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REDUCED TILLAGE MAXIMIZES FALLOW SOIL WATER STORAGE

by

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SUMMARY:

Reducing or eliminating tillage during the 14 month fallow period in a wheat-fallow rotation increased soil water potential and nitrate-N accumulation to greater soil depths than the all tillage treatment. Thereby creating a more favorable environment for root development which was reflected by increased production of a higher quality.

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Reduced Tillage Maximizes Fallow Soil Water Storage [1/]

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Winter wheat can consistently be produced on dryland in the semi-arid Central Great Plains when a 10 to 14 months fallow period immediately preceeds planting of the wheat crop (Greb, et.al. 1974, Smika 1970). Increasing amounts of wheat residue on the soil surface at the start of fallow has been shown to increase soil water storage during a 14 month fallow period (Greb, et.al. 1967). The quantity of crop residue on the soil surface is reduced by each tillage operation during fallow regardless of type of implement used (Fenster, et.al. 1965). Therefore, substituting herbicides for mechanical tillage for weed control during fallow will leave more crop residue on the soil surface to increase soil water storage (Wicks & Smika 1973). Soil water storage during fallow has been shown to be greater where herbicides were used for weed control than when tillage alone was used (Greb 1974, Smika & Wicks 1968, Wicks & Smika 1973).

Most of the herbicide research on fallow in the Central Great Plains has been concerned with only soil water storage aspects. Little emphasis has been given to the affects of herbicide treatments on the fertility status of the soil. However, Greb (1974) found that for the complete 14 month fallow period there was no difference in total soil NO_3-N accumulation whether weeds were controlled by tillage alone or with herbicide-tillage combinations. However, good weed control by either method resulted in 31 kg/ha more nitrate-N at the end of fallow compared to no weed control during the first 15 weeks of fallow.

The experimental results reported herein will show the effects of reduction or elimination of tillage during the 14 month fallow period in a wheat-fallow rotation through the use of herbicides on soil water and soil NO_3-N storage and distribution and their potential influence on the plant root environment.

Methods and Materials

Field Experiments were conducted in a farmers field near Oakley, Kansas during the 1970-71 and 1971-72 fallow periods and on the U. S. Central Great Plains Field Station near Akron, Colorado during the 1974-75 fallow period. Treatments in both locations were (a) weed control

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during fallow as needed with subsurface tillage implements (all tillage), (b) residual + contact herbicides applied only at start of fallow with subsequent tillage as needed for weed control when the residual herbicide no longer gave satisfactory weed control - this usually occurred late in the 11th or during the 12th month following the initial herbicide application (reduced tillage), and (c) residual + contact herbicides applied at start of fallow with subsequent contact herbicide applications as needed for weed control when the residual herbicide no longer gave satisfactory weed control (no tillage). Each treatment was replicated three times at both locations and plots were 11 m wide by 30 m long.

Soil water was determined gravimetrically by 30 cm increments to a depth of 180 cm. At Oakley, samples were collected after winter wheat harvest on July 9, November 4, April 12, and September 20, both years. At Akron, samples were collected on September 29, April 21, and September 9. The initial sampling was delayed due to late establishment of the treatments on stubble following winter wheat harvest. However, weeds on the entire experimental site were uniformly controlled immediately after harvest with a contact herbicide application.

Soil samples for soil NO_3-N analysis were collected on the same dates as the initial and final soil water samplings at both locations. Samples were collected in 30 cm increments and NO_3-N determined by the phenoldisulfonic acid method. Residue on the soil surface at the end of fallow was determined from 2 sites per experimental plot using standardized procedures (Whitfield et.al. 1962). Grain yield at Oakley was determined by combine harvesting an area 5 m wide by 25 m long from each plot. A small grain sample was randomly taken from the yield for Kjeldahl nitrogen analysis. Protein contents reported are the factor 5.7 times the percent Kjeldahl nitrogen. All values reported from Oakley are an average of the 2-years of study.

RESULTS AND DISCUSSION

Soil water storage within sampling periods as well as for the entire fallow period was consistently highest in the no-till treatment and generally lowest for the all tillage treatment at Oakley, Kansas (Table 1). The quantity of residue on the soil surface at the end of fallow for the two years of study averaged 1250, 1570, and 2090 kg/ha for the all tillage, reduced tillage, and no tillage treatments, respectively. Thus, reducing or elimination tillage increased residue quantity on the soil surface which in turn effectively increased soil water storage. Storage efficiencies ranged from a low of 4.5% for the all tillage treatment during the harvest to November 4 period to a high of 161.8% for the no tillage treatment during the November 4 to April 12 period (overwinter). The high overwinter storage was attributed to snow trapping in standing wheat stubble (Smika and Whitfield 1966). Total fallow period storage efficiencies ranged from 34.8% for the all tillage treatment to 53.2% for the no tillage treatment. These results were similar to those obtained at North Platte, Nebraska (Smika & Wicks 1968, Wicks & Smika 1973).

No tillage and reduced tillage increased soil water content (potential) to a deeper depth in the soil profile than did the all tillage treatment (Fig. 1). The higher water storage from harvest to November 4 in the reduced and no tillage treatments accounts for the higher water storage in the 90-120 cm depth compared to the all tillage treatment. Thus comparing reduced or no tillage to the all-tillage treatment the soil environment for root development to greater depths was more favorable due to the higher soil water potential because root development is reduced as soil water potential decreases (Klute & Peters 1969).

Although soil NO_3-N was not measured on November 4, Greb (1974) during a similar period found a small increase in soil NO_3-N content where weeds were controlled with herbicides compared to tillage alone. Thus, it is believed the same phenomena occurred in this study and the NO_3-N accumulated in the soil in the fall with the fall stored water was moved deeper into the soil profile with the storage of the overwinter precipitation (Fig. 2). The higher soil water storage and the higher NO_3-N levels in the 60-120 cm depth where tillage was eliminated or reduced is conducive to the production of wheat grain with higher protein levels (Smika & Grabouski 1975).

Total soil water storage amounts were directly reflected in production of both straw and grain (Table 2). The total soil water storage - production relationships were $r^2 = 0.922$ and 0.899 for straw and grain, respectively. For each cm more water in the soil of the reduced or no tillage treatments than was stored in the all-tillage treatment, straw production was increased an average 95 kg/ha and grain yield an average of 35.6 kg/ha. Grain protein content (Table 2) increased with the more favorable environment for root development in the deeper soil depths with reduced- and no-tillage compared to the all tillage treatment. Soil NO_3-N increases with no- and reduced-tillage were small compared to the all tillage treatment. However, because reduced and no tillage treatments had a more favorable soil water - soil NO_3-N distribution in the soil profile, winter wheat roots utilized the available NO_3-N deeper in the soil profile more efficiently than that in the all tillage treatment (Fig. 2). The NO_3-N increases were therefore very effective for increasing grain protein because they largely occurred between the 60 to 120 cm depth. This soil depth has been shown to be the most effective for NO_3-N in the soil to increase grain protein (Smika & Grabouski 1975).

At Akron soil water storage during the entire fallow period was highest for the no tillage treatment and lowest for the all tillage treatment (Table 3). In this study the initial soil water sampling was in late September and there was no sampling in November, thus the fall and overwinter periods were combined. The storage efficiency for the all tillage treatment was somewhat higher than normally expected but may have occurred because the late initial sampling excluded July, August, and most of September which are normally months of low water storage efficiency. Although difference in total soil water storage was small, two important advantages occurred with the water stored where tillage was reduced or eliminated compared to the all tillage treatment, (1) consistently more water was stored in the 60 to 120 cm depth (Fig. 3) and (2) there was a somewhat higher water content in the 0-30 cm depth. The deeper stored water has the same advantage in encouraging root development to utilize the deeper stored soil NO_3-N (Fig. 4) as occurred in the study at Oakley, Kansas. The higher soil water content near the soil surface provides a better environment for plant establishment and initial growth.

CONCLUSIONS

Reducing or eliminating tillage during the 14 month fallow period in a wheat-fallow rotation increased total soil water storage 52% over that in the all tillage treatment. Increasing total water storage increased soil water potential to a greater soil depth. Reducing or eliminating tillage also increased soil NO_3-N accumulation in the 60 to 120 cm soil depth. Thus with a higher soil water potential and higher NO_3-N accumulation a more favorable environment for root development was created. This was reflected by the grain and straw production increases and the higher protein level grain produced.

References

1. Fenster, C. R., N. P. Woodruff, W. S. Chepil, and F. H. Siddoway. 1965. Performance of tillage implements in a stubble mulch system III. Effects of tillage sequences on residue, soil clodiness, weed control and wheat yield. Agron. J. 57:52-55.

2. Greb, B. W. 1974. Yield response to fall weed control in new wheat stubble in a fallow-wheat rotation. Proc. Colo. Crop Prot. Inst. Colo. State Univ. Press.

3. Greb, B. W., D. E. Smika, and A. L. Black. 1967. Effect of straw mulch rates on soil water storage during summer fallow in the Great Plains. Soil Sci. Soc. Am. Proc. 31:556-559.

4. Greb, B. W., D. E. Smika, N. P. Woodruff, and C. J. Whitfield. 1974. Summer fallow in the Central Great Plains. Chapt. 4, p. 51-85. In: Summer fallow in the Western United States. USDA Cons. Res. Rpt. No. 17.

5. Klute, A. and D. E. Peters. 1969. Water uptake and root growth. In: Root Growth (W. J. Whittington, ed.). Butterworths, London.

6. Smika, D. E. 1970. Summer fallow for dryland winter wheat in the semiarid Great Plains. Agron. J. 62:15-17.

7. Smika, D. E. and P. H. Grabouski. 1975. Manage fallow to boost wheat protein. Crops & Soils. 28:7-8.

8. Smika, D. E. and C. J. Whitfield. 1966. Effect of standing wheat stubble on storage of winter precipitation. J. Soil & Water Cons. 21:138-141.

9. Smika, D. E. and G. A. Wicks. 1968. Soil water storage during fallow in the Central Great Plains as influenced by tillage and herbicide treatments. Soil Sci. Soc. Amer. Proc. 32:591-595.

10. Whitfield, C. J., et.al. 1962. A standardized procedure for residue sampling. A committee report. USDA, ARS 41-68. p. 9.

11. Wicks, G. A. and D. E. Smika. 1973. Chemical fallow in a winter wheat-fallow rotation. J. of Weed Sci. of Am. 21:97-102.

Table 1. Soil water storage and storage efficiency as affected by fallow treatments at Oakley, Kansas, 2-year average.

Treatment Period	Fallow Treatments					
	All Tillage		Reduced Tillage		No Tillage	
	Water Stored	Storage Eff.	Water Stored	Storage Eff.	Water Stored	Storage Eff.
	cm	%	cm	%	cm	%
Harvest to Nov. 4	0.66a*	4.5	3.60b	24.8	3.66b	25.2
Nov. 4 to April 12	6.78m	98.1	10.95n	158.5	11.18n	161.8
April 12 to Sept. 20	13.64s	34.9	12.47s	31.9	17.32t	44.3
Total fallow period (Harvest to Sept. 20)	21.08x	34.8	27.02y	44.7	32.16z	53.2

* Soil water storage values for each treatment period accompanied by different letters and significantly different at the 5% level.

Table 2. Straw and grain production and grain protein content as influenced by fallow treatment at Oakley, Kansas, 2-year average.

Fallow Treatment	Yield		Grain Protein
	Straw	Grain	
	kg/ha		%
All tillage	3620a	1546s	11.9x
Reduced tillage	4310b	1680s	12.3xy
No tillage	4440b	2033b	13.1y

Table 3. Soil water storage and storage efficiency as affected by fallow treatments at Akron, Colorado.

Treatment Period	Fallow Treatments					
	All Tillage		Reduced Tillage		No Tillage	
	Water Stored	Storage Eff.	Water Stored	Storage Eff.	Water Stored	Storage Eff.
	cm	%	cm	%	cm	%
Sept. 29 to Apr. 21	2.99a*	35.7	6.12b	73.0	5.92b	70.6
Apr. 21 to Sept. 9	14.45u	45.0	12.29t	38.1	13.41tu	41.8
Total fallow period (Sept. 29 to Sept. 9)	17.45x	43.1	18.36xy	45.3	19.33y	47.7

* Soil water storage values for each treatment period accompanied letters a, b are significantly different at the 5% level and by the letters t, u and x, y are significantly different at the 10% level.

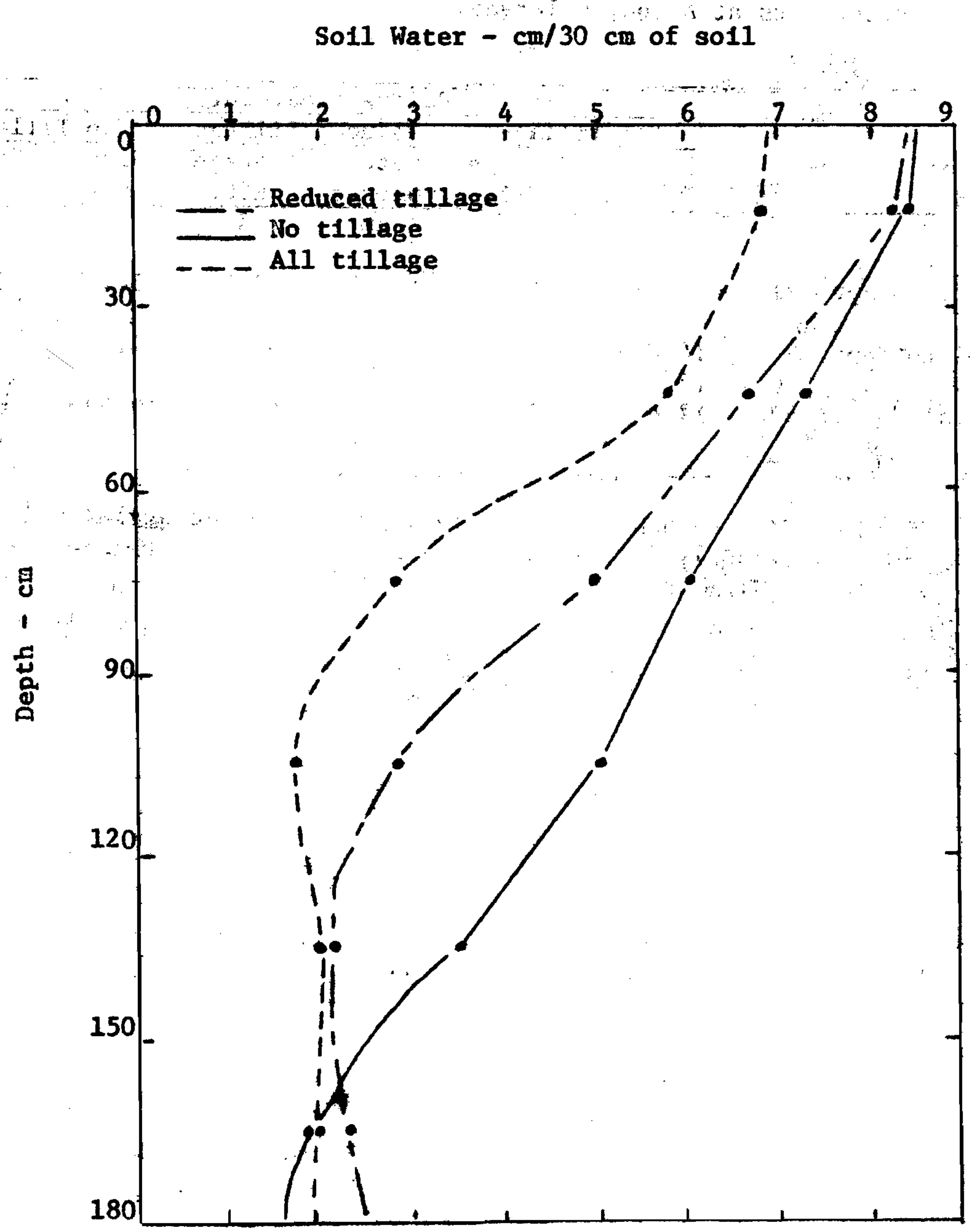

Figure 1. Water content of soil profile to depth of 180 cm at end of fallow on Sept. 20 for three treatments at Oakley, Kansas, 2-year average.

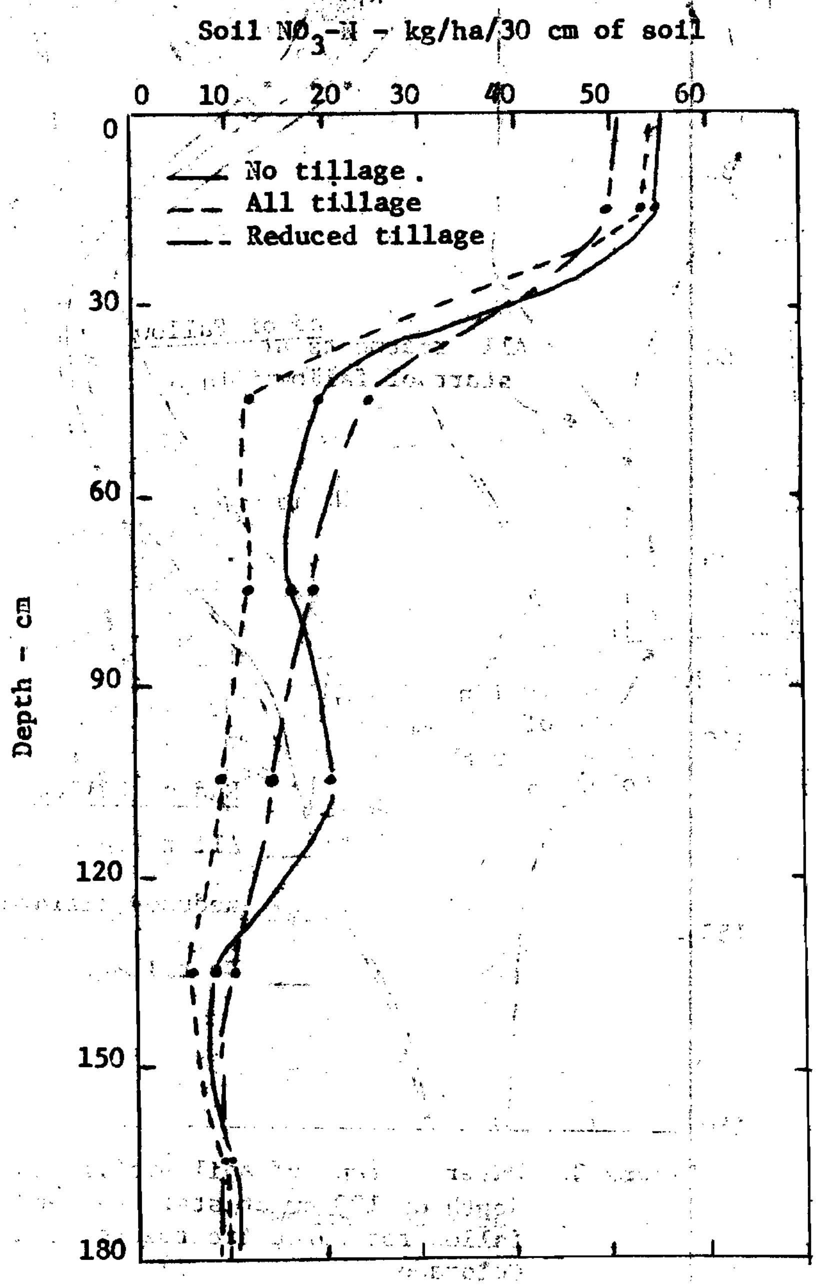

Figure 2. Distribution of NO_3-N in soil profile to depth of 180 cm at end of fallow on Sept. 20 for three treatments at Oakley, Kansas, 2-year average.

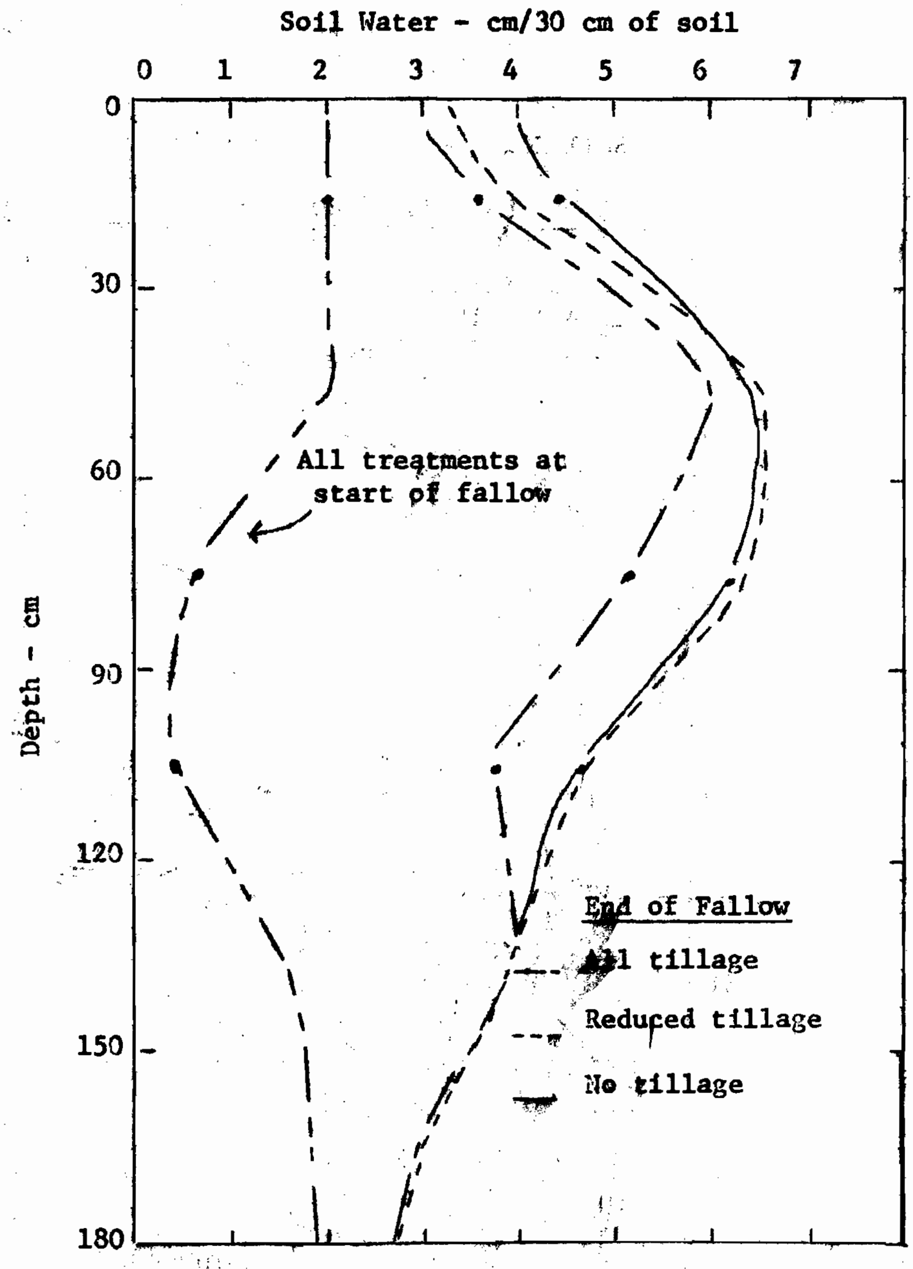

Figure 3. Water content of soil profile to a depth of 180 cm at start and end of fallow for three treatments at Akron, Colorado.

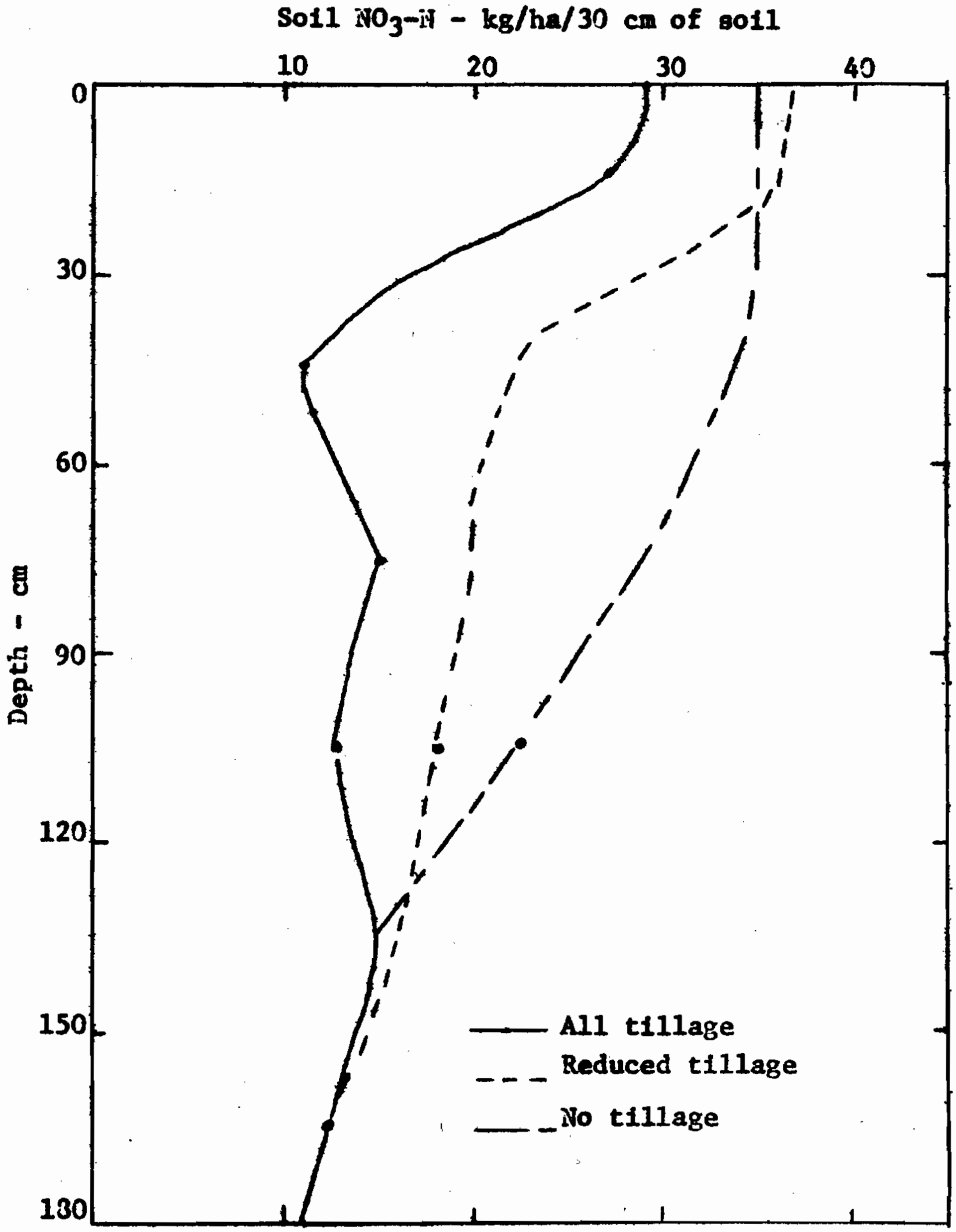

Figure 4. Distribution of NO_3-N in soil profile to depth of 180 cm at end of fallow for three treatments at Akron, Colorado.