1,779 lb/ac) were significantly greater (P = 0.001; $LSD_{.05}$ = 574 kg/ha) than in 1992 (1,171 kg/ha, or 1,046 lb/ac). The lower grain yield in 1992 reflects the lack of soil water recharge during the initial fallow period and below normal April and May precipitation (Tables 1 and 2).

Winter wheat grain yields in 1994 for the second cycle of the W-C-F rotation on the first set of treatments showed no significant response to tillage or N treatment. Wheat yields averaged 2,129 kg/ha, or 31.7 bu/ac. This is an acceptable yield considering the below average precipitation in May and June 1994 (Table 2). Precipitation from April 1 to June 30, 1994, was only 8.9 cm (3.5 in). Due to the drought, the 1994 wheat crop did not respond to N fertilization.

Wheat residue (straw) returned to the soil surface at harvest averaged 3,875 kg/ha (3,460 lb/ac) over the 3 yr, with the only significant response due to year. Straw yields were not affected by tillage and N treatment. Straw yields did vary significantly (P = 0.01; $LSD_{.05}$ = 1,397 kg/ha) by year with yields of 4,306 kg/ha (3,845 lb/ac) in 1991, 2,006 kg/ha (1,791 lb/ac) in 1992, and 5,313 kg/ha (4,744 lb/ac) in 1993. Total phytomass production (grain + straw) varied only by year with 1991 (7,454 kg/ha, or 6,655 lb/ac) and 1993 (8,237 kg/ha, or 7,354 lb/ac) producing significantly (P = 0.003; $LSD_{.05}$ = 1,840 kg/ha) higher phytomass yields than 1992 (3,201 kg/ha, or 2,858 lb/ac). Tillage and N treatments had no affect on phytomass production in this study.

Corn yields. Corn grain yields (15.5% moisture) were significantly (P = 0.03; $LSD_{.05}$ = 570 kg/ha) affected by tillage treatment when averaged across the 3 yr with MT (2,063 kg/ha, or 32.9 bu/ac) having a significantly greater yield than CT (1,233 kg/ha, or 19.7 bu/ac). The NT grain yield was 1,564 kg/ha (24.9 bu/ac). Corn yields were not significantly influence by N fertilization. Corn grain yields were significantly different (P = 0.01; $LSD_{.05}$ = 728 kg/ha) across years with 1992 (2,350 kg/ha, or 37.4 bu/ac) and 1994 (1,796 kg/ha, or 28.6

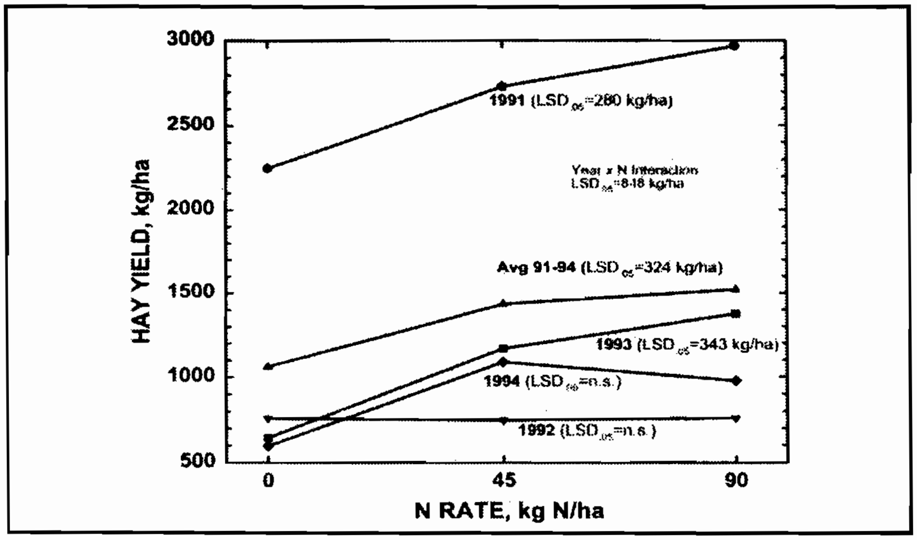

Figure 2. Grass hay yields (oven dry basis) as a function of N fertilizer rate for 1991, 1992, 1993, 1994, and 4-yr average (significant year x N rate interaction).

bu/ac) having a greater yield than 1993 (714 kg/ha, or 11.4 bu/ac). Growing season precipitation was below average in 1993 and 1994 (Table 2), which resulted in low corn yields due to water stress.

Corn silage yields (70% moisture) were only influenced by years with no significant affect of tillage treatment or N fertilization, with an average yield of 16.8 Mg/ha (7.5 t/ac) or a dry matter yield of 5 Mg/ha (2.2 t/ac). Silage yields for 1992 (25.4 Mg/ha, or 11.3 t/ac) were significantly ($P = 0.01$; $LSD_{.05} = 7.3$ Mg/ha) greater than those for 1993 (12.4 Mg/ha, or 5.5 t/ac) and 1994 (12.8 Mg/ha, or 5.7 t/ac). Dryland corn produced acceptable silage yields, but there was not enough soil water or rainfall to produce acceptable grain yields. Salvaging the corn crop as a forage crop rather than as a grain crop in drought years may be an option for some producers. A crop requiring less water to produce an economical yield, such as proso millet (*Panicum miliaceum* L.), may have been a better choice following winter wheat planted on grassland that had not had a lengthy fallow period to recharge the soil profile with water.

Grass hay yields. Grass response to N fertilization varied by year (Figure 2) with a significant ($P = 0.03$) year x N interaction. Hay yields increased with increasing N fertility levels in 1991 and 1993, but not in 1992 and 1994. The largest response to N came with the first 45 kg N/ha (40 lb N/ac) added, with yields tending to level off above this N rate. Hay yields averaged across N treatments were significantly ($P = 0.01$; $LSD_{.05} = 907$ kg/ha) greater in 1991 (2,649 kg/ha, or 2,365 lb/ac) than in 1992 (755 kg/ha, or 674 lb/ac), 1993 (1,063 kg/ha, or 949 lb/ac), and 1994 (887 kg/ha, or 792 lb/ac). The greater hay yield in 1991 most likely resulted from the 104 mm (4.1 in) rain received during May that stimulated growth of the grass. Average hay yield across N rates and 4 yr was only 1,339 kg/ha (1,196 lb/ac), a very low yield that would not compete well with crop production. Spring soil NO_3-N averaged 31, 34, and 53 kg N/ha/180 cm depth (28, 30, and 47 lb N/ac/6 ft) for the 0, 45, and 90 kg N/ha (0, 40, and 80 lb N/ac) treatments, respectively, when averaged across 1992, 1993, and 1994 with no significant differences among years. Spring soil NO_3-N levels were not significantly different ($LSD_{.05} = 13$ kg N/ha) between the 0 and 45 kg N/ha (40 lb N/ac) rates, but increased significantly with the 90 kg N/ha rate (80 lb N/ac), indicating that the grass was not utilizing all of the N applied. Spring soil water averaged 30 cm (11.8 in) in the 0-to 180-cm (6-ft) profile, which was about 9 cm (3.5 in) less water than a full soil profile and did not vary over years or N treatment. Limited plant-available water (soil water plus growing season precipitation) contributed to the low hay yields in this study.

Discussion

Crop yields following grass will depend on the amount of soil water storage that occurs during the initial non-crop fallow period before planting the first crop, and rainfall during the crop production period. Winter wheat grain yields were 24 and 20% greater with CT and MT, respectively, than with NT because of poor grass control in the NT plots. In this study, herbicide alone in the NT system did not completely control the perennial grasses, which competed with the wheat and corn crops for water and nutrients. Combining one tillage operation with herbicides controlled the grasses in the MT system. Schlegel and Thompson (1997) also reported problems with controlling grass when using NT systems in Kansas to convert CRP grassland back to cropland. Our observations suggest that at least one tillage operation may be needed to kill the grass. The herbicides burned the grass down to the point that it looked dead, but new shoots would reestablish from the crowns in the NT plots following precipitation events.

Environmental concerns and a desire to preserve the positive effects of soil carbon storage during CRP (Aase et al. 1997; Follett 1998; Reeder et al. 1998; Schertz 1995) by governmental agencies and producers has resulted in efforts to convert CRP grassland to cropland using NT. However, NT may not be the most effective nor the most economical method for producers in semiarid regions, such as eastern Colorado, western Nebraska, and western Kansas. Herbicides effectively controlled perennial grasses for short periods in this study, but long-term control was not consistent. Schlegel and Halvorson (1996) and Lyon and Holman (1997) also reported varying results on the effectiveness of using NT practices to convert CRP grassland to cropland in the central Great Plains. This contrasts with the work of Aase et al. (1997) in northeast Montana, who reported no problems with killing crested wheatgrass with glyphosate in a NT system when precipitation was above average. Their NT spring wheat yields were equal to those with moldboard plow and sweep tillage.

Reasons for lack of long-term grass control in NT may be two-fold. First, translocation of glyphosate to older roots and dormant root buds can be ineffective in old plant stands (Claus and Behrens 1976). Therefore, buds in the root system not affected by glyphosate reestablished the grass community. Secondly, glyphosate is generally most effective when applied to grasses in early stem elongation. Our grass stand was composed of both cool- and warm-season species, which reached the appropriate growth stage for effective control approximately 4 to 6 wk apart. In this study, we experienced drought conditions that may have impacted the effectiveness of glyphosate in killing the grass (Kelvorn and Wyse 1984). Grass control possibly could be improved with fall application of glyphosate when sufficient fall moisture is present to stimulate fall growth (Ivany 1981).

Producers are encouraged to view take-out of CRP from a long-term perspective involving crop rotations for the central Great Plains. NT corn after winter wheat has been shown to increase gross income (Dhuyvetter et al. 1996) and produce more residue over the length of the rotation compared to a NT winter wheat-fallow rotation. When converting from grass to cropland in the central Great Plains, best results may be obtained by using an MT system with one or two non-inverting shallow tillage operations along with herbicides to initially take out the grass before planting the first crop. Then convert to an NT production system for the second crop, such as corn or proso millet. This sequence may offer producers an economic and environmental benefit. Sufficient residue was maintained with the MT and NT systems, even following a poor 1992 wheat crop with low straw production, to provide substantial protection from soil erosion. Until the rootzone has been recharged with water following grass kill, selection of a crop with lower water requirements than corn following wheat in the rotation may be advised to obtain economical grain yields of the second crop.

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