yield data are plotted against the average EC_e of the entire rootzone (0 to 1.2-m depth), a good linear relation is obtained except for the treatment resulting in the lowest average EC_e value (Fig. 2). Thus, in agreement with the findings of Shalhevet and Bernstein (1), the growth of alfalfa was highly related to the average EC_e of the rootzone, marked differences in the distribution of salt having no significant effect. The treatment resulting in the lowest average EC_e value consistently gave somewhat less than maximum yields, suggesting that alfalfa responds slightly to a modest level of soil salinity. Assuming that maximum yield is obtained when the average EC_e value for the rootzone is 3 mmho/cm, the average EC_e values at 10 and 50% yield decreases are about 5 and 11 mmho/cm, respectively (Fig. 2).

The curves in Fig. 3 relate average rootzone EC_e values to LF and to the ratio depth of water applied (D_{iw})/depth of water evapotranspired (D_{ew}) for irrigation waters of equal EC. The curves indicate that the LF's required to maintain the average rootzone EC_e value at about 5 mmho/cm with corresponding yield decreases of only about 10% (Fig. 2) are .13 and .29 for the irrigation waters having EC's of 2 and 4 mmho/cm, respectively. More importantly, the curves in Fig. 3 clearly show that the first increments of leaching are the most effective in preventing salt accumulation in the soil, and that at high LF's much of the water applied in excess of that required for evapotranspiration has little effect in lowering soil salinity. Thus, for saline irrigation waters, maximization of crop yield/unit of water applied will usually require growing the crop at an average rootzone EC_e value that permits less than maximum yield/unit of area.

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Soil Nitrate, Soil Water, and Grain Yields in a Wheat-Fallow Rotation in the Great Plains as Influenced by Straw Mulch[1]

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ABSTRACT

Wheat straw mulch rates greater than 3,360 kg/ha were needed to significantly reduce soil NO_3-N during fallow at three Great Plains locations. Smaller amounts of NO_3-N in the soil at the end of fallow with stubble mulch did not limit grain production. Grain yields of wheat (*Triticum aestivum* L.) were positively correlated with stored soil water at seeding all years at Akron, 2 out of 5 years at North Platte and 2 out of 3 years at Sidney, but there was no relation between grain yields and soil NO_3-N at seeding at any of the locations. Mulched soils contained more water and less NO_3-N at seeding than bare soils. In 7 out of a total of 11 crop years from all locations when grain yields were higher from mulched soil than from bare soil, soil NO_3-N was available in sufficient quantity under both treatments so that final grain yields were not limited. In those years when grain yields were reduced by the presence of a straw mulch, no evidence was obtained that indicated this reduction was due to an inadequate supply of N. Grain yield responses to added N were greater on bare soil than on mulched soil.

Additional key words: Stubble mulched soil, Bare soil, Semiarid.

LOWER NO_3-N content of soil under mulch as compared to bare soil has been proposed as the cause for lower grain yields that sometimes occur under mulching (5). For many years workers have compared soil NO_3-N content during fallow under stubble mulch and moldboard plowing in humid and subhumid areas. These reports have been summarized by Jacks et al. (4). However, information for semiarid conditions and comparison between stubble mulch and shallow-working disk-type implements is very meager. The limited information available (1, 3) indicates that mulching in the semiarid Great Plains reduces soil NO_3-N, but not grain yields. In the two instances cited, the amounts of residue on the soil surface were not reported, and in one case a moldboard plow was used instead of a disk-type implement. Soil NO_3-N accumulation depends upon soil moisture, soil temperature, soil aeration, source and amount of nitrifiable and carbonaceous material and their interactions; all of these factors are in turn influenced by tillage implements used and climatic zone. A need exists for detailed information on soil NO_3-N levels under different mulch rates and where shallow-working, disk-type implements have been used under semiarid conditions.

To obtain this information, parallel studies were initiated on Weld silt loam soil at Akron, Colo., Sprole sandy loam at Sidney, Mont., and Holdredge silt loam at North Platte, Nebr. Data on soil water storage, soil NO_3-N, and soil temperature relationships, as they affect plant growth and development are being studied. Recently published information from these studies shows that soil water storage is consistently increased with increasing straw mulch rates (2). The data reported herein show (i) the effect of straw mulch rates on soil NO_3-N accumulation during the fallow period in the semiarid Central and Northern Great Plains using tillage implements and practices common to the area, and (ii) the relationship of soil water and soil NO_3-N at seeding to final grain yields with and without N fertilizer.

EXPERIMENTAL PROCEDURE

General descriptive information of the plots and some of the procedures used at each of the three Great Plains locations

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Table 1. Description of plot areas and procedures used at three Great Plains locations.

Experimental variable	Great Plains locations		
	Akron, Colo.	North Platte, Nebr.	Sidney, Mont.
Soil type	Weld silt loam	Holdrege silt loam	Sprole sandy loam
Slope of area, %	0.5	2 to 3	3 to 4
Straw rate, kg/ha	1,680; 3,360; 6,720	0; 3,360; 6,720; 10,080	0; 1,680; 3,360; 6,720
Replications	3	3	3
Plot size, m	9.1 × 25.4	4.6 × 25.4	7.8 × 25.4
Harvest area, m^2	186	5.6	1.7

are given in Table 1. The results include five years of fallow (1963-1967) and three years of grain yield (1964 and 1967-68) data from Akron, 5 years of fallow (1962-1966) and grain yield (1963-1967) data from North Platte, and 3 years of fallow (1965-1967) and grain yield (1966-1968) data from Sidney.

Straw mulch at all locations was managed identically during fallow. However, the straw mulch on the soil surface at the end of fallow was disked into the soil prior to seeding Fortuna spring wheat at Sidney, but was left on the soil surface when Wichita and Lancer winter wheats were planted at Akron and North Platte, respectively. Nitrogen fertilizer treatments were established by broadcasting ammonium nitrate at rates of 168 and 34 kg/ha at North Platte and Sidney, respectively, just before the final tillage prior to seeding winter wheat at North Platte and spring wheat at Sidney.

Soil NO_3-N at all locations was determined by the phenoldisulfonic acid method using a minimum of two samples per treatment plot and three replications per treatment. At Akron, Colo. the sampling depth was 91 cm during fallow and 182 cm at the end of fallow. At North Platte, Nebr. and Sidney, Mont. the surface 91 cm of soil was sampled during both the fallow and crop growth periods. Each 91-cm depth was divided into five increments (0-7.5, 7.5-15, 15-30, 30-60, and 60-91 cm). At North Platte, the total sample depth was 182 cm. Below 91 cm, sample increments were 91-121, 121-152, and 152-182 cm.

Soil water content at seeding was determined by gravimetric procedures at Akron and Sidney but with a neutron probe at North Platte. Sampling depth was 182 cm at Akron and North Platte and 152 cm at Sidney.

The silt loam soils at Akron and North Platte are in the medium to high P content range and past experiments have not shown wheat to respond to application of P fertilizer. However, wheat grown on the sandy loam soil at Sidney consistently responds to applied P, therefore, an application of 34 kg/ha of P was made to all treatments.

RESULTS AND DISCUSSION

Fallow Period

The influence of mulch rate on soil NO_3-N during fallow was similar at all locations (Fig. 1). Nitrate-N content of the soil at the end of fallow was significantly lower with a mulch rate of 6,720 kg/ha at Akron and Sidney and with the 10,080 kg/ha rate at North Platte.

At North Platte, the NO_3-N contents of soils were similar among the 0, 3,360, and 6,720 kg/ha mulch rates at the beginning (all soils had 25 kg/ha NO_3-N) and at the end of fallow (107, 110, and 106 kg/ha NO_3-N, respectively). However, straw mulch rates did cause differences in time of soil NO_3-N release within the fallow period. In late May and early June, soil NO_3-N increased sharply in all treatments, with the sharpest increase occurring where no mulch was present. From late July to the end of the fallow period there was little increase in soil NO_3-N under bare soil, but NO_3-N in mulched soils continued to increase until the end of fallow, at which time the bare soil and soils with the two lower mulch rates had approximately the same NO_3-N level. The slower rate of NO_3-N accumulation in the bare soil during the latter portion of fallow may have been caused by the occurrence of unfavorable surface soil conditions for nitrate release (lower soil water and/or high soil temperatures), or the supply of easily nitrifiable material in the bare soil may have been exhausted by early August.

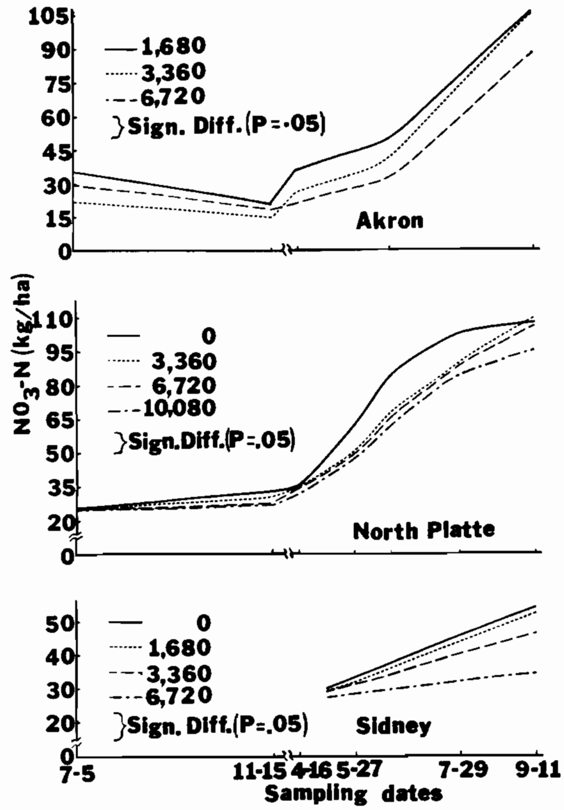

Fig. 1. Effect of straw mulch rate during fallow on soil NO_3-N content of the surface 91 cm of a Weld silt loam soil at Akron, Colo., a Holdrege silt loam soil at North Platte, Nebr., and a Sprole sandy loam soil at Sidney, Mont.

Distribution of NO_3-N in the soil profile at the end of fallow at North Platte and at Sidney (Fig. 2) shows the bare soil with more NO_3-N than the mulched soil for only the upper 30 cm of soil at North Platte, and below 15 cm at Sidney. At North Platte the 30- to 60-cm depth of mulched soil contained 3-6 kg/ha more NO_3-N than did bare soil. Data from these two Great Plains locations also indicate that at normal seeding depth there is no significant difference in NO_3-N available to plants with rates of surface mulch less than 10,080 and 6,720 kg/ha at North Platte and Sidney, respectively.

Grain Yields

Plant growth and yields are largely controlled by the supply of available water and the amount of essential nutrients available to the plant. Under dryland conditions in the semiarid Great Plains water is generally considered to be limiting more often than is the supply of essential nutrients for crop production. Soil water at seeding has been shown to increase with increasing straw mulch rates (2), with corresponding grain yield increases (Table 2). For 7 out of a total of 11 crop years, final grain yields were positively correlated with stored soil water at seeding time when no N was added, with correlations of $r = 0.891$ ($p = 0.05$), $r = 0.983$ ($p = 0.01$) and $r = 0.963$ ($p = 0.01$) for Akron, North Platte, and Sidney, respectively. With applied N, final grain yields were still positively correlated with stored soil water at seeding with $r = 0.868$ ($p = 0.05$) and $r = 0.965$ ($p = 0.01$) for North

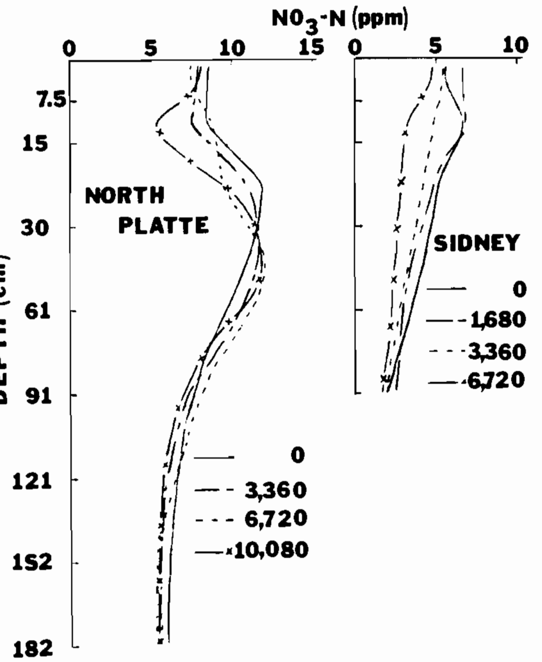

Fig. 2. Distribution of NO_3-N in a Holdrege silt loam soil profile at North Platte and a Sprole sandy loam soil profile at Sidney at the end of fallow as influenced by rates of wheat straw mulch.

Platte and Sidney, respectively. Table 3 shows that in 4 experimental years there was no correlation between soil water at seeding and grain yields at North Platte and Sidney.

When grain yields were related to soil water at seeding (Table 2), the highest grain yields were obtained where soil NO_3-N was lowest. Adding N at North Platte and at Sidney resulted in near equal grain yield increases regardless of mulch rate, but the increase from the added N was larger at Sidney than at North Platte. This would be expected since the soil at Sidney was a sandy loam while that at North Platte was a silt loam. When grain yields were not related to soil water at seeding (Table 3) there was no relationship between grain yields and soil NO_3-N at seeding either with or without N fertilizer. It is important to note that the largest yield increase from the fertilizer at both locations was obtained where no residue was present. When grain yields were less from mulched soil than from bare soil the lower soil NO_3-N level associated with mulched soils was not the predominant factor influencing grain yields.

At North Platte, Nebr., average daily soil temperatures in the crown zone of the wheat plant were as much as 5 C below the optimum soil temperature for wheat plant growth for periods of 25 to 40 days longer in the spring under mulched soil compared to bare soil in the years when yield reductions occurred. This prolonged soil temperature below the optimum growth range is believed to be the factor responsible for reducing plant growth and subsequent grain yield under mulch in some years at North Platte. Lower soil temperature with mulch and a light infestation of leaf spot disease may have been responsible for the yield variations obtained for the one year at Sidney, Mont.

Of greatest importance for sustained crop production in the semiarid Plains are the soil water and soil

Table 2. Influence of fallow straw mulch rate on soil water and soil NO_3-N at seeding and subsequent grain yields in years when plant growth was related to stored soil water with Weld silt loam soil at Akron, Holdrege silt loam soil at North Platte, and Sprole sandy loam soil at Sidney.

Straw mulch rate	Soil water at seeding	Soil NO_3-N		Grain yields	
		O	N*	O	N*
kg/ha	cm	kg/ha		kg/ha	
		Akron 3-yr avg (1964 and 1966-67)			
1,680	19.6a†	106b	-	1,540a	-
3,360	20.3a	106b	-	1,620ab	-
6,720	23.0b	88a	-	1,730b	-
		North Platte 2-yr avg (1963 and 1967)			
0	24.5a	107b	191c	1,880a	2,030a
3,360	28.1b	110b	175b	1,970a	2,140ab
6,720	30.8c	106b	173b	2,120b	2,280b
10,080	33.6d	96a	150a	2,240c	2,380c
		Sidney 2-yr avg (1966 and 1968)			
0	25.1a	60b	-	1,630a	2,130a
1,680	26.3a	60b	-	1,660a	2,270a
3,360	26.8a	54b	-	1,910ab	2,410ab
6,720	29.2b	35a	-	2,090b	2,560b

* Rate of N at North Platte was 168 kg/ha and at Sidney 34 kg/ha. † Values accompanied by the same letter or letters are not significantly different (p = .05).

Table 3. Influence of fallow straw mulch rate on soil water and soil NO_3-N at seeding and subsequent grain yields in years when plant growth was not related to stored water with Holdredge silt loam soil at North Platte and Sprole sandy loam soil at Sidney.

Straw mulch rate	Soil water at seeding	Soil NO_3-N		Grain yields	
		O	N*	O	N*
kg/ha	cm	kg/ha		kg/ha	
		North Platte 3-yr avg (1964-1966)			
0	23.6a†	107a	171ab	3,030b	3,380b
3,360	27.4b	110b	180b	2,480a	2,760a
6,720	32.8c	106a	164a	2,560a	2,880a
10,080	35.4d	94a	168a	2,400a	2,720a
		Sidney 1-yr (1967)			
0	24.9a	72b	-	1,500a	1,990a
1,680	24.9a	72b	-	1,730b	1,880a
3,360	26.4a	64b	-	1,590a	2,040a
6,720	28.7b	34a	-	1,620ab	1,900a

* Rate of N was 168 kg/ha and 34 kg/ha at North Platte and Sidney, respectively.
† Values accompanied by the same letter or letters are not significantly different (p = .05).

NO_3-N levels at the end of fallow, or at seeding. Mulch on the soil surface may result in a lower soil NO_3-N level than that in bare soil but soil water content will be greater in mulched soil than in bare soil; and under semiarid conditions where fallow is a necessity, soil water is a more predominant factor influencing grain yields than is soil NO_3-N. No positvie relationship was established between soil NO_3-N at seeding and final grain yields either when yields were related to soil water at seeding and soil temperature was not a factor, or when yields were not related to soil water at seeding and soil temperature was a factor whether with or without added N. This indicates that the soil NO_3-N was adequate for normal plant development with all mulch rates.

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