The Effects of Reduced Tillage on the Soil Environment

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Summary. The physical characteristics of a particular soil affect its suitability for reduced tillage. Vegetable crops managed with reduced tillage generally will increase crop yields as drainage improves. Under reduced tillage, advantages over conventional tillage include better control of soil erosion, enhanced crop yields, soil water conservation, and more-efficient use of fossil fuel-based nonrenewable resources. Disadvantages with reduced tillage may include reduced soil temperature and increased soil moisture contents in udic soil moisture regimes, which can decrease crop yields.

Conventional tillage has been described as the physical turning of a soil surface to prepare a seedbed for crop germination and growth (Sprague, 1986). Manipulating the physical environment with tillage has been practiced for centuries, gaining widespread acceptance since the invention of the moldboard plow (Duley and Mathews, 1947). Plowing buries plant materials and kills weeds, providing an orderly appearance and releasing trapped nutrients from the turned plant materials. Plowing also incorporates fertilizer nutrients into the root zone, resulting in increased nutrient availability and generally increased crop yields. Finally, plowing inverts and mixes the soil surface, temporarily increasing the water-absorbing capacity of the soil. The result of all these physical changes provides an ideal location for placement, germination, and emergence of vegetable seeds because of increased contact with loose, moist soil. The added benefits of interrupted insect, disease, and weed cycles

during the initial stages of crop growth made plow agriculture the standard for hundreds of years (Sprague, 1986).

Herbicide development over the past 40 years has greatly reduced the need for complete inversion and soil mixing (Rice, 1983). In the past 3 decades, additional research has compared the effects of reduced and conventional tillage systems on crop production, soil physical characteristics, and energy efficiency. Much of the past research with reduced tillage has been the examination of the seed environment, development of reduced tillage equipment, and erosion control. Distinct advantages of reduced tillage over conventional tillage include the control of soil erosion, enhanced crop performance, soil water conservation, more-efficient use of nonrenewable energy, and reduced labor requirements (Frye et al., 1981; Phillips, 1984; Sprague, 1986). Disadvantages include reduced spring soil temperature (Hoyt and Konsler, 1988), greater weed control problems and herbicide dependency (Standifer and Beste, 1985), increased pest problems, and reluctance of farmers to accept the new practice (Phillips, 1984).

Reduced tillage systems develop a soil surface that differs drastically from conventional systems. Surface mulch created from previous crop residue decays over the growing season, creating microclimates that lower soil temperature and increases moisture regimes (Griffith et al., 1986). Fertilizers may be more dependent on leaching to accrue mobile plant nutrients down into the soil profile (Gilliam and Hoyt, 1987). Non-mobile nutrients will accumulate in the soil surface layer (Robbins and Voss, 1991). Increases in surface residue and organic matter produce an agroecosystem controlled by more biological mechanisms that change the soil environment and increase nutrient pools and pathways (Doran, 1980; Groffman, 1985).

Rainfall patterns and cropping

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systems will affect soil water content differences associated with tillage practices. Soil water content is usually increased throughout the growing season when conventional tillage is replaced by reduced tillage practices (Griffith et al., 1986). Reduced tillage increases the infiltration capacity of the soil by reducing crusting that accompanies conventional tillage in many soils, enhancing the amount of rainfall absorbed by the soil during the growing season. Griffith and coworkers suggest that the two main mechanisms of water outflow associated with tillage systems are evaporation at the beginning of the season and plant transpiration during the latter portions of the growing season. Reduced tillage generally decreases evaporative losses compared to conventional tillage and increases transpiration losses. This often results in more precipitation absorption by the soil earlier in the season. This water is conserved and used more efficiently during the growing season. Conservation of soil water often results in plants having a greater amount of soil water available for transpiration. This can be a great advantage on soils in which water limits crop growth. On the other hand, in poorly drained soil, increased soil water contents can be detrimental to crop yields (Griffith and Mannering, 1985).

Griffith et al. (1986) concluded that surface residues, which commonly are found on reduced tillage fields, greatly increase infiltration. In rainfall simulation trials, they found that the greatest infiltration rates were on treatments with maximum mulch covers in a no-till management system. Mulching reduced surface crusting and slowed surface water movement, allowing more time for water infiltration.

Thomas (1986) suggested that increased infiltration with decreasing tillage is a function of a developing porous soil structure. Under reduced tillage systems, the soil profile reverts back to a more-natural structural condition. That pattern includes extensive root systems, root channels, and clay coatings on macropores. He concluded that the method of tillage has a major effect on surface macroporosity. Conventional tillage systems often completely destroy soil macropores, creating surface crusting and slowing infiltration rates during rainfall events.

Mulch-covered soils have less evaporative water loss from the soil

surface than bare soil surfaces. Because evaporative losses are greatest before a plant canopy forms, mulch cover on the soil can greatly reduce evaporative losses (Unger and Parker, 1968). Thomas (1986) found that mulch affects the soil surface in two ways. Mulch reflects much of the sunlight away from the soil surface, reducing energy inputs that enhance evaporation. Mulch also creates a resistive path for water diffusion. Relative humidity in the soil is higher in and below the mulch layer as compared to bare soils. This higher humidity also can decrease evaporative losses. As the crop canopies of both reduced tillage and conventional tillage systems develop, differences in evaporative losses also can decline (Griffith et al., 1986).

No-till systems with mulch residues have more water available during the early stages of plant growth due to reduced water evaporation (Phillips, 1980). In Ohio, Triplett et al. (1973) found that crops grown under no-till had more vigorous growth and transpired more water than under conventional tillage. The volumetric water content of the soil was 4.1 inches higher for no-till than conventional tillage soil planted in corn during the May to September period. In a later study, Triplett and Van Doren (1985) indicated that soil characteristics such as drainage ability had a profound influence on a soil's suitability for no-till management. They concluded that, in general, as drainage improves, the need for tillage to maintain crop yields decreases.

Higher soil water content and transpiration by plants in no-till systems can produce greater nutrient uptake. Nutrients that are absorbed by plants via mass flow, such as calcium, are generally transported in greater quantities to crop root systems under no-till systems (NaNagara et al., 1976). Nutrients moving through the soil by diffusion have greater diffusion coefficients, which can result in more-efficient nutrient uptake (Mahtab et al., 1971). Increased soil water contents in calcareous soils may increase the leaching rates of ions such as nitrate and calcium (Blevins et al., 1983). Again, under poor drainage or udic soil moisture regimes, excessive soil water in no-till systems can limit crop growth and nutrient utilization (Griffith and Mannering, 1985; Triplett and Van Doren, 1985).

Many no-till systems use cover crops of winter annual plants to conserve soil and water and increase nutrient recycling (Hoyt and Hargrove, 1986). Cover crop residues usually increase initial soil water content at planting because of their complete mulch cover (Griffith et al., 1986). An important consideration in managing cover crop systems is timing the cover crop kill to maximize soil water conservation (Waggoner, 1989). If cover crops are not killed until late spring, plant transpiration may remove more soil water before planting than their mulch will conserve after planting. This is important in areas of low spring and summer rainfall and high evapotranspirational potential (Griffith et al., 1986).

Mulch acts as both a reflector and an insulator of the soil surface. Soils managed with reduced tillage and residue covers have lower daytime temperatures than conventional tillage as a result of the mulch covers (Hoyt and Konsler, 1988). The magnitude of the reduced temperature is site-specific, but, in general, both well- and poorly drained soils have lower daily maximum temperatures in no-till systems (Griffith et al., 1986). The temperature effects resulting from mulch reflection and insulation during the day are reversed during the night. No-till soils cool less and tend to maintain higher night temperatures. The final result is less-variable soil temperature in no-till systems on a diurnal basis (Burrows and Larson, 1962; Thomas, 1986).

Thomas (1986) found that as soils become wetter, more energy is required to increase their temperature. Soil temperatures were also more stable in reduced tillage than conventional tillage due to the greater soil water content in reduced tillage. Thus, reduced-tillage soils heat more slowly and rarely reach the same soil temperatures as conventional tillage systems. The significance of reduced soil temperatures depends on planting date, latitude, and the crop grown (Griffith et al., 1986). An environment with temperatures of 25 to 35°C provides the best root growth for most crops. In northern climates, the reduced soil temperature of no-till systems may reduce yields below acceptable levels. In the southern United States, reduced temperatures have been shown to increase yields (Griffith et al., 1986).

Griffith and coworkers (1986) concluded that reduced tillage systems with associated mulch covers dramatically reduced soil erosion. Soil erosion stems from the cumulative impact of falling raindrops. Continued impacts break individual soil particles from their aggregates; this allows runoff water to remove them. Mulch residue is an effective shield against the impact of raindrops and absorbs most of the incoming force, thus decreasing soil aggregate destruction. Mulch further reduces soil water runoff by reducing surface sealing. In addition, mulch reduces runoff by creating surface barriers that inhibit the acceleration of surface runoff (Griffith et al., 1986).

In summary, the soil physical characteristics of a particular soil affect its suitability for reduced tillage. Generally, as drainage improves, crop yields will increase with reduced tillage practices. Under reduced tillage, advantages over conventional tillage include better control of soil erosion, enhanced crop yields, soil-water conservation, and more-efficient use of fossil fuel-based nonrenewable resources. Disadvantages may include reduced soil temperature and increased soil moisture contents in udic soil moisture regimes, which can decrease crop yields.

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