DEEPER ROOTING IN MINIMUM TILLAGE TO CONSERVE ENERGY

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Conserving energy in the 1980's is more than just reducing fuel or "petrol" use. We would like to believe a little energy conservation is essential, preferably by someone else or by some governmental action that will provide us with labor saving productivity improvements to maintain the comforts we have become accustomed to. Scientific reality, however, dictates that quick easy solutions will not be developed without careful planning for the efficient use of our energy resources and without strong efforts to find and develop new sources of energy. Because agriculture is the primary source of our food supply, energy must be considered in relation to the total crop production potential, i.e. production per petrol dollar spent or production per unit of energy input.

Reduced tillage defined

No-till farming in concept is directed to lower use of energy for crop production. Unfortunately the word no-till is misleading, in fact, no-till is not no till at all. The term has been coined to refer to a system of residue management. In this system, seeds are drilled into soil with live or dead plant materials still remaining on the soil surface. Weeds are mostly controlled by the application of constant or residual grass and broad leaf herbicides. However, mechanical weed control is possible under some circumstances. This concept of residue management has been referred to as eco-fallow (2), minimum till (5), or conservation tillage (3). These systems require higher levels of soil and crop management than conventional clean till farming methods.

Advantages and problems in minimum tillage

Often claimed advantages of minimum tillage over conventional tillage include: lower erosion, water conservation, ability to plant earlier, planting on steeper less fertile slopes, lower fuel costs, and lower compaction (5). Minimum tillage methods can be used in multiple cropping systems (4). Even though these appear to be distinct advantages, there are disadvantages or special challenges that must be addressed to make minimum tillage successful. Because minimum tilled land is not 'smooth and open, stands of crops are difficult to establish. Birds, and rodents are more active because the residue provides protective cover. Fungi and insects infestations are more common when residues remain on the surface. The real question is how can these problems be solved. Most certainly they can be solved, but only with greater scientific input.

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The soil physical system and minimum tillage

Recognizing soil physical and chemical conditions is an essential part of residue management in different parts of the country. Minimum till farming in the Southeast has to be accomplished in deep sandy soils or in sandy loam or loamy sand soils with genetically compact or mechanically compacted layers (1). These soils also have low water retentivity, consequently it is just as important to consider deep rooting and ways of achieving deeper rooting in minimum tillage as in conventional tillage. Without giving proper attention to these soil physical conditions, minimum tillage practices would eventually reduce the production base and actually increase energy use per unit of crop production.

In view of the limitations that soil physical conditions may have on residue management and energy use, corn rooting patterns were studied in relation to soil strength and soil water availability to corn in a Norfolk loamy sand soil with a compact A^2 horizon. Large acreages of these soils occur in the Southeast. For example, in Florence County, South Carolina alone, 58% of the tilled soils have an A layer (1). Although these layers vary in compactness, they are easily compacted by tillage tools and wheel traffic.

Describing soil physical parameters

Soils are never uniform in texture, structure and bulk density. Roots are not symetrically distributed in soil, therefore, water withdrawal can not be uniform. Consequently, a mean value and frequency distribution of certain properties such as bulk density are frequently used to describe soil conditions shown in Table 1.

Table 1. Bulk density and related frequency distribution for a Norfolk soil at Florence, SC

Bulk Density	Relative Frequency - %		
g/cm^3	Ap	A_2	B
1.25-1.29			10.0
1.30-1.34	4.3		5.0
1.35-1.39	2.1		5.0
1.40-1.44	2.1		5.0
1.45-1.49	8.7		20.0
1.50-1.54	26.1		30.0
1.55-1.59	17.5		20.0
1.60-1.64	8.7	2.9	5.0
1.65-1.69	8.7	7.7	
1.70-1.74	17.4	15.4	
1.75-1.79	2.2	32.7	
1.80-1.84	2.2	38.5	
1.85-1.89		1.9	
1.90-1.94		0.9	
Mean g/cm^3	1.57	1.78	1.48
Std. deviation	0.155	0.049	0.099
Schewness	-0.0107	-0.2283	-0.7704

The mean bulk density values for the Ap, A_2 , and B horizons are 1.57, 1.75, and 1.48 g/cm^3, respectively. The wide distribution of the Ap layer is a result of subsoiling in a minimum tillage experiment in which corn was planted into a standing rye cover crop. The subsoil tool[1] produced a narrow slot 10-15-cm wide in the A_2 layer that penetrated 47 cm, about 5 cm into the B horizon. The Ap bulk denaity measurements were more normally distributed about the mean value than the A_2 or B horizons.

Rooting and soil strength

Increasing bulk density increases resistance to rooting but bulk density is not the only factor that affects rooting because decreasing soil water content also increases the strength of soil. Therefore, root penetration is a function of bulk density, water content, and texture. We have determined that soil probes give a reliable index of rootability in soil, and that a penetrometer index of 20 kg/cm^2 represents a value beyond which few roots penetrate. In the Ap horizon at the mean bufk density of 1.57 root penetration is severely restricted at a matric potential of a little over -1000 mb. One could anticipate that roots would be well distributed throughout the A_2 horizon because of the wide range in the bulk density frequency distribution (see Table 1). In the A_2 horizon however, the matric potential at which roots were redtricted was -220 mb at a mean bulk density of 1.78 g/cm^3. Root development observations in a corn field showed that rooting in the A_2 horizon occurred only in the subsoiled portion of the A_2. Rooting in the B horizon was restricted to those roots that extended down the A_2 subsoiled soil. The B horizon had the lowest bulk density of all layers studied, 1.48 g/cm^3. Rooting observations demonstrated that once a root grew through the disturbed A_2 horizon, root growth into the B horizon was only slightly impeded. Because soil strength restricted rooting, soil strength affects water availability. By taking *-50* mb as the upper limit of water availability and the water content corresponding to 20 kg/cm^2 as the lower limit of water availability to the plant, the amount of water storage for each layer to the 75-cm depth can be calculated. These calculated water storage values are given in Table 2.

Table 2. Water storage in a 75-cm profile based on -50 mb and the matric potential water content at 20 kg/cm^2 as the upper and lower availability water limits, respectively. (only the subsoiled portion of the A_2 was considered)

Layer	Depth (cm)	Storage (cm)
Ap	0-17	2.37
A_2	17-35	0.30
B	35-75	2.91
Total		5.58

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[1] Brown-Harden Superseeder with an attached subsoil tool. Mention of tradenames is for reference and does not constitute endorsement by USDA or its cooperators.

Various assumptions were made for calculating effective soil water storage. Four examples taking various limiting factors into consideration are presented in Table 3.

Table 3. Calculated available water storage in a Norfolk loamy sand profile to depth of 75 cm.

Limiting Condition for Estimating Available Water	Soil Water Storage (cm)
(1) -50 mb and -1000 mb upper and lower limits	7.1
(2) -50 mb to 20 kg/cm^2 strength (all layers)	6.0
(3) -50 mb to 20 kg/cm^2 in (subsoiled in A_2 only)	5.6
(4) -50 mb and -1000 mb in actual observed rooting volume	4.0

These data show the importance of having roots uniformly distributed throughout the soil profile and further the necessity of expanding the volume of rooting in the B horizon. If roots were restricted only to the A horizon, the effective water availability to the plants would have been about 43% of that of the subsoiled soil - 2.37 vs. 5.58 cm.

These soil water storage calculations do not take into account the amount of water that would have been provided to the plant by unsaturated flow for most regions in the soil to the root surfaces.

These data indicate efficient energy use in minimum tillage agriculture when depth of rooting and methods of offsetting the effects of drought are taken into account. High crop production insures efficient use of fuel that has been expended in establishing the crop which is an important aspect of the energetics of residue management.

References

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