NO-TILLAGE

Its Influence on SOIL MOISTURE and SOIL TEMPERATURE

by

R. L. Blevins and Doyle Cook

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By R. L. BLEVINS and DOYLE COOK[1/]

As the demand increases for higher levels of crop production, conservation of soil and water resources becomes more important. The modern farmer must continually seek cultural practices which increase profits and at the same time conserve natural resources.

For these reasons, a relatively new production management system called "no-tillage" has been adopted by many corn and soybean producers and is receiving widespread attention from agricultural scientists.

No-tillage offers a decrease in labor costs and at the same time uses the soil and water resources more efficiently.

When one is trying to intensify crop production, a very important factor is more efficient use of water. No-tillage production is a positive step toward increasing water use efficiency and protecting the crop against short-term droughts. No-tillage increases the infiltration capacity of soils, hence, decreasing the amount of surface runoff and serving as a very effective erosion control measure.

This publication deals primarily with the effect of no-tillage systems of crop production on soil moisture and soil temperature.

EXPERIMENTAL PROCEDURE

Soil moisture was measured on experimental corn plots, using the neutron backscattering method (3) during the 1968 and 1969 seasons. During the 1968 growing season soil moisture was monitored at a depth of 9 inches between corn rows under chemically-killed bluegrass-sod and under adjacent conventionally cultivated plots. Under conventional tillage the previous cropped residue was plowed under to a depth of 8 inches with a standard moldboard plow and disked to establish a seedbed. Chemical weed control was used in lieu of row crop cultivations. In no-tillage, the bluegrass sod was chemically killed and corn was planted with a modified planter that disturbs only a narrow band of soil, just enough to allow placement of seed and subsequent coverage.

During the 1969 growing season soil moisture was measured on (a) conventional tillage plots, (b) 1st year no-tillage, sod-killed and (c) 2nd year no-tillage (corn stover from previous year returned to surface and fall seeded rye chemically killed at planting time). To acquire a higher degree of accuracy, gravimetric moisture determinations were made on 0-3 inches, 3-6 inches, and 6-9 inches layers of soil. A neutron backscattering device was used to measure soil moisture by volume at depths of 12-, 18-, 24-, 30-, and 36-inch depths to obtain a seasonal distribution of moisture with depth in the soil profile. All treatments were replicated three times.

The 4-row experimental plots, such as were used in this study, are considered large enough to preclude appreciable lateral movement of soil moisture from adjacent plots to points of measurement in the center of the plots.

1/ Assistant Professor, Department of Agronomy, and Advisory Agricultural Meteorologist, ESSA, Weather Bureau Office for Agriculture, University of Kentucky, Lexington, respectively.

These plots were located on the University of Kentucky Woodford County Experimental Farm in the Inner Bluegrass Region of Kentucky. The plots were on a Donerail silt loam, gently sloping soil. This soil is a deep, moderately well-drained soil developed from phosphatic limestone. Mean annual precipitation for this region is approximately 45 inches.

NO-TILLAGE SOIL MOISTURE

It is generally agreed among soil scientists (6, 8) that soil covered with dead sod will have a greater infiltration over a growing season than the same soil after normal plowing and cultivation. The presence of the undisturbed but decaying plant roots in the soil and old root channels may serve as a ready avenue for water infiltration into the soil (1). This enables the soil to store more water following appreciable rainfall.

Soil moisture is normally lost from the plant root zone by evaporation from soil, runoff as surface water, transpiration by growing plants, and percolation to depths beyond the normal root zone. One would expect that a killed sod cover would reduce soil moisture losses due to evaporation and runoff. When compared with normally cultivated land, the sod cover should have little effect on the amount lost due to transpiration. Percolation losses may be a little greater under no-tillage conditions, owing to increased infiltration of water during periods of rainfall. As shown in Fig. 1, except during the first few measurements, soil moisture at the 9-inch depth was always greater under killed sod than under adjacent cultivated ground. Total rainfall during the 1968 season was near normal. Distribution of rainfall

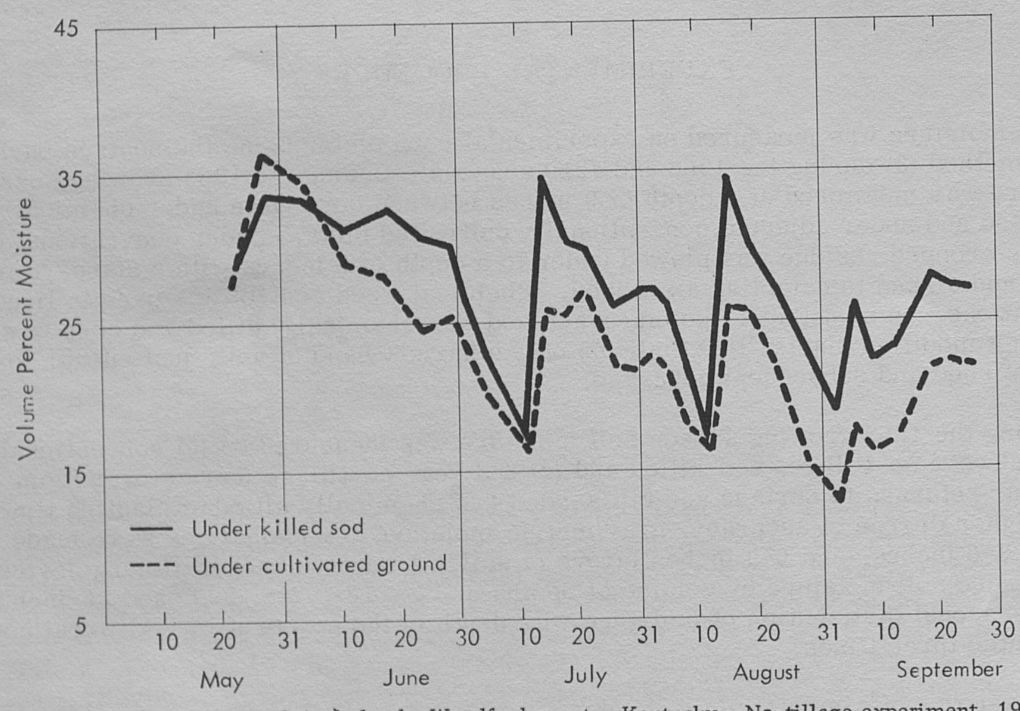

Fig. 1. - Soil moisture at 9-inch depth, Woodford county, Kentucky. No-tillage experiment, 1968.

was such that no serious moisture deficiency was observable, as indicated by plant response, under either no-tillage or conventional tillage conditions. On one occasion, on July 12 prior to showers on the 13th, conventional tillage corn leaves were observed to "curl" to a minor degree during the afternoon while no-tillage corn leaves showed no visible effect.

All the tests under killed sod were conducted with nearly continuous sod cover. There were few bare patches. Most workers agree that, owing to soil compaction in the areas where no sod has been grown, unless a fairly continuous sod cover can be attained prior to application of the herbicide the next most favorable soil moisture environment for growing corn is in a well cultivated soil without weed competition.

During the 1969 growing season, rainfall distribution was near normal (except for August) with 3.78 inches in May, 4.61 in June, 4.37 in July, and 5.96 inches in August for a total of 18.72 inches. This represents about 42 percent of the mean annual precipitation. The 5.96 inches for August is about double the normal monthly precipitation for the month of August.

Soil moisture in the top 0-3 inch soil layer under no-tillage was significantly higher than that under conventional tillage plots throughout the entire growing season (Fig. 2).

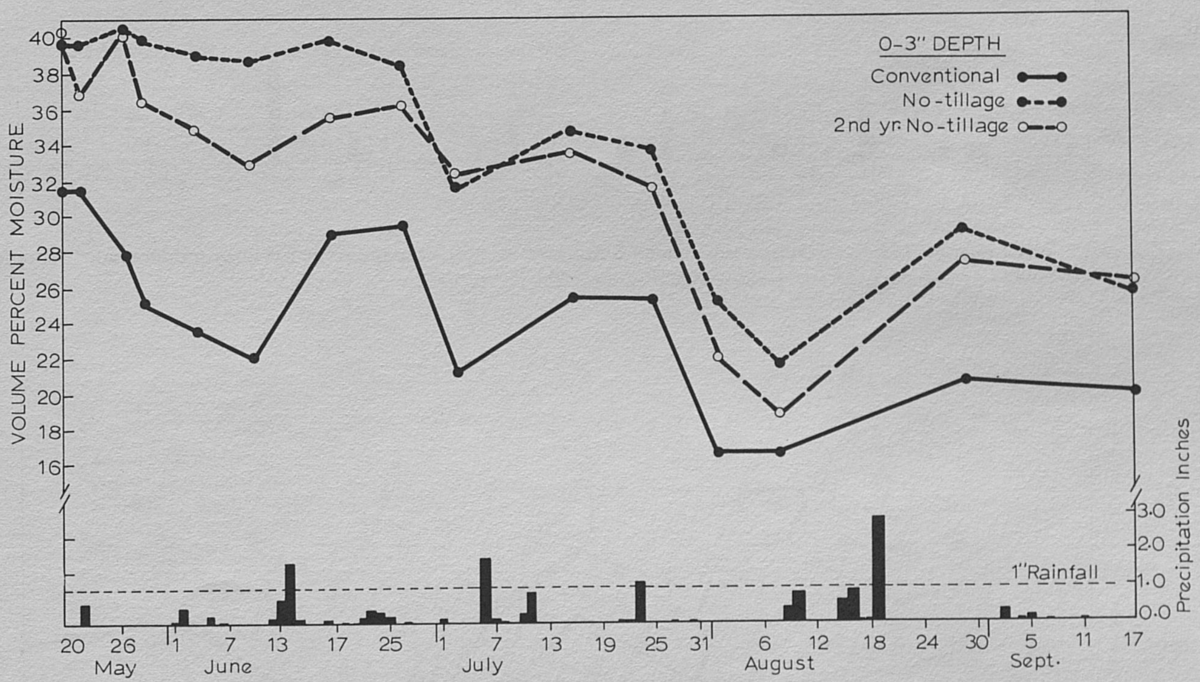

Fig. 2.- Soil moisture (0- to 3-inch depth) under 3 methods of soil management for corn production. Woodford county, Kentucky. No-tillage experiment, 1969.

This moisture difference was about 10-15 percent until a slight drought occurred during the 1st week in August in which the moisture levels were lowered under all systems of tillage. This difference between tillage systems in the 1st half of the growing season might be anticipated because of the evapotranspiration factor. It has been well documented (2, 4, 7) that in the early part of the growing season under conventional tillage, evaporation accounts for a high percentage of water losses. As the aerial portion of a plant grows, a shading effect is produced that decreases evaporation. The increased growth results in greater leaf area, and transpiration becomes the key source of water losses. The mulch from the chemically-killed bluegrass sod serves as insulation for upper part of soil profile, thus reducing evaporation. High moisture levels were observed near the organic mulch-soil interface. This zone of high organic residue content has a much greater capacity to store water owing to its high absorptive properties. During the early part of the growing season

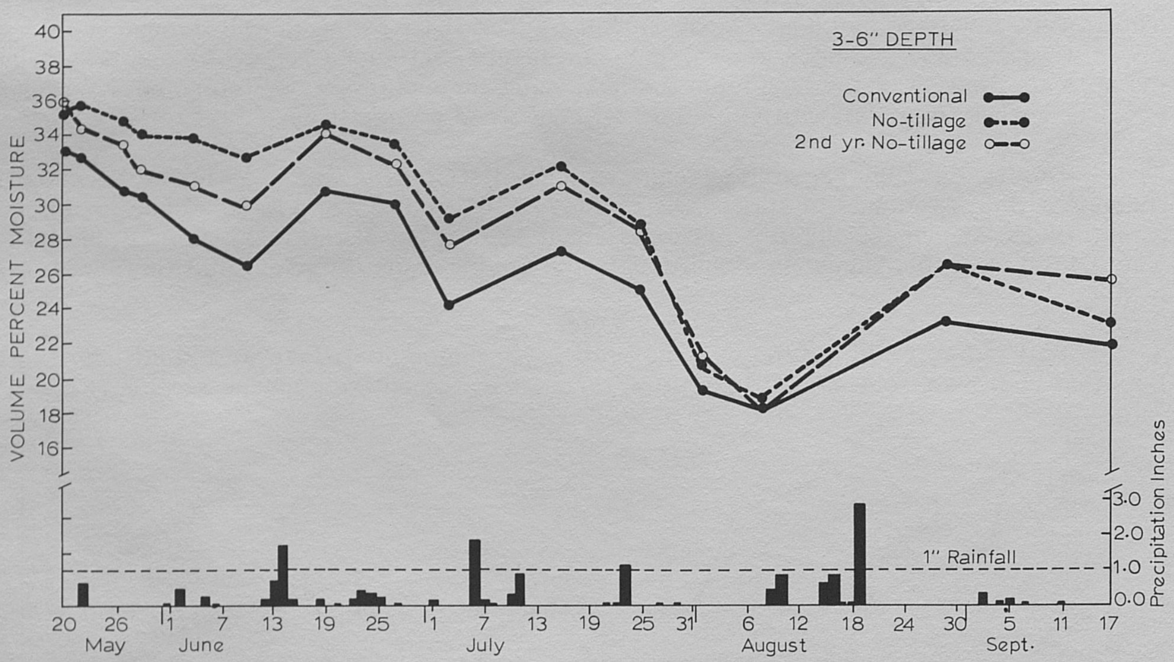

Fig. 3. - Soil moisture (3- to 6-inch depth) under 3 methods of soil management for corn production. Woodford county, Kentucky. No-tillage experiment, 1969.

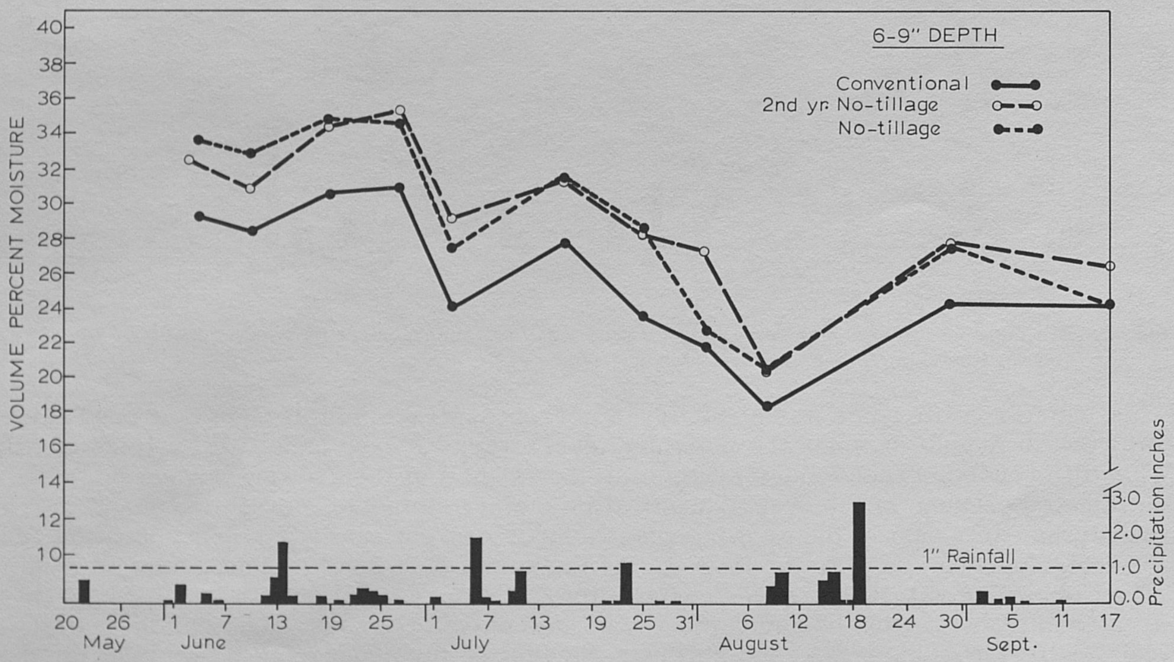

Fig. 4. - Soil moisture (6- to 9-inch depth) under 3 methods of soil management for corn production. Woodford county, Kentucky. No-tillage experiment, 1969.

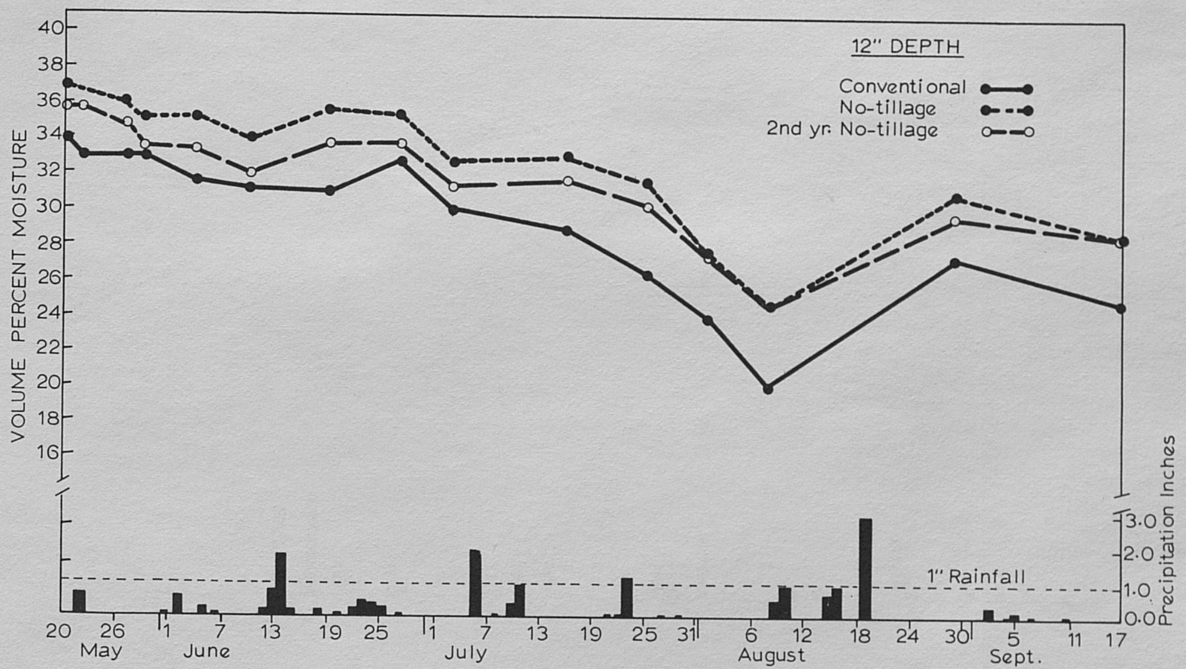

Fig. 5. - Soil moisture (12-inch depth) under 3 methods of soil management for corn production. Woodford county, Kentucky. No-tillage experiment, 1969.

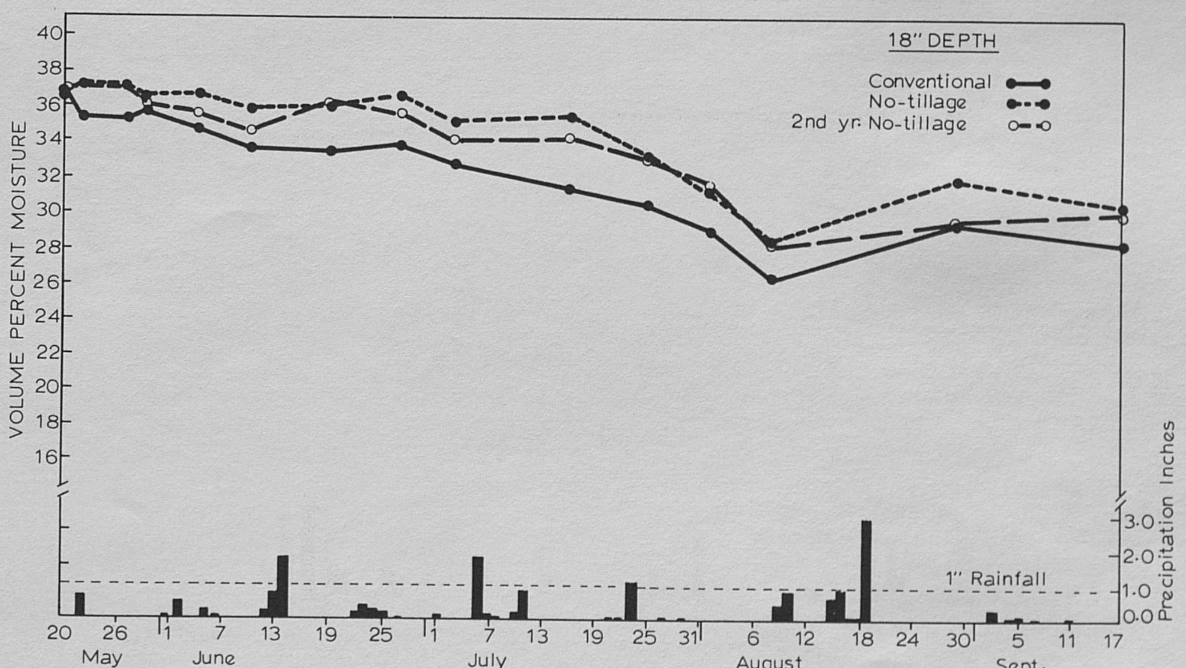

Fig. 6. - Soil moisture (18-inch depth) under 3 methods of soil management for corn production. Woodford county, Kentucky. No-tillage experiment, 1969.

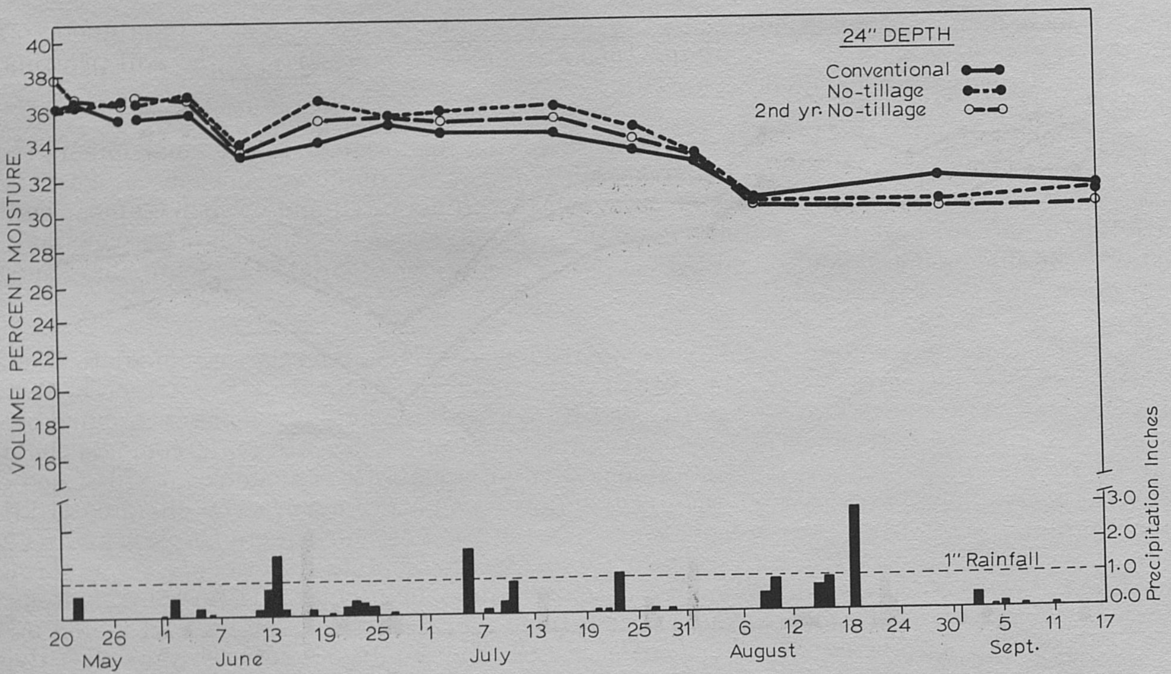

Fig. 7. - Soil moisture (24-inch depth) under 3 methods of soil management for corn production. Woodford county, Kentucky. No-tillage experiment, 1969.

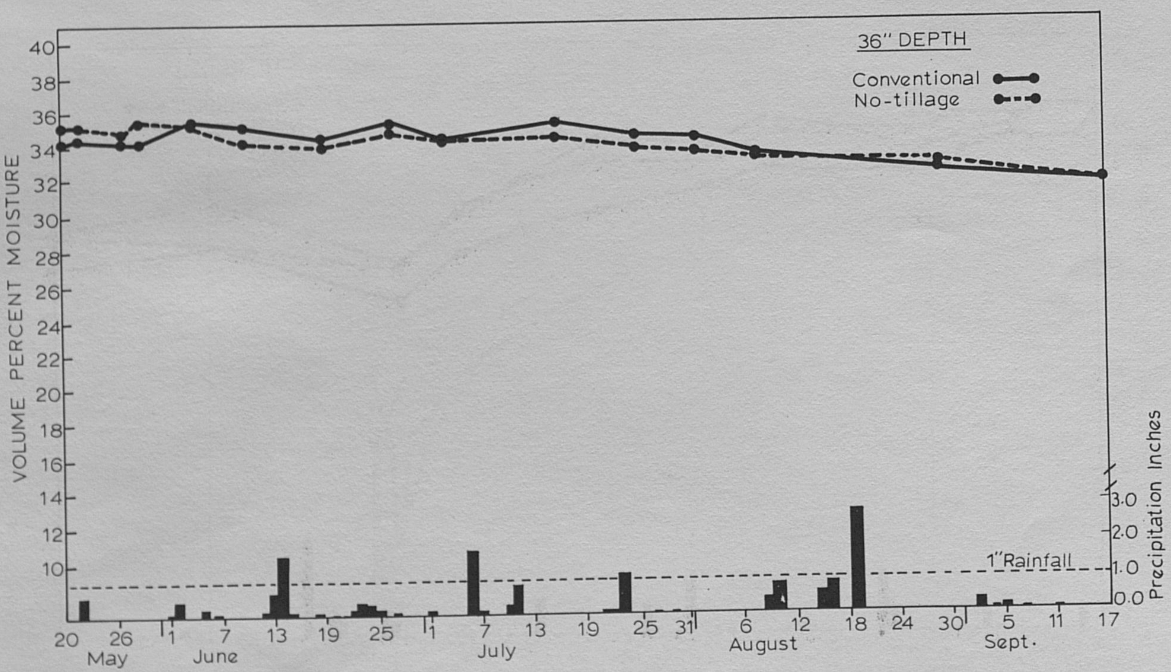

Fig. 8. - Soil moisture (36-inch depth) under no-tillage and conventional tillage for corn production. Woodford county, Kentucky. No-tillage experiment, 1969.

the 0-3 inch surface layer of soil had a higher moisture content than even the fine-textured subsoil (Figs. 6, 7, and 9). During the 1969 season, soil moisture for the soil profiles was higher at all times for those under no-tillage.

The difference in seasonal moisture under the three methods of management (Figs. 2, 3, 4, 5, 6, 7) show no-tillage to be considerably higher in volume percent moisture to a depth of 24 inches. Beyond a depth of 24 inches, systems of tillage or management had very little effect on soil moisture contents over the growing season. The volume percentage soil water at 36 inches depth decreased by 2-3 percent (Fig. 8) from May to September under both no-tillage and conventional.

The plots referred to as 2nd year no-tillage were consistently intermediate to no-tillage (1st year sod-killed) and conventional tillage in its seasonal soil moisture content and distribution within the soil profile. The 2nd year no-tillage actually compares more closely to 1st year no-tillage because of a comparable amount of surface (organic residue) mulch. The mulch for 2nd year no-tillage plots consisted of remaining residue from killed sod of the previous years, corn stover from the previous crop and a rye cover crop chemically killed prior to planting of corn. At corn planting time the 2nd year no-tillage had a heavier, but less uniform, surface mulch than the no-till bluegrass sod plots. However, the vigorous, succulent growth of the rye in the spring prior to being chemically killed removed some of the water reserve in the plots. Corn harvest from these plots in 1969 showed yields of 117, 125 and 136 bushels per acre for conventional, 2nd year no-tillage and 1st year no-tillage, respectively.[2]

A comparison of soil moisture distribution with depth and different methods of tillage is presented in Fig. 9. Presented are moisture curves for July 25 (36 hours following a 1-

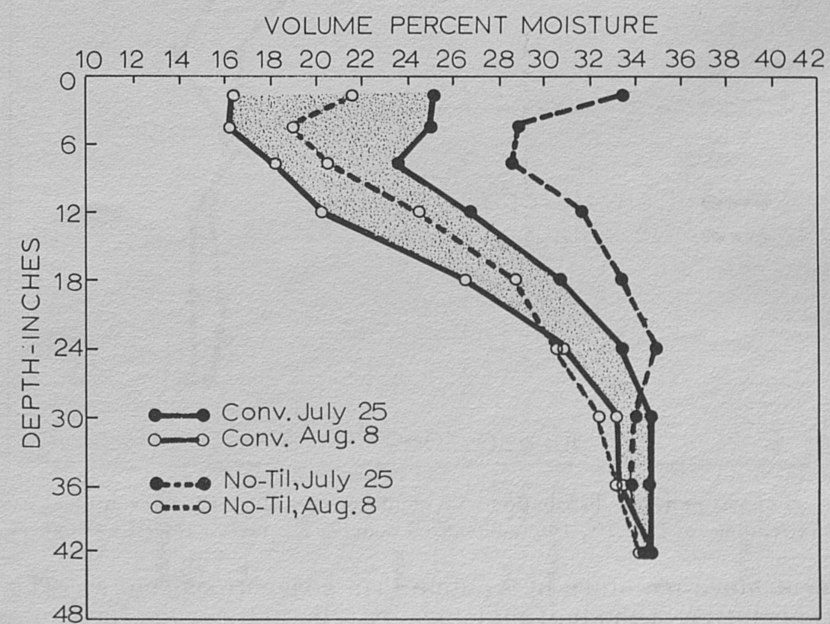

Fig. 9. - Soil moisture distribution with depth and different methods of tillage. Soil moisture curves for July 25, 1969, and August 8, 1969.

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[2] Personal communication with Shirley Phillips, Extension Specialist in Agronomy, University of Kentucky.

inch rain) and then again on August 8. Calculation of soil moisture to a depth of 42 inches showed that the no-tillage plots contained one inch more soil water on July 25 than the conventional plots. During the following 2 weeks of very hot and dry weather, water withdrawal was 2 inches for the no-tillage and 1.5 for the conventional plots. No-tillage plots had a larger reservoir of water to utilize during the period and made near optimum growth throughout this period. Conventional tillage corn was showing visible signs of moisture stress by the end of the 2 weeks.

This decrease in evaporation under no tillage and the greater ability of the soil to store moisture serve as a moisture reservoir which can carry the crop through periods of short-term drought without strong moisture stresses developing in the plants.

None of the corn plots exhibited visual signs of moisture stress during May or June. The Donerail soil has a potential for storing a reasonably large quantity of water because of its moderately high organic matter content in the surface 10-14 inches and a silty clay subsoil. To compare the soil moisture distribution with depth for no-tillage vs. conventional refer to soil moisture readings for June 10 (Fig. 10). The 0-3 inch layer of no-tillage

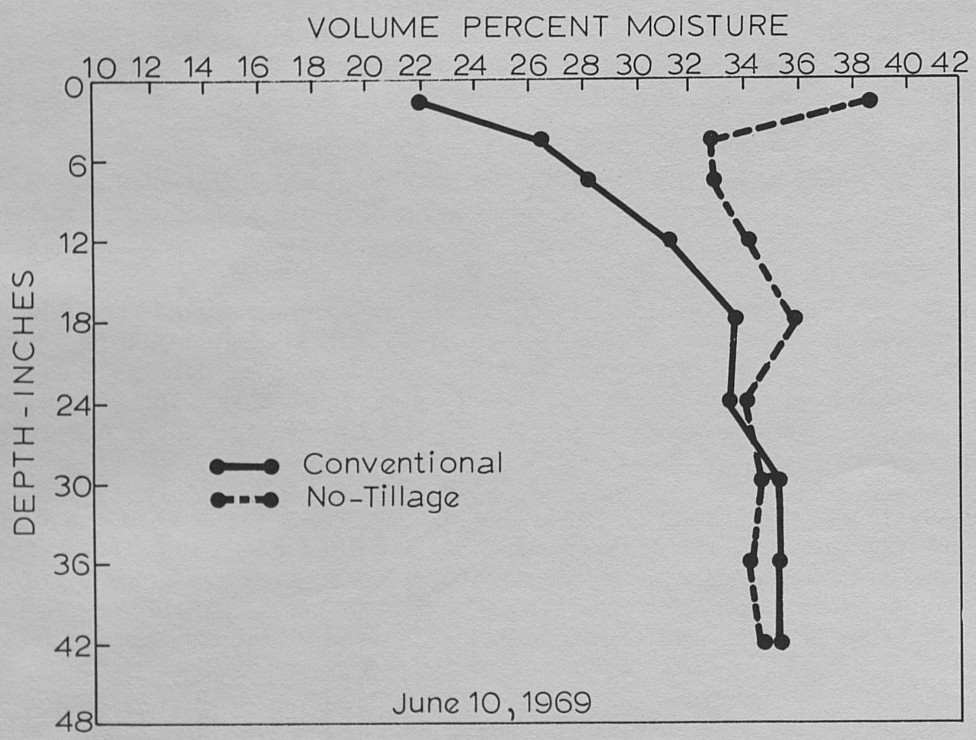

Fig. 10. - A comparison of soil moisture distribution with depth for no-tillage vs. conventional from soil moisture readings of June 10, 1969. Woodford county, Kentucky. No-tillage experiments.

treatment had 16 percent more moisture by volume than conventional plots. The curves in Fig. 10 are also representative of the soil moisture distribution curves for two extreme tillage systems. Soils under conventional tillage are normally characterized by the lowest soil moisture values at surface and increasing with depth. The no-tillage is normally higher near surface then decreases until one reaches the depths of high clay content, below the 18-24-inch depth. (Figs. 10 and 11.)

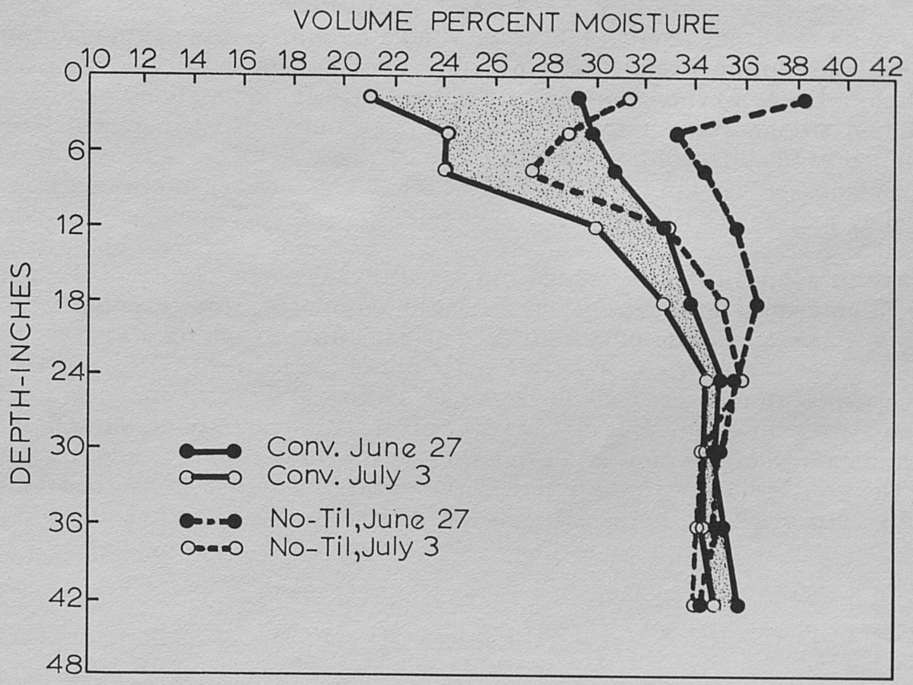

Fig. 11. - Soil moisture distribution with depth and different methods of tillage. Soil moisture curves for June 27, 1969 and July 3, 1969.

NO-TILLAGE SOIL TEMPERATURE

During the few days immediately after planting, soil temperatures should be above 50°F as much as possible to assure a high percentage of corn seed germination. Soil temperatures at the 2-inch depth (the usual depth for corn seed) rise during the day time mainly owing to sunshine directly on the soil. Also, soil temperatures fall at night because no sunshine is received and heat which was stored by the soil during the day may be carried away at night.

A dense layer of killed grass on top of the soil contains a certain amount of air which the sod prevents from moving. This "dead" air is an excellent insulator. One would expect that the sod would keep some sunshine from reaching the soil, thus producing lower day time temperatures under a killed sod cover. Also, the sod and dead air should prevent loss of heat at night, producing higher night time temperatures under sod killed after spring growth has begun.

These expected effects were observed during 1967, 1968 and 1969 on the University of Kentucky Agricultural Experiment Station Farm at Lexington. Daily observations of soil temperature at the 2-inch depth, under both a bare soil surface and sod during March, April and May, showed daytime maximum temperatures averaging between 4.9° and 9.9° cooler while nighttime minimum temperatures averaged between 2.2° and 7.2° warmer under sod compared with those of adjacent bare ground. All temperatures were measured under level ground with a close-clipped bluegrass sod or under bare ground maintained in a bare condition by hand cultivation. There were no extended periods of unusually wet nor dry weather. Field tests in 1967 confirmed that these conditions closely approximate those found under no-tillage and conventional tillage with similar level field exposure. Either a heavier sod cover, a heavy mulch such as one might obtain by chemically killing a large rye grass cover crop, or a period of extremely dry weather would undoubtedly have magnified the observed effects.

After the corn seedlings reached sufficient height to provide shading between the rows, the 1967 tests indicated no difference between temperatures measured under no-tillage and conventional tillage conditions.

It is well known that heavy mulches delay warming of the soil during the spring. However, in Kentucky, it appears that soil temperatures during the spring are normally high enough that, even with the daytime lowering due to a killed sod cover, the rate of corn seed germination is not materially decreased. Heavier mulches provide cooler conditions but, owing to the generally moderate level of all soil temperatures in Kentucky, the rate of seed germination does not appear to be significantly less than that under conventional tillage. This generalization may not hold for some wet fine-textured soils where the mulch may magnify the normally wet cool conditions in April and May. Soil temperature tests, however, have not been made under these wet-cool soil conditions. Corn seedling emergence under no-tillage conditions has been observed to take place in approximately the same time as under conventional tillage conditions in a reasonably wide range of soils in Kentucky. This condition may not hold true in locations farther north where the sun's rays have a lower angle of incidence during the spring.

CONCLUSIONS

The higher moisture content in the soil surface under no-tillage cropping has significant implications in soil reactions that control the availability of nutrients to the plants. The seasonal moisture difference between no-tillage and conventional extends to an approximate depth of 24 inches. This provides a greater reservoir of soil moisture in the major plant rooting zone.

The conservation of moisture under no-tillage is associated with soil conditions that maintain good surface infiltration throughout the cropping season, reduction in evaporation due to the surface mulch and the absorptive properties of the decaying roots and surface mulch. The greater moisture storage in the soil profile under no-tillage results in more efficient utilization of water by the plants and provides a measure of safety against droughts.

The soil moisture data reported in this paper should not be extrapolated to all soils and all seasons. Obviously the seasonal distribution of rainfall will alter the differences, and different soil types will have an influence on the moisture conservation under the different cropping systems. However, other workers (5, 6) making comparisons over 4- and 5-year periods and different soil types have consistently shown the no-tillage method to have greater soil profile moisture over the seasons.

The killed sod cover under no-tillage contains a dead air space that serves as an insulator. This surface mulch prevents some of the sunshine from reaching the soil and produces lower day soil temperatures under no-tillage than under bare conventional plots. This insulating effect also produces a slightly higher nighttime soil temperature. After the corn seedlings reach sufficient higher to shade the ground the difference in soil temperature between no-tillage and conventional diminishes. The differences in soil temperature are probably not very important on most soils of Kentucky because soil temperatures are normally high enough for good germination with or without a mulch.

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