Published May, 1990

No-Till Proso Millet Production

R. L. Anderson*

ABSTRACT

Proso millet (*Panicum miliaceum* L.) is well-adapted for the Central Great Plains and is commonly grown with a mechanical tillage production system in a winter wheat (*Triticum aestivum* L.)-millet-fallow rotation. The use of tillage results in extensive wind and water erosion, however. Research was conducted on a mesic Aridic Paleustoll soil near Akron, CO, to determine proso millet response to a no-till production system. Eliminating tillage increased proso millet grain yields from 2290 to 2730 kg/ha in 1985 and from 1200 to 1610 kg/ha in 1986, compared to tilled proso millet production. Water use efficiency (WUE) also increased in the no-till system. Nitrogen fertilizer at 22 or 44 kg N/ha increased grain yield, N concentration of grain, and WUE of no-till proso millet regardless of whether growing-season precipitation was near normal or 33% below the long-term site average of 212 mm. Atrazine [6-chloro-*N*-ethyl-*N*′-(1-methylethyl)-1,3,5-triazine-2,4-diamine] applied either in the previous fall or 60 d before planting provided effective in-crop weed control for the no-till production system. Atrazine applied in the spring required two paraquat (1,1′-dimethyl-4,4′-bipyridinium ion) applications at 0.28 kg ai/ha to control weeds the previous fall. Nitrogen fertilizer did not affect the bioactivity or soil persistence of atrazine.

A WINTER wheat-proso millet-fallow rotation is successful in the drier parts of the central Great Plains, provided fall weed control after wheat harvest is achieved. Fall weed growth can consume 80 to 250 mm of soil water (7). Proso millet grain yield increased 23% when fall weeds were controlled by sweep plowing (2). Tillage is not required for controlling weeds when residual herbicides are used (3). By eliminating tillage, wheat stubble remains upright and increases snow trapping, which results in more soil water storage (6,7). Soil water relations change under no-till systems, with higher water content in the 0- to 15-cm depth and less evaporation from the soil surface (17), conditions which are more favorable for crop growth in the drought-prone central Great Plains. However, no-till production systems in the cornbelt have occasionally had deleterious effects on corn (*Zea mays* L.) establishment and grain yields. These effects were attributed to: (i) lower soil temperatures during emergence which delayed early season plant growth, and (ii) ineffective weed control (17).

The elimination of tillage from crop production systems also affects soil processes that influence N status of soil (11). The rate of nitrate mineralization is usually depressed when crop residues are maintained on the surface during fallow (8). In the central Great Plains, tilling in the fall increased soil nitrate levels the following spring by 43% compared to tilling in the spring only (2). Previous research has indicated that proso millet does not consistently respond positively to the addition of N fertilizer (2), but if tillage does not occur in the fall, a possible shortage of soil N may occur in a no-till production system and reduce the efficiency of water conversion into grain.

USDA-ARS, P.O. Box 400, Akron, CO 80720. Contribution from the USDA-ARS Northern Plains Area. Received 25 May 1989. *Corresponding author.

Published in Agron. J. 82:577–580 (1990).

Nitrogen fertility also influences weed-crop interactions. The use of N fertilizer on small grains has influenced weed density and competition (5,16,18). Common lambsquarters (*Chenopodium album* L.) density was increased in barley (*Hordeum vulgare* L.) with N fertilizer, and caused a grain yield reduction (5). However, the application of more than 40 kg N/ha significantly depressed weed populations in wheat (16).

Triazine herbicides are used for weed control in proso millet (1). However, herbicide by N fertilizer interactions have been reported. As the level of ammonium nitrate fertilizer increased, weed control with simazine (6-chloro-*N*,*N*′-diethyl-1,3,5-triazine2,4-diamine) decreased (12,13). The explanation for this loss of weed control was that ammonium nitrate enhanced simazine degradation. Atrazine is the prevalent triazine herbicide used with proso millet and its degradation has been either reduced or enhanced by N fertilizer, depending on soil type (9).

The objectives of this study were to determine if: (i) eliminating tillage will increase the efficiency by which proso millet converts a limited water supply into grain; and (ii) weed control in a no-till system will be affected by N fertilizer.

MATERIALS AND METHODS

The experiment was conducted on a Weld silt loam (fine, montmorillonitic, mesic Aridic Paleustoll) at Akron, CO. The soil contained 12 g/kg of organic matter and the pH was 7.0. Growing-season precipitation (June 1–September 30) was 99% of the normal in 1985 and 67% normal in 1986; the 78-yr average is 212 mm.

The experimental design was a split plot factorial, with tillage system being the main plots and N fertilizer rate assigned to the subplots. Two tillage systems were compared: (i) a conventional system of sweep plowing twice in the fall for weed control after wheat harvest, followed by spring disking to prepare a seedbed; and (ii) a no-till system, with herbicides providing weed control. Paraquat at 0.28 kg ai/ha was applied twice in the fall after wheat harvest, and atrazine at 0.56 kg ai/ha was applied in April, approximately 60 d before planting. The herbicides were applied in 280 L/ha of spray solution with a 4-m boom sprayer. Three N levels (0, 22, and 44 kg N/ha as ammonium nitrate) were applied 30 d before planting. The fertilizer was applied by hand, and was incorporated only in the conventional system by the spring disking. Plot size for each individual cell of a particular tillage by fertilizer treatment was 4 m by 4 m. Both main and subplot treatments were replicated four times.

'Cope' proso millet was planted 1 to 2 cm deep with a deep-furrow hoe drill at 11 kg/ha in 0.3-m rows on 7 June 1985 and 18 June 1986. Soil water content was determined gravimetrically for all treatments on three dates: (i) after wheat harvest, (ii) at proso millet planting, and (iii) after proso millet harvest. The sampling depth was 1.3 m, with two random samples collected per plot. Plant samples were harvested in September from three rows 1.2 m long in all plots to determine grain and straw yields and harvest index.

Table 1. Effect of tillage system on soil water storage at planting time and argonomic response of proso millet grain production. Treatment means are an average of all N levels within each tillage system.

	Tillage system	Soil water storage	Seedling establishment	Grain yield	Harvest index†	Water use efficiency	Grain N concentration
		mm/1.3 m	plants/m²	kg/ha		(kg/ha)/mm	g/kg
1985							
	Conventional	150	66	2290	0.43	7.6	12.1
	No-till	160	93	2730	0.42	8.9	12.7
	F test	*	**	**	NS	**	NS
	CV (%)	2	8	15	3	15	3
1986							
	Conventional	84	80	1200	0.44	7.9	15.7
	No-till	86	81	1610	0.47	9.4	15.4
	F test	NS	NS	**	NS	**	NS
	CV (%)	3	4	7	6	11	3

*,** Significant at the 0.05 and 0.01 probability levels, respectively.
NS= not significant at the 0.05 probability level.
† Harvest index = grain yield divided by aboveground biomass.

The WUE was calculated by dividing grain yield by crop water use (soil water use from planting until harvest + crop season precipitation). Nitrogen concentration in the grain was determined (10).

A second study examining N fertilizer-atrazine interactions in a no-till system was established adjacent to the above study. Nitrogen was broadcast by hand to the main plots 30 d before planting at the same rates as in the first study. The second factor for the split-plot factorial design was atrazine level. Four atrazine treatments were applied to the subplots: a split application of 1.12 kg ai/ha applied after wheat harvest the year preceding planting (12 July 1984 and 16 July 1985) plus 0.28 kg ai/ha applied approximately 60 d before planting (5 Apr. 1985 and 17 Apr. 1986); and three spring applications, 0.28, and 0.56, and 0.84 kg ai/ha applied on the April dates. Weed control in the preceding year for the three spring-applied atrazine treatments was achieved by applications of paraquat at 0.28 kg/ha in August and September. The herbicides were applied in 280 L/ha of spray solution with a 4-m boom sprayer. Plot size for each individual cell of a particular fertilizer by herbicide combination was 4 m by 4 m. All treatments were replicated four times.

Soil samples to a depth of 25 mm were randomly collected from each plot 60, 90, and 120 d after application of atrazine to determine its persistence. Subsamples of 350 g were placed in 90-mm diam. by 90-mm depth plastic pots (without drainage holes). Five soybean (*Glycine max* (L.) Merr.) seeds were planted, thinned to two plants per plot after emergence, moved to a glasshouse (average temperature 25 ± 5 °C) and watered daily. Aboveground fresh weight was measured 21 d after emergence to determine growth inhibition by atrazine. This data was used to extrapolate atrazine persistence. The number of seed-bearing weed plants were recorded in each plot on the day of harvest. The harvesting procedure for grain yield was the same as in the first study.

RESULTS AND DISCUSSION

No-Till vs. Conventional Till Comparison

Eliminating tillage increased proso millet grain yields and WUE in both years (Table 1). The growing season precipitation between years was 32% less in 1986 than in 1985, yet no-till proso millet yielded over 20% more than conventional-till proso millet in both years. This positive effect of eliminating tillage on grain yields was more pronounced during the dry year (1986), as grain yield were 34% higher with the no-till system. In 1985, seedling establishment was 42% greater in the no-till system (Table 1). This may have been due to the disking operation to prepare the seedbed for the conventional-till system drying out the surface soil and no precipitation occurring until 17 d after planting. In 1986, tillage did not affect seedling establishment because 7 mm of precipitation occurred 2 d after planting. Soil water storage at planting time was increased by eliminating tillage in 1985, but not in 1986. Harvest index and N concentration in the grain were not affected by tillage system in either year.

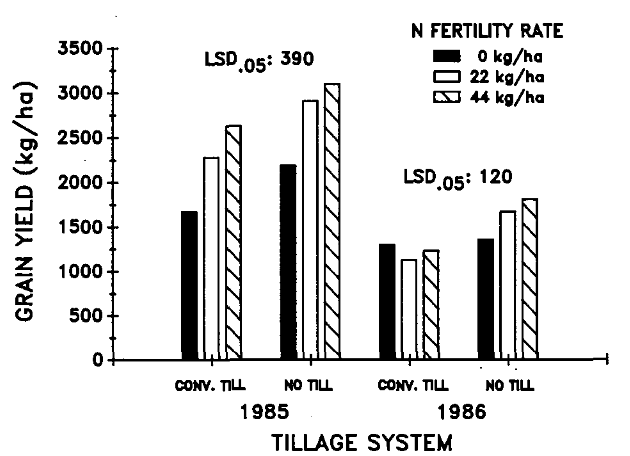

Fig. 1. Effect of N fertilizer within each tillage system on grain yield of proso millet in 1985 and 1986.

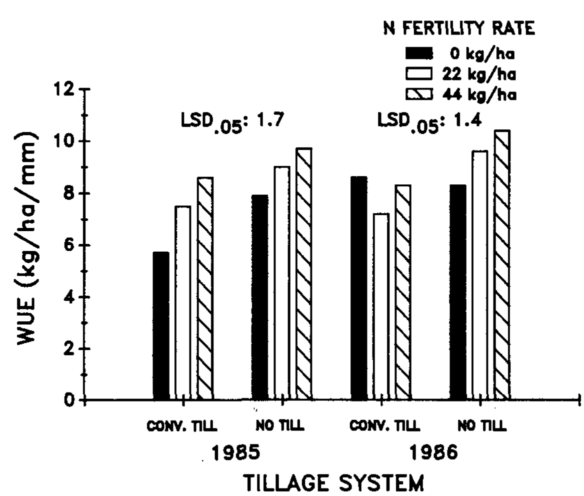

Fig. 2. Effect of N fertilizer within each tillage system on water-use-efficiency (WUE) of proso millet in 1985 and 1986.

Table 2. Effect on N fertilizer on duration of bioactivity of four atrazine rates in a no-till system. The data are the average of 1985 and 1986.

Atrazine level	N level (kg/ha) 0	22	44	Mean
kg ai/ha		d		
0.28	63†	66	66	65
0.56	97	100	97	98
0.84	110	112	110	111
1.12 + 0.28	359	367	364	363
Mean	157	161	159	

LSD (0.05): atrazine = 10; N = NS; atrazine × N interaction = NS
CV (%) = 16

† Data expressed as number of days required before growth inhibition of soybean shoots was less than 20% as determined by the bioassay procedure.

Table 3. The number of seed-bearing weed plants in September of each year as affected by N fertilizer within a no-till system.

Atrazine level	1985 N level (kg/ha) 0	22	44	Mean	1986 N level (kg/ha) 0	22	44	Mean
kg ai/ha	Kochia plants/16 m^2				Redroot pigweed plants/16 m^2			
0.28	11	13	15	13.0	1	2	2	1.7
0.56	5	7	5	5.7	0	1	1	0.7
0.84	3	3	3	3.0	0	1	0	0.3
1.12 + 28	0	0	0	0.0	0	0	0	0.0
Mean	4.8	5.8	5.8		0.3	1.0	0.8	
LSD (0.05): atrazine		3.0				1.0		
LSD (0.05): N		NS				NS		
LSD (0.05): atrazine by N interaction		NS				NS		
CV (%)		87				60		

Nitrogen Fertilizer Effect on Proso Millet Production

Tillage system and precipitation level influenced proso millet response to N fertilizer. Nitrogen increased grain yield in both tillage systems in 1985 when growing-season precipitation was about average (Fig. 1). In 1986, when growing-season precipitation was only 67% of average, N increased grain yield only with the no-till system.

Nitrogen fertilizer effect on WUE of proso millet was similar to its effect on grain yield. In the no-till system, WUE was increased by N in both years, but only in 1985 with conventionally tilled proso millet (Fig. 2). During the dry year (1986), proso millet WUE in the conventional-till system was not increased by N. These results show that proso millet grown in a no-till system will respond positively to N fertilizer, even when cropping-season precipitation is below average. Previous research in the central Great Plains has shown that fall tillage increases the level of soil nitrates in the following spring (2). Without fall tillage, N fertilizer may be needed to ensure an adequate N supply for plant growth in the no-till system.

Nitrogen Fertilizer Effect on Nitrogen Concentration of Proso Millet Grain

A major use of proso millet grain is for livestock feed (14), thus, higher protein in the grain is desirable. Atrazine has been shown to increase N concentration of grain in some crops (4,15). In this study, however, that effect did not occur. Nitrogen fertilizer increased N concentration of proso millet grain in both years (Fig. 3), but this fertilizer effect was not influenced by tillage system (Table 1) or atrazine level (data not shown). If the producer of proso millet feeds his grain to livestock, he would accrue a double benefit of both a yield and grain N content increase from N fertilizer application.

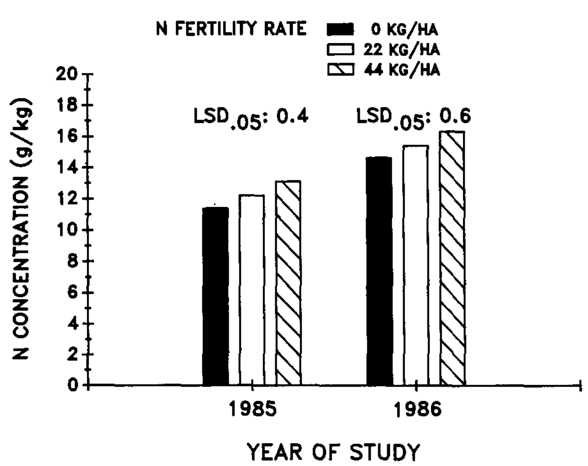

Fig. 3. Effect of N fertilizer on N concentration of proso millet grain in 1985 and 1986. The treatment means represent the average for both tillage systems within that N treatment.

Nitrogen Fertilizer Effect on Soil Persistence of Atrazine

Nitrogen applied as ammonium nitrate did not affect the persistence of atrazine in this soil type (Table 2). Duration of bioactivity was affected only by rate of atrazine. Atrazine applied at 0.28 kg ai/ha in early April persisted 65 d when averaged over all N treatments, and would be insufficient for consistent weed control within the crop canopy of millet planted in early June. In a previous study (1), atrazine at 0.28 kg ai/ha applied immediately prior to planting maintained proso millet weed free. In this study, however, an application 60 d before planting required a rate of at least 0.56 kg ai/ha.

Nitrogen Fertilizer Effect on Weed Control

Ammonium nitrate did not influence weed control with atrazine in the no-till system as shown by the number of established plants of kochia (*Kochia scoparia* L.) in 1985 or of redroot pigweed (*Amaranthus retroflexus* L.) in 1986 (Table 3). Each species was the prevalent weed infesting the site in that particular year; representing more than 90% of the total weed population established within the proso millet canopy. When atrazine was applied at 0.28 kg ai/ha in 1985, 13.0 kochia plants/16 m^2 established within the corp. Doubling the atrazine rate reduced the number of kochia plants by 56%. The split application treatment of atrazine at 1.12 + 0.28 kg ai/ha maintained weed-free proso millet for the entire cropping season. In 1986, less than two redroot pigweed plants developed per plot in the 0.28 kg ai/ha atrazine treatment, with fewer plants establishing in the higher atrazine rate treatments.

Nitrogen fertilizer did not affect weed numbers within the canopy, but it did alter the competitive interaction between proso millet and kochia in a no-till system in 1985, as shown by the regression curves in Fig. 4. When 44 kg N/ha was applied, one kochia

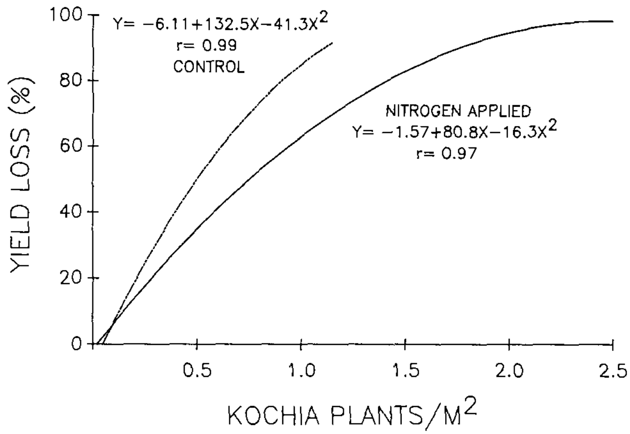

Fig. 4. Effect of 44 kg/ha of N fertilizer on no-till proso millet yield loss due to kochia competition in 1985.

plant/m^2 reduced grain yield 63%, 22% less than when no N was applied. The addition of N increased proso millet tolerance to the competing kochia. The infestation level of redroot pigweed in 1986 did not affect proso millet grain yield, thus no regression equations were developed.

CONCLUSIONS

Proso millet grain yields and WUE in a winter wheat-proso millet-fallow rotation in the central Great Plains were increased more than 20% by eliminating tillage in the production system. Nitrogen fertilizer at either 22 or 44 kg N/ha increased grain yields and WUE of no-till proso millet. Nitrogen fertilizer did not deleteriously affect the duration of bioactivity of atrazine or its in-crop weed control. The addition of N fertilizer altered the competitive interaction between proso millet and kochia in 1985, increasing proso millet tolerance to kochia. The implementation of these two cultural practices, eliminating tillage and adding N, increased the effectiveness of proso millet for producing grain with a limited supply of water, and will decrease the probability of crop failure due to drought in this region.

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