Tillage Effects on the Soil Moisture Regime

G. B. Triplett, Jr., William Kingery and Mark Shankle

Department of Plant and Soil Sciences
Box 9555
Mississippi State University, MS 39762
gtriplett@pss.msstate.edu

Before the development of herbicides capable of providing full-season weed control without pre-plant tillage or post-emergence cultivation, both were necessary for crop production on all soils and for all crops. By eliminating weed control as a reason for tillage, conservation tillage practices, including no-tillage (NT), are increasingly being adopted by producers. But large differences in soils and their response, which includes available moisture, to tillage and other components of management systems, have become apparent. On some soils, but not on others, no tillage can lead to improvement in the amount of water available for the growing crop, which may translate into greater crop productivity during growing seasons with limited rainfall. A major factor in moisture supply, crop response and soil management for NT crop production is the potential of the soil to shrink and crack as it dries. Soils that crack upon drying include individual members of entisols, inceptisols, mollisols, alfisols, and ultisols, as well as vertisols. Cracks provide convenient avenues for rapid rainfall infiltration into dry soil, although some cracking soils with high clay content may have hydraulic conductivity rates in the range of millimeters/day when saturated. In the Southeastern US, moisture regimes with respect to tillage should be given as much attention as other aspects of cropping systems.

When tilled, soils that do not contain adequate amounts of 2:1 clay to crack upon drying and have a sandy loam or finer texture exhibit a positive yield response to postemergence cultivation even in the absence of weeds. Raindrop impact on bare, tilled soil orients soil particles to form a crust that seals the soil surface and reduces the rainfall infiltration rate. Cultivation following rainfall breaks the crust, increasing the amount of water infiltrating with the next rainfall event. However, in many cases, after the crop canopy is formed and as the crop matures, cultivation is not practical. In tilled production systems, fall or spring tillage loosens the soil and buries part of or all crop residue. Tillage is a drying operation and loosened soil dries on the surface. Although macropores are disrupted, if the layer loosened by primary tillage is not pulverized with additional tillage and remains rough with voids between clods, water intake from the first rainfall event following tillage is rapid with little runoff. But, without additional cultivation the soil surface crusts with successive rainfall events, reducing infiltration and greatly increasing runoff. In turn, crop productivity response to NT and non-cultivated management, without cover, can be precipitous. Crop yield can be as much as 20% lower than that of tilled and cultivated during years with moisture deficits during the growing season (Triplett et al., 1968). Conversely, with optimum management, crop yields can be 20 to 30% greater for NT than the best tilled production systems on these same soils.

Various mechanisms are involved in improved moisture supplies with NT and mulch cover on non cracking soils. These include: increased rainfall infiltration, less runoff, changes in water movement patterns, reduced evaporation from the soil surface, improvement in the availability of moisture in the soil profile, and better utilization of small rainfall events. Although these effects may be additive, the relative importance of each likely varies with site, soil, crop, growing season and rainfall patterns. However, improved infiltration so that less water runs off, making more available for the crop, is a dominant mechanism. A brief review of each follows:

No-tillage yields on non cracking soils increases with the amount of **mulch cover** present. Mulch cover of 70 to 80% of the soil surface at planting time decreases to ~60% as the crop matures but is adequate to protect the soil surface and provide yields equal to, or better than, tilled plus cultivated systems. The mulch can be from crop residue, cover crops, killed weeds, or animal waste applied to the field. Crops vary in the amount of mulch remaining after crop harvest and its persistence, and this must be considered in management systems employed. For example, corn provides greater and more persistent residue than soybeans. Mulch intercepts energy from raindrop impact, decreasing the amount of crusting that occurs in bare soil. Mulch on the soil surface feeds earthworms. These, in turn, burrow to create macropores.

Recent interest in removing crop residue as a source of biomass for energy production or for animal feed could impact crop management systems. On non cracking soils, a cover crop grown to provide mulch for NT production would be needed. On cracking soils that do not respond to mulch cover when under NT management, removing residue would have less effect on moisture availability for the crop, although the potential for soil loss would be increased.

Triplett et al (1968) determined the **infiltration rate** on a non cracking soil with a sprinkling infiltrometer on tilled and NT treatments after three yrs corn production (Table 1). Treatments included tilled and cultivated, NT bare, and NT with either a normal or a double application of mulch for the study period. Infiltration runs included NT both with mulch present and removed. The infiltration rate for NT bare tended to be less than for the tilled treatment. Infiltration increased with the amount of mulch and was significantly greater with the double-mulch treatment than for the tilled treatment, even when the mulch was removed. Apparently the soil surface was stabilized and macropores formed under the mulch were maintained and functional, even with the mulch removed.

Edwards et al. (1988) characterized macropores on a 0.5 ha watershed with a 9% slope and a silt loam soil managed with NT. With annual rainfall of greater than one meter, **runoff** averaged less than one centimeter on an annual basis. Thus, practically all of the rain falling on this site moved into the soil. However, macropores must be continuous to the soil surface in order to function. Tillage destroys their continuity and there is some evidence that, following tillage, three years of NT crop production with mulch cover is required to reestablish a fully functional macropore system (Triplett et. al 1996). These large pores are important for rainfall infiltration and **water movement patterns**. Doubling the diameter of the pore increases water conduction by 4X. Ehlers (1975) demonstrated that rainfall on the soil surface flows into macropores then moves into the surrounding soil from the pores rather than moving from the soil surface as a wetting front as occurs in tilled soil.

Evaporation from the soil surface is reduced by mulch cover, although moisture use is similar for tilled and NT with mulch, once the crop canopy is formed (Blevins et al 1971). Van Doren and Triplett (1969) compared early corn growth with several treatments which included soil covered with crop residue and soil fitted with a medal grid which prevented runoff. They reported improved vegetative growth under the mulch. In turn, these larger plants produced greater grain yield. The mechanism of the crop response is not known but could reflect differences in infiltration pattern with macropores under the mulch, and/or greater evaporation from the soil surface without mulch, or modification of soil temperature variation during early crop growth, or rooting pattern as suggested in the next paragraph, or a combination of factors.

Moisture availability for crops is influenced by rooting patterns and root development. The mobility of water in unsaturated soil is limited at best, and roots must be present to explore the soil and extract soil moisture. Tilled production systems with postemergence cultivation destroy roots to the depth of cultivation and rainfall must infiltrate and percolate through the cultivated zone to be available for the crop. Triplett and Van Doren (1969) demonstrated that corn roots developed at the mulch-soil surface interface in a NT system. Although the focus in their study was toward availability of non-mobile, surface applied nutrients, the presence of roots in this zone indicates conditions were favorable for their development, and that moisture from small rainfall events passes through the mulch to the soil surface and would be available for the crop. In a later study, Paltineanu and Starr (2000) noted that small rainfall events were utilized more effectively with NT. They also observed that rain falling on the corn canopy ran down plant stems and infiltrated closer to the crop row than in tilled systems.

The tillage response and moisture patterns are different in soils that crack when dry. Shrinkage cracks open to the depth of drying. These cracks form convenient avenues for rainfall infiltration and as rainfall moves into the cracks, it wets the soil deeper in the profile, much as described for precipitation moving into macropores for non-cracking soils. There has been no positive crop yield response to cultivation in the absence of weeds reported on cracking soils. In fact, there can be a negative response because of root pruning. There is little or no yield response to mulch cover, even in years with rainfall deficit. Crop productivity on cracking soils has not been improved with NT and can be reduced under some circumstances. Since crop yields comprise a dominant factor in profitability, yields must be maintained at or near the potential for tilled systems for reduced or NT to be readily adopted. Morrison et al (1990) described a system for successful NT on vertisols. In this system, wide beds were formed and multiple crop rows were planted on the beds. Crops were rotated, which reduced disease potential described earlier as a problem for corn grown in monoculture on a cracking soil (Tiarks, 1977).

If yields can be maintained at an acceptable level, factors in addition to moisture conservation that might favor adoption of reduced tillage systems include:

1. Increased worker productivity. NT eliminates trips over the field and workers can increase the area managed (Triplett and Dick. 2008).
2. Land considered marginal because of erosion hazard can be used for cropping. In recent studies (unpublished), we have been planting NT corn in permanent pastures on sloping sites and harvesting the crop by grazing with steers. Grain sampling on these sites for crop yield indicated productivity in the 7 to 9 Mt/ha range. Soil compaction and reduced infiltration was not an obvious problem on the soils and sites used for these studies.

Table 1. Mulch and tillage effect on infiltration, bulk density and air filled porosity. Mean of 3 replications (after Triplett et al., 1968)

Treatment	Initial Run			Wet Run		
	Antecedent Bulk density 1. 3-8.9 cm	Instantaneous infiltration rate after 1 hr.	Total infiltration after 1 hr.	Antecedent Bulk density 1.3-8.9 cm	Instantaneous infiltration rate after 1 hr.	Total infiltration after 1 hr.
	gm cm^{-3}	cm hr^{-1}	cm	gm cm^{-3}	cm hr^{-1}	cm
A. Plowed bare	1.33a*	0.66b	1.80b	1.33a	0.43bc	1.04c
B. NT bare	1.43b	0.28b	1.22b	1.42ab	0.25c	0.64c
C. NT 40% residue	1.50b	1.17b	2.34b	1.48b	0.46bc	1.35bc
D. NT 80% residue	1.46b	2.64a	4.39a	1.46b	1.41a	3.48a
E. NT 40% residue, residue removed	1.50b	0.48b	1.63b	1.49b	0.30bc	1.04c
F. NT 80% residue, residue removed	1.46b	2.41a	4.17a	1.51b	1.09b	2.49ab
LSD at 5%	0.10	1.07	1.73	0.10	0.76	1.17

*Values within each column followed by the same letter are not significantly different at the 5% level of probability. Duncan’s multiple range test.

Literature Cited

Blevins, R. L., D. Cook, S. H. Phillips, and R. E. Phillips. 1971. Influence of no-tillage on soil moisture. Agron. J. 63: 593-596.

Edwards, W. M., L. D. Norton, and C. E. Redmond. 1988. Characterizing macropores that affect infiltration into nontilled soil. Soil Sci. Soc. Am. J. 52:483-487.

Ehlers, W. 1975. Observations on earthworm channels and infiltration on tilled and untilled loess soil. Soil Sci. 119:242-249.

Morrison, J. E., Jr., T. J. Gerik, F. W. Chichester, J. R. Martin and J. M. Chandler. 1990. A no-tillage farming system for clay soils. J. Prod Agric. 3:219-227.

Paltineanu, I. C., and J. L. Starr. 2000. Preferential water flow through corn canopy and soil water dynamics across rows. Soil. Sci. Soc. Am. J. 64:44-54.

Tiarks, A. E., 1977. Causes of increased corn root infection of continuous corn in no-tillage Hoytivlle clay loam in Northwestern Ohio. Ph.D thesis. Ohio State Univ. Diss. Abstr. DCJ 77-17145. Univ. Microfilms, Ann Arbor, MI.

Triplett, G. B. Jr., D. M. Van Doren, Jr., and B. L. Schmidt. 1968. Effect of corn (*Zea mays* L.) stover mulch on no-tillage corn yield and water infiltration. Agron. J. 60:236-239.

Triplett, G. B. Jr., D. M. Van Doren, Jr. 1969. Nitrogen, phosphorus and potassium fertilization of non-tilled maize. Agron. J. 61:637-639.

Triplett, G. B., Jr., S. M. Dabney, and J. H. Siefker. 1996. Tillage systems for cotton on silty upland soils. Agron. J. 88: 507-512.

Triplett, G. B. Jr. and Warren A. Dick. 2008. No-tillage crop production: A revolution in agriculture. Agron. J. 100:S-153-S-165.

Van Doren, D. M. Jr., and G. B. Triplett. 1969. Mechanism of corn (*Zea mays* L.) response to cropping practices without tillage. Res. Circ. 169. OARDC, Wooster OH.

Van Doren, D. M. Jr., and G. B. Triplett. 1973. Mulch and tillage relationships in corn culture. Soil Sci. Soc. Am. Proc. 37:766-769.