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173 Zonal Surface Management for Rainfed Vertisols

K. L. Srivastava, G.D. Smith, and L. S. Jangawad
Resource Management Program, International Crops Research Institute
for the Semi-Arid Tropics (ICRISAT)
Patancheru, A.P. 502 324, India

Introduction

The optimum water range for traffic and tillage on Vertisols is narrow. Tillage of dry soil requires high energy inputs, whereas tillage or traffic on wet soil leads to puddling and compaction. But farmers of the semiarid tropics (SAT), particularly those practicing double cropping, are often compelled by weather and socioeconomic factors to work on wet soils. This paper reports on the effects of (i) compaction by human foot traffic on establishment and yield of two sequentially sown post rainy-season crops: chickpea (*Cicer arietinum* L.) and safflower (*Carthamus tinctorius* L.), (ii) compaction on size of soil cracks. It also suggests some criteria for determining the need for zonal management of surface soil.

Method

The two experiments reported in this paper were conducted on a Vertisol (Typic Pellustert, Kasireddipalli Series [El-Swaify et al., 1985]) at ICRISAT Center, Patancheru, India.

Experiment 1

This experiment was conducted in 1981/82 and 1983/84 on plots where maize (*Zea mays* L.) was grown during the rainy season. The experimental area had been under the broadbed-and-furrow (BBF) system (El-Swaify et al., 1985; Kampen, 1982) since 1976. During this time, all animals and equipment wheels followed the furrow (50-cm width), and the double-cropped bed zone (100-cm width) was generally free of traffic. In both years, the soil was wet (about 35-36% water by weight in the 0- to 10-cm layer) at the time of maize harvest. Treatments were imposed by having laborers harvesting and hauling maize either to walk in the furrow (normal beds) or to walk on the beds (trampled beds). When the surface soil (0-10 cm) dried to 25-26% water content by weight, shallow blade harrowing (4-6 cm deep) was done by an animal-drawn, wheeled tool carrier with a blade attachment. Immediately after this cultivation, chickpea and safflower were planted by a planter attached to the wheeled tool carrier. In both of these operations, traffic was confined to the furrow.

Experiment 2

This experiment was conducted in summer in an uncropped field. Steel frames 150 cm square and 30 cm high were installed in the soil to a depth of 15 cm to create two miniplots. The soil in each miniplot was wetted uniformly by quick flooding with 50 mm of water. On the following day, wet soil in the middle strip (Fig. 1) was removed with a hand tool to a depth of 15 cm and subsequently compacted in 5-cm layers by rolling with a pneumatic wheel. Bulk density of compacted soil was 1.45 Mg/m^3 at a gravimetric water content of 301 g/kg, compared with 1.33 Mg/m^3 for uncompacted soil (Srivastava et al., in press). Eight days after the second wetting, the cracking patterns were photographed, and the depth of major cracks (>5 mm width) was measured by probing with a 2-mm diameter wire.

Results

Table 1 shows that foot traffic on the bed during the maize harvest significantly ($P < 0.05$) reduced establishment and yield of sequentially sown chickpea and safflower. Also, draft requirement for the planting operation was higher on trampled beds than on normal beds (1240 N versus 1005 N).

Figure 1 shows that compaction of wet soil led to formation of deeper and wider surface cracks. The mean depth of cracks was 5.1 cm in the compacted zone, compared with 2 cm in the uncompacted zone.

Discussion

Trampling and Crop Growth (Table 1)

In the improved technology developed at ICRISAT for management of Vertisols, one aim is to quickly establish sequential post rainy season crops. In order to minimize evaporation losses, it is usual to avoid intensive tillage between harvest of the rainy season crops (maize in this case) and planting of the post rainy crops (Kampen, 1982). The seedbed preparation for post rainy crops usually consists of the blade-harrowing operation we used which controls weeds, but loosens only about 5 cm of soil. This operation clearly did not remedy the effects

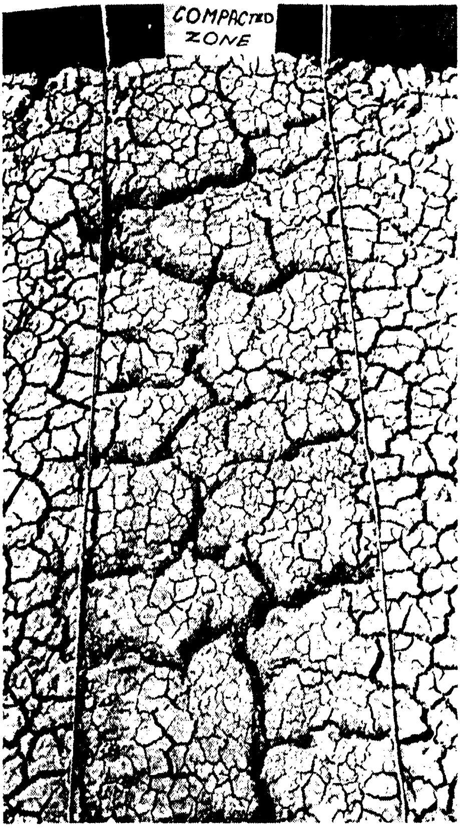

Figure 1. Effect of zonal compaction on cracking in a Vertisol, ICRISAT Center (from Srivastava et al., in press).

Figure 2. Gross cracks arrowed in a furrow of BBF system. This photograph was taken one day after 36 mm of rain fell on June 17, 1987 (peak 15-min intensity was 90 mm/h).

of bed trampling during harvest. We consider that the lower plant population and uneven crop stand on trampled beds may have been caused by reduced germination in the coarser tilth of this seedbed. The seedbeds in trampled beds were obviously cloddier, which would have reduced seed-soil contact, increased evaporation and exposed seeds to birds and insects. We observed many uncovered seeds after sowing on trampled beds. Also, some seeds may have failed to emerge from under coarse clods. Apart from effects due to lower plant population, yield on trampled beds may have been lower because of more rapid drying of the cloddy seedbed and slower root system development. There may have also been nutritional effects due to denitrification losses or to inaccessibility of nutrients in large clods.

These adverse effects of trampling occurred despite the previous history, which should have improved soil structure. This highlights the fragility of structure in these soils, the danger of even one instance of puddling and the harm that can result from ill-timed compaction despite the soil's ability to recover later.

Compaction and Cracking (Fig. 1)

Compaction induces deeper and wider surface cracks, which may develop with further drying into gross cracks. Formation of deeper and wider cracks on compacted soils can be explained by a qualitative model (Srivastava et al., in press). If compaction is restricted to a particular traffic zone, most gross cracks will be located there. When rain intensity exceeds the intake rate of the soil in the cropping zone, runoff will be

Table 1. Effect of laborers walking on beds when soil is wet (trampling) on the establishment and yield of sequentially sown chickpea and safflower on a Vertisol, ICRISAT Center, 1981/82 and 1983/84.

	Plant population				Grain yield			
	Chickpea		Safflower		Chickpea		Safflower	
Treatment	1981/82	1983/84	1981/82	1983/84	1981/82	1983/84	1981/82	1983/84
	no. m^{-2}				Mg ha^{-1}			
Normal bed	32.6	21.6	13.8	9.6	1.8	2.3	1.4	1.5
Trampled bed	17.0	14.8	9.2	7.0	1.0	1.9	0.8	1.1
SE ±	1.15	3.39	0.68	0.96	0.04	0.03	0.07	0.07

intercepted by the gross cracks in the traffic zone and channeled into the subsoil. This hypothesis was confirmed by observations in two Vertisol watersheds at ICRISAT Center following high intensity storms in June 1987 and April 1988. The cracks in the compacted furrows of a BBF system intercepted runoff from the bed (cropping) zone (Fig. 2) and conducted it to the 30- to 70-cm layer (Srivastava and Smith, unpublished data).

Concluding Comments

The importance of keeping compaction in a particular zone, in a given farming system, will depend on: (a) susceptibility of a soil to puddling and compaction, (b) joint probability of a compacting operation coincident with the periods of high soil water (above plastic limit), (c) scope for alleviating negative effects of soil trampling and compaction in the cropping zone by natural (e.g., wetting and drying cycles) and artificial (e.g., tillage) processes before they impinge on crop productivity, (d) scope and value of water conservation and energy saving through zonal surface management, and (e) negative effects (if any) of compacted zones on neighboring cropping zones (e.g., limitations to root growth).

Further research is needed to fully understand the processes associated with zonal management and to develop prediction models. The BBF system includes zonal surface management. But in this system, the effect of zonal surface management is confounded with microtopography effects created by the raised bed. We need to develop a better understanding of soil processes associated with zonal surface management *per se*.

References

El-Swaify, S.A., P. Pathak., T.J. Rego, and S. Singh, 1985. Soil management for optimized productivity under rainfed conditions in the Semi-Arid Tropics. Advances in Soil Science 1:1-64.

Kampen, J. 1982. An approach to improved productivity on deep Vertisols. Information Bulletin No. 11. Patancheru, A.P., India: International Crops Research Institute for the Semi-Arid Tropics.

Srivastava, K.L., G.D. Smith, and L.S. Jangawad. Compaction and shading effects on surface cracking in a Vertisol. Soil and Tillage Research. (In press).