PHYSICAL CONDITIONS OF SOIL AFFECTING NO-TILIAGE TECHNIQUES

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Fields have been tilled to bury surface debris for many generations, and they have been overworked in order to leave a covering of smooth, pulverized soil. Although these fields may present an attractive appearance, the soil is exposed to the forces of wind and water with potentially devastating effects, To reduce the damage, as well as to keep costs down, fields toddy should be tilled only to reclaim the undesirable features in a soil profile. If soils need tillage, they should he tilled no deeper than necessary for reclamation of all barrirrs to assure deep air, water, and root permeability. Indiscriminant tillage not only wastes fuel, money, and time, but leaves the soil vulnerable to serious recompaction. The first pass of a wheel over well–tilled soil seriously affects root and water permeability so that by the time a field has been trafficked in many locations to apply all needed cultural operations, a great portion of the field has become a poor medium for moisture capture and root development.

Conservation tillage and related practices have been suggested to conserve moisture. and reduce erosion. But farmers will only adopt those conservation methods that allow them to produce a crop profitably. No-tillage farming, which became feasible with the advent of chemicals to control weeds, is one of the principle ways to conserve soil while utilizing the land. More water can be absorbed where the rain drops fall when a mulch is left on the soil surface. This leaves less water to wash rills that join to accumulate erosive volumes of runoff capable of carrying away tons of topsoil. We are now becoming aware of the expensive and wasteful proportion of the applied fertilizers and the amount of protective chemicals that are carried off the farm in this runoff. At the same time, we are more aware of the sediment, plant nutrients, and chemical pesticides carried to our streams and lakes––and the effect they have on the quality of our water.

If no–till farming is a simple and sure answer to soil and water conservation, why has it not become more readily accepted? Initial failures––and there have been many––have discouraged some farmers, but failures do not mean that the system will not work. More often farmers have not sufficiently mastered the new skills and techniques necessary for no-till farming to be successful. Just as farmers have to develop skills using the familiar tools for success with conventional farming, so must they master the new no-till farming tools and techniques,

For no–till farming to be acceptable special chemicals and different implements had to be devised. Some have been available to the American farmer for several decades, and, as interest in no–tillage practices has expanded, better chemicals and improved no–till implements are rapidly

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being introduced. However, to keep up with advancements, a determined farmer must make time to acquire special knowledge to know which chemicals and implements are needed for his specific set of conditions, and how and where and when to apply them. And, although farmers skilled in the use of chemicals can control most weeds without tillage, limited shallow cultivations may still be necessary to control certain undesirable plant competition. However, new technology is needed for cultivating no-tillage crops if a residue cover is to remain effective.

Farmers interested in making no-till farming work may have difficulty developing certain needed crop rotations into a no-till system. They may have crop residue problems capable of interfering with planting or of delaying the warming of soil in the spring. Invariably they will encounter obstacles in controlling certain weed species. Resolutions to these problems are needed if farmers are to be successful. They must become pioneers, discovering solutions to their problems just as their predecessors did when they cleared our nation using the only tools and techniques available to them.

Soil surfaces must remain permeable to rains in order to capture and store more moisture for profitahle use. Standing stubble, when killed with chemicals, can conserve moisture, reduce erosion, and increase yields in fallow farmed sections of the country (Good and Smika, 1978). However, in addition to a good surface soil condition, farmers must also recognize the significance of a good roothed. After all, a seedhed is needed for only a few days, whereas a good rootbed is required for the life of the crop. Although good weed control is imperative, no-tillage farming can fail unless proper attention is focused on all conditions of the entire soil profile.

In this paper the physical properties of soil will he discussed as they affect no-tillage farming. Three types of no-tillage farming will be considered to point out their use as related to the soil condition: (A) Standard no-tillage, where a special planter inserts the seed into a sparsely prepared seedbed; (B) No-tillage-plus, where seeds are planted over an access way through a soil horizon in poor physical condition; and (C) No-tillage--no-trafficfarming, a new concept where all operations, from preplanting through postharvesting, are done on widely separated wheelways.

No-tillage-plus cannot, in the strictest sense, be called "no-tillage farming." To the purist, however, even the standard no-till planter is accused of "tilling" a seedbed. However, neither system exposes the land to moisture losses or wind and water erosion prior to planting or during early crop-growth stage. On the other hand, no-tillage--no-traffic farming usually requires a drastic tillage to remove all existing harriers to water, air, and root movement before its establishment; but, after being established, it becomes typical of the standard no-till system.

A. Standard No-Tillage Farming

As well as reducing runoff and erosion, no-tillage farming can reduce the time, effort, and cost of preparing a field for planting, Often this translates into the possibilities of multiple cropping which can increase the production capahilities of every acre. Phillips and Young (1973) have discussed the many advantages to be gained from no-tillage farming, La1 (1976) and Smith and Lillard (1976) have demonstrated that no-tillage farming Substantially increased the production of each crop grown over that obtained with conventional tillage-oriented farming.

However, production from each no-tillage crop is increased only when the soils farmed are already in a good physical condition. Initially, *soils* must be without barriers to root and water movement and must not be compacted during crop production. Well-aggregated soils with a stable fabric strength capable of supporting the cultural equipment used to produce the crop can withstand trafficking. Soils with such physical characteristics are found only in near-virgin areas or in well-managed, established pastures. Unfortunately, most of our heavily farmed fields lost these attributes years ago, and we have too few acres today that are well-suited to standard no-tillage techniques.

For the no-tillage method of farming to be successful, the farmer must obtain a crop stand using newly designed planters. These planters are specifically designed to place seeds into soil not previously prepared for their entry by cutting through the surface residue and loosening a shallow, narrow seedbed. Where and when soil conditions are inadequate for deep, rapid moisture percolation and root penetration, this method fails because a suitable rootbed has not been provided.

Fields ideally suited for no-till farming can gradually lose their productive capacity through mismanagement. Mismanagement of soil structure deteriorates the surface soil condition so that the minimum effort exerted by most no-till planting tools cannot merge the seedbed with the rootbed. Vehicles too heavy for the once stable aggregates may shatter the surface aggregates and compact the soil surface. Application of cultural operations when soils are weakened by rains, or by excessive slippage of drive wheels applying shear stresses, easily fracture the once stable soil fabric and lead to surface compaction. Increases in compaction of the surface soil will seriously reduce the amount of moisture entering a soil to be stored for crop use. Soil compaction is also responsible for reducing root development which reduces the rate of moisture and nutrients retrieved. As soil compaction becomes more prevalent, crop yields will decrease and the field will become less desirable for additional no-till farming. Decreased yields are not necessarily characteristic of the no-till system since a few long-term experiments have shown that production can be maintained with proper management. Instead, it is evidence that better management is required to make the standard no-till farming system work on a sustained basis.

B. No–Tillage–Plus Farming

Just as some no–till planters can be adapted to obtain a slightly deeper or wider seedbed, so can the no–till planter be modified to pierce still deeper barriers to root and water movement. Normally, such planters will require some form of coulter *to* cut through the surface trash in front of an in–row subsoiler, followed by a device to pulverize, condition, and firm the seedbed prior to planting. Called “no–tillage plus,”––the plus refers to “plus subsoiling" --the technique offers most of the advantages of no–tillage farming in soils that require deep remedial action below the planted row- Lands tilled and trafficked for several years with standard equipment develop compacted horizons, and only no–tillage–plus can provide rootbeds that readily absorb the water necessary for profitable production when lands are in poor physical condition.

Most conventionally farmed fields have deep bands compacted by indiscriminant traffic, and, unless deep chiseling is done directly beneath the row, crops are denied most nutrients and moisture stored in subsoils. With no-tillage–plus, soil is loosened directly under the row by deep chiseling as the crop is planted. Such chiseling, or shallow subsoiling, should he just deep enough to pierce the harriers to rapid root development, and allow roots normal access through the compacted surface barrier, dense harrowsole, and restrictive plowpan. Roots are then able to develop at their genetic capahilities so that rapid early growth is assured and the mass of the root system can proliferate and retrieve the moisture stored in the deeper subsoils.

No–tillage–plus does not provide ready access to horizontal root develop–ment through the surface soil between the rows. About two–thirds of the fertile surface soil horizon remains compact, thus denying the nutrients and moisture it contains to the current crop. Unless sufficient ferti–lizers are placed in the loosened zone near each planted row, the crop may have difficulty obtaining adequate nutrition from the surface soil at rates which allow rapid growth.

Depriving crops of the nutrients and moisture in the fertile surface soil horizon is not new, For a long time now, roots have not developed in the interrow zone of surface soil in fields tilled in the conventional manner. It is not commonly realized how much interrow damage is done by traffick–ing while performing our present cultural practices since yield increases from new technology, including better varieties, additional nutrient availabilities, and improved pesticides, mask the losses resulting from compaction.

Compaction does not occur only on wet soil or only under heavy vehicles. Serious compaction can occur in well–tilled soil-when it is quite dry under the wheels of light tractors and sprayers, and even under the equipment support–, guide–, and depth–wheels. It cannot be stressed strongly enough that regardless of the type of implement used to till a field, all subse–quent traffic can compact the tilled horizon. This includes all secondary tillage implements and planting equipment. In fact, the benefit of primary tillage is frequently lost before the planted seeds germinate. Therefore, that part of the fertile horizon not loosened under the no–tillage–plus technique is in no worse condition than the interrow soil in field.: tilled and trafficked conventionally. In addition, because no-tillage-plus loosens the zone beneath the planted row through the plowpan, it offers better rooting conditions than the conventional system.

Two important factors that can limit production with no-tillage-plus are: (1) settlement within the excessively loosened seedbed and (2) inadequate seedbed prepararion.

Some form of seedbed conditioning is required to assure thdt seeds or young seedlings are not washed into the suhsoiler slot since suhsoiling often leaves the soil beneath the planted row in an unstable condition. The loosened soil contains lumps that can temporarily bridge the subsoiler slot, forming a large void near the bottom of the slot which leaves the seedbed vulnerable to settlement during heavy rains. Settlements can be disasterous to stand establishment, especially during the first 3 weeks after planting.

In the convrntional system, farmers can harrow repratedly before planting, if necessary, to prepare a seedbed. Not so with no-tillage-plus, since farmers must assure the proper pulverization for a good seedbed during a single pass. With no-tillage-plus, farmers must adjust all actions of the machinery prior to the first pass because they do not have a second chance before planting. Skill is required to assure adequate pulverization for a satisfactory seedbed in any no-till operation; a good seedbed is a prerequisite for adequate plant emergence--and an adequate stand is required for good production.

C. No-Tillage--No-Traffic Farming

The ultimate in no-tillage farming would allow for the crop to take advantage of the entire fertile surface soil horizon, as well as the deep, subsurface material; it would allow for the capture of most of each rain, and allow roots to develop to their genetic capacity, In addition, the rooting volume would not be lost progressively because of the additional compaction that occurs through continued conventional traffic. With the no-till--no-traffic technique, superior yields can be expected and sustained indefinitely when all other crop needs are properly managed and maintained. However, no-till--no-trafficfarming is difficult, if not impossible, using the machinery and implements available today.

Fields must first be put into an ideal physical condition with only a few narrow, permanently established wheelways for equipment travel. All operations from preplanting through postharvesting must he done from these wheelways so that soil barriers will not be re-formed within the farmed portions of the field. Deep profile modifications are possible to improve soil characteristics between wheelways, but regardless of improvements, the soil cannot be maintained in a productive condition when subjected to the forces of man's machines.

Our long term studies have shown that when deeply modified soils were used to produce crops, natural settlement was not objectionable. Without traffic, such soils remained permeable to water and loose enough for good root proliferation without annual tillage. Our untilled, untrafficked strips captured more of each rain and reduced both runoff and the amount of soil and field-applied chemicals that left the strips to become pollutants. Yields not only equalled those of test strips tilled each year and kept free of traffic, but were superior to those from strips tilled annually and trafficked in the traditional manner. Additional analyses indicated that no-till--no-traffic not only reduced operational costs, but benefited from more timely application of all operations.

To my knowledge, only one farmer in the United States has undertaken the equipment alterations necessary to perform no-tillage--no-traffic farming on a realistic scale. He is pleased with his production and cost reductions over the past 4 years. His vehicles operate on only 60-inch centers, which means that only about two-thirds of the surface of his fields can be used for production, since one-third forms the traffic network. He uses the same wheelways during all operations, including harvesting, without trafficking his beds, and is able to multiple-crop into loose soil without tillage.

I visualize that, in the future, all operations, including harvesting, will be done from spanning units that span much wider areas so that from 96 to 98 percent of the field will be free of wheel traffic. More of the field will be free to absorb the rains and remain free of barriers to rapid root proliferation. The only downward thrust upon the soil would be under the wheels of spanners that would fully support all weights now applied to the field, including that of the harvested crop.

Conclusions

Traffic, following tillage, is the major culprit responsible for soil compaction. Compacted soil prevents the effective entry of rain and irrigation waters into soil and prevents utilization by roots of moisture stored within and often beyond the compacted soil bands. When roots are unable *to* function at rates required for adequate moisture and nutrient retrieval, crop production declines. Depressed interrow trafficways accumulate and channel erosive volumes of water from fields, which not only denies water to the crop, but erodes fields, floods lowlands, and pollutes streams and lakes. Soil and water conservation measures are required to improve mechanized farmlands for sustained production.

Standard no-tillage farming is well-suited to lands already in excellent physical condition, but such lands are few, and their physical condition can be expected to deteriorate with sustained use.

No-tillage-plus can be used on lands that are already in poor physical condition. It can sustain crop production, but cannot produce yields that soils are capable of producing and that may be called for in the 21st Century.

The newest concept in keeping with the no-till principle is no-tillage--no-traffic farming. This system, promises both sustained and optimum production. Its value needs to be proved, however, before farmers and industry will be willing to abandon present farming implements and techniques for a whole new system of agriculture that demands an entirely new array of vehicles, tools, and practices.

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