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# Compact Soil — Visual Symptoms

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# Compact Soil — Visual Symptoms

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Water, air and plant root penetration into and through soil are restricted by excessively compact soil. This has been proved by researchers who evaluated the physical condition of soil by measuring bulk density, water infiltration rates, soil aggregate stability, soil strength, pore space, pore size, oxygen diffusion rates, etc. Such methods are time consuming and some are expensive because they require relatively sophisticated instrumentation. They are, therefore, not suited for farmer use.

This publication presents data and references illustrating that some soils are naturally compact and that soil conditions in Michigan are changing. It also summarizes the observations of researchers that an extremely compact soil can be diagnosed with visual methods by crop producers and farm advisors.

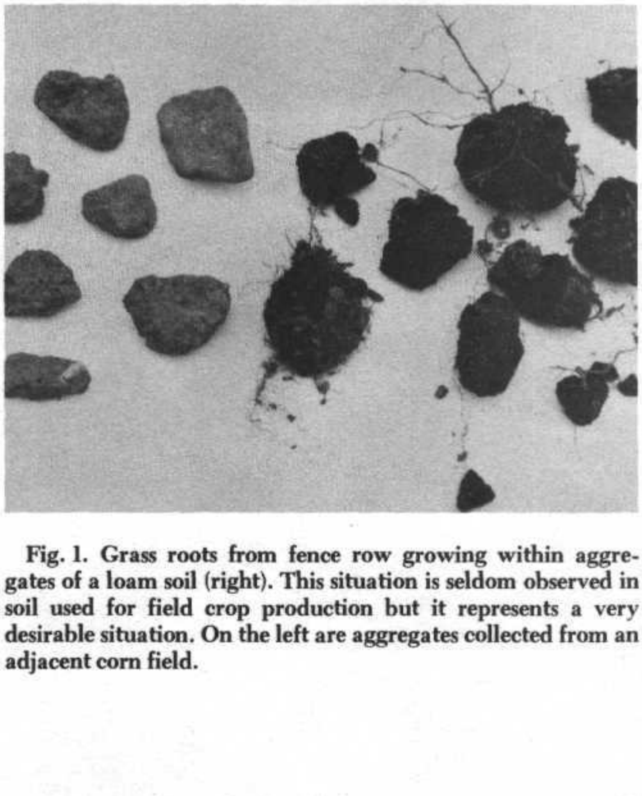

**Fig. 1. Grass roots from fence row growing within aggregates of a loam soil (right). This situation is seldom observed in soil used for field crop production but it represents a very desirable situation. On the left are aggregates collected from an adjacent corn field.**

## SOIL CONDITIONS CHANGING

The physical condition of soil is changing rapidly on many Michigan farms. To show this change, compare a soil that has been used for crop production for a long period with that in an adjacent woodlot or fence row.

The field soil will be much lighter colored, which denotes lower organic matter content. Upon close examination, crop roots will be found growing **between** soil aggregates (granules). Furthermore, the aggregates are likely to have sharp and distinct edges.

Soil from a fence row will be composed of aggregates that tend to be spherical in shape. The smaller aggregates may contain grass roots, a situation seldom observed in field soil (Fig. 1).

Extensive research data are available to prove that the physical condition of soil changes with time. The information in Table 1 is but one example. These data were selected because they illustrate that relatively sandy soil can be compact which is a poorly understood concept.

**Table 1. The effect of cropping upon porosity bulk density and percolation rates of a Fox sandy loam soil (Soil Management Group, 3/5a) (a).**

| | Cropped | Fence Row |
|---|---|---|
| Total pore space (percent) | 41.8 | 59.8 |
| Air pore space (percent) | 10.5 | 26.0 |
| Water pore space (percent) | 31.3 | 33.8 |
| Bulk density (g/cm$^3$) | 1.48 | 1.11 |
| Percolation rate (minutes/100 ml. water) | 40.2 | 0.8 |

(a) From R. L. Cook

Soil porosity represents the space in a soil volume which is occupied by air and water. The ideal soil contains approximately 50% total pore space. Relatively large pores normally contain air. Under ideal conditions for crop production, air space represents one half of the total pore space or 25% of the total soil volume.

[1]Appreciation is expressed to Dr. C. M. Harrison for assistance in the preparation of this bulletin.

The cropped soil has been compacted, as shown by the relatively low value reported in Table 1 for the air pore space. There is a great difference in both total and air pore space between field soil and that from a fence row.

Water pore space normally represents relatively small pores. The data in Table 1 indicate that both soils have similar water pore space and therefore capacities to hold and store water but not to receive it.

Bulk density is a measure of the dry weight of a standard volume of soil material. It is most frequently measured in grams per cubic centimeter ($g/cm^3$). Interpretation of bulk density values is difficult, except when paired samples are taken at the same time from similar soils. The data in Table 1 show a larger number representing the bulk density of the field soil. This means that the field soil contains a smaller volume of large pores or that it is more compact than that in the adjacent fence row.

Perhaps the most dramatic difference in soil conditions is shown by percolation data. The mean value of 0.8 minutes was required for 100 ml of water to percolate through cores of soil material from the fence row but more than 40 minutes to percolate through cores from the cropped field.

In summary, the information in Table 1 shows clearly that the physical condition of the soil used for field crop production deteriorated with time.

## Is Your Soil Compact?

The soil in some parts of the state is naturally compact (Fig. 2). Recently published County Soil Survey Reports contain tables which summarize the "physical

**Fig. 2. Wheat showing the location of tile drains placed in a soil formed on a naturally compact till in Huron County. Deep tillage and deep rooted legumes help to solve this problem.**

**Fig. 3. Alfalfa with exceptionally variable color and height caused by variable degrees of compact soil during a short period drought. The year after this picture was taken, light rains frequently occurred. Yields from the first cuttings in even the poor area were in excess of two tons per acre (Photo by M. B. Tesar, MSU).**

and chemical properties" of soil. Bulk density values are reported as ranges for the major horizons of each soil series.

The recently published Huron County Soil Survey Report contains bulk density data where the lowest value reported for subsurface samples is much larger than the highest value reported in Table 1.

Approximately 85% of Huron County soils have C horizons (parent material) with bulk density values in excess of 1.7 $g/cm^3$. With the special methods used to determine the values published in the Huron County Report, any value greater than 1.6 is likely to represent conditions where soil water storage and crop root penetration are severely limited. Thus, crop yields are limited.

Compact conditions created in the farming process are much more extensive than those that occur naturally. Inadequate drainage, field operations on wet soil, excessive tillage, intensive cash crop operations and the design of some farm implements all create soil physical problems. Symptoms of excessively compact soil have been observed in every county in the state. The opportunity to see them on your farm is great because the condition is so widespread.

Symptoms of soil physical problems can be observed in both crops and soil. They are most evident when both soil and weather conditions are extreme (Fig. 3). In evaluating the situation, care should be exercised because similar symptoms may be caused by other factors such as dry weather, plant nutrient deficiencies, insects, diseases, high water table, etc. If such conditions are not present, the chances are great that the correct interpretation will be made.

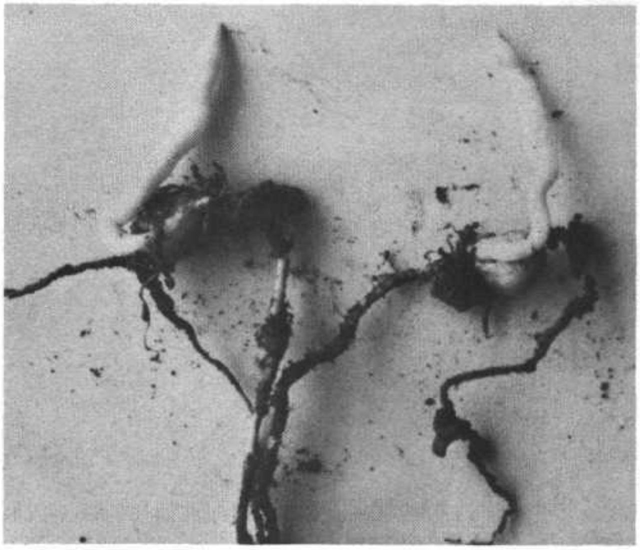

**Fig 4. Distorted corn shoots caused by thin but strong soil crusts. (See Fig. 19 on soil crusts.)**

Interestingly, symptoms do not necessarily show at all times during the growing season. The use of irrigation water or the event of timely showers may prevent some symptoms, such as wilted plants or variable sized plants, from showing.

### Visual Symptoms Shown By Plants

Distorted stem shoots, variable sized plants, wilted plants, off colored leves, shallow root systems, malformed roots and lodging are the most obvious and frequently observed symptoms of excessively compact soil.

**Distorted stem shoots** are the first symptom usually seen, especially on large seeded crops such as corn or beans. Shoots are frequently crooked and vary greatly in diameter (Fig. 4). This condition is most common where strong soil crusts are present, but may develop where the entire plow layer is too compact. On dry beans and soybeans, "bald" seedlings may be a symptom, especially where the soil is both compact and wet (Fig. 5).

**Fig. 5. The abnormal characteristic (bean plants with no primary leaves) shown here is referred to as baldhead. This can be caused by several situations, including a sticky compacted soil.**

**Variable plant emergence** from the soil and inadequate stands are easily and frequently observed (Fig. 6). These conditions could reflect low soil temperature, wet soil, soil crusts or cloddy soil conditions which can all be related to undesirable soil physical conditions, even though adequate rates of high quality certified seed were used. They may also suggest rodent, insect or disease problems.

Where compact soil restricts water drainage and creates wet soil conditions, seedlings and more advanced plants are susceptible to damage from both an oxygen deficiency and from disease organisms. Root rot in dry beans and soybeans, Phytophthora root rot in alfalfa and black root in sugarbeets are all associated with these conditions.

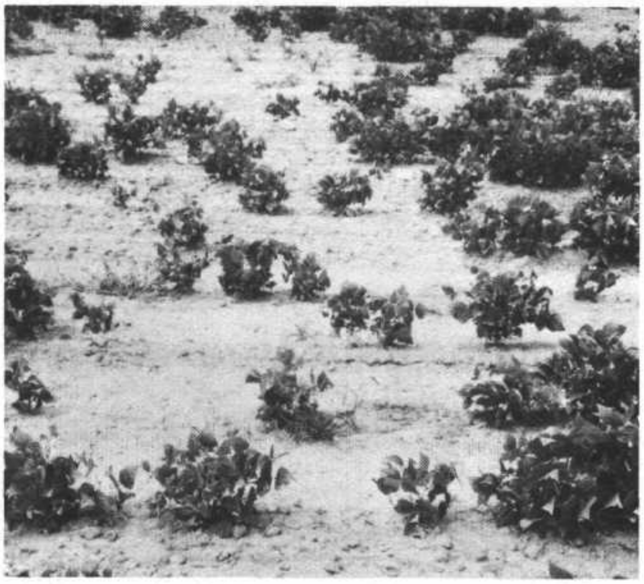

**Fig. 6. Variable sized bean plants and stand are symptoms of major problems. In this instance, slow water infiltration rates in this tiled field are evidence of excessively compact soil.**

**Variable sized plants** down a row or even across rows is an easily and frequently observed condition. Delayed emergence from the soil and slow growth result in shorter than normal plants which may be either randomly or systematically distributed in a field (Fig. 7). Variable sized plants have been seen in cloddy seedbeds when wet fine textured soil was plowed in the spring. Such conditions are relatively common—especially on loam, silt loam, clay loam or clay soils.

Also, plants of different heights have been observed in wheel tracks of manure and fertilizer spreaders that

**Fig. 7. Variable sized sugarbeet plants. Notice the tractor wheel marks which show diagonally across the picture. The compacted soil developed while discing a wet soil previous to planting.**

were used on excessively wet soil (Fig. 8). Harvesting potatoes, corn silage and sugarbeets under wet conditions sometimes results in excessively compact soil which shows as smaller plants in streaks across the field. Nematodes and root damaging animals, variable nutrient deficiencies, fertilizer or pesticide toxicities or plant disease may create similar symptoms; but their effect may also be the product of compact soil (Fig. 9).

**Wilted plants** may reflect the effect of dry weather, root insects or a shallow root system. The combination of dry weather and a limited root system can be devastating as illustrated in Fig. 10. In this instance a tillage pan limited root penetration to approximately

**Fig. 8. Small bean plants and reduced populations occur where soil was compacted by a fertilizer spreader truck. This situation would not have developed if the fertilizer had been applied previous to plowing and if the soil had been drier.**

**Fig. 9. Manganese deficient soybean plants growing on noncompacted soil between tractor wheel marks. Plant nutrient requirements increase as the physical condition of the soil improves. The bulk density of the soil at a depth between 3 and 6 inches, where the short dark colored plants were growing, was 1.75 g/cm$^3$. The soil with the taller light colored manganese deficient plants had a bulk density of 1.29 g/cm$^3$.**

10 inchest. Frequently, wilting occurs only during the warmest part of the day.

**Abnormal leaf color** reflecting nutrient deficiencies or even disease has been observed where compact soil limited root growth. The purple color of corn leaves, suggesting a phosphorus deficiency, has been associated with excessively compact soil conditions on low testing soils.

**Fig. 10. Wilted corn caused by a shallow root system growing in compacted soil. In other parts of the field, where the soil was not as compacted, corn plants were not wilted because roots penetrated more deeply into the soil.**

Nitrogen deficiency symptoms, however, are most common (Fig. 11). Losses of fertilizer nitrogen by denitrification from waterlogged soil is occasionally the result of compact soil. More fertilizer may reduce the intensity of the symptoms and cause color of the leaves to be normal, but crop yields are usually limited. The best solution to this problem is to create a good soil structure, where excessive water can rapidly drain out of the root zone. This can be done by using tillage implements to loosen the soil and by being certain that the soil is not wet during field operations. Tile or surface drainage may be beneficial.

**Fig. 11. Corn in foreground is growing in an old severely eroded farm lane where livestock had trampled the soil and had kept it free of vegetation. Only a disc was used to prepare a seedbed. As a result, germination and plant emergence were delayed and without extra nitrogen the plants growing in the compact soil, where the lane was formerly located, were nitrogen deficient. The corn in the background which received the same fertilizer and tillage treatments shows little evidence of stress caused by compact soil.**

**Shallow root systems** are a frequently observed symptom of compact soil. Roots in a soil with good physical properties grow either directly down into the soil or extend in a downward diagonal direction. The depth of the system at maturity should be at least two feet. Roots of long season, high yielding crops—such as corn, sugarbeets and alfalfa—invariably penetrte to depths in excess of four feet (the roots of irrigated crops may be less).

The number of roots in a soil profile should gradually decrease with depth. On many soils there is an abrupt change in root numbers and size from the plow or disc layer into the subsoil (Fig. 12). This condition could reflect many conditions, including a compact subsoil.

**Fig. 12. Soybeans with a severely restricted root system due to excessively compact soil. Notice the crinkly nature of the roots and the horizontal growth pattern. Only a few nodules are present.**

**Fig. 13. Navy bean roots growing on surface of compacted soil. This situation can be observed only if soil area is shaded and when soil moisture levels are excessively high. Under these conditions, the plants are stressed due to oxygen deficiency.**

Some roots may be seen on the surface of soil if plants are growing in compact soil and if an extended period of wet weather occurs. Under normal circumstances, roots on the surface die rapidly, but they survive long enough to be seen during wet periods if they develop in the shade of a row (Fig. 13).

Malformed roots can be caused by several conditions, including compact soil. Healthy normal roots are usually round in shape while those growing only in soil cracks are likely to be relatively flat or elliptically shaped. Obviously such symptoms are most easily observed on root crops such as sugarbeets and carrots, but may be seen on the larger roots of other crops.

In compact soil, root growth is relatively slow and the root may tend to grow laterally as much as downward. It is likely to abruptly and frequently change direction of growth as it gradually expands into volumes of soil with less resistance (Fig. 14). Root hairs will be close to the tip in compact soil. Where root growth is normal, the distance between the root tip and the closest root hair may be an inch or more (Fig. 15).

**Fig. 14. Sprangly alfalfa root development in field shown in Fig. 3. Notice the non-continuous layers of soil and how the roots tend to follow the layering. The taproot should grow straight down into the subsoil.**

**Fig. 15. Healthy, white navy bean roots growing in a soil that has no physical problems. The distance between the root tip and the root hairs is almost one inch, which suggests a very rapidly growing root. Root hairs are sometimes easily visible to the naked eye but a handheld magnifying glass is an aid in evaluating this characteristic. (Photo by A. C. Trouse, Jr., National Tillage Machinery Lab.)**

A shallow, crinkled fibrous root system of crop plants restricted to the surface few inches of soil is a definite symptom of excessively compact soil. Numerous observations, especially of dry beans, suggest that root rots are likely to be more damaging when such conditions exist.

**Lodging** may reflect several conditions including compact soil. Where roots occupy only a small volume of soil, the soil does not serve well its function of mechanical support for plants (Fig. 16). The combined weight of an ear, the weight of rain water on the leaves and only a slight wind can cause lodging where root volumes are limited and root strength is low.

### Visual Symptoms Evident in Soil

Strips of clods, crusts, cracks in tractor wheel marks, soil volumes devoid of roots, standing or ponded water, excessive erosion by water and partially decomposed crop residues are also visual evidence of compact soil.

**Clod strips** caused by tilling compacted fine textured soil are seen with increasing frequency, especially where the soil was plowed relatively deep in the spring with a large implement (Fig. 17). Farmers who plow in the fall have not been greatly concerned about clod strips because the large clods are fragmented during the

**Fig. 16. Lodged corn grown on a compacted soil where the root volume was limited. This corn was growing directly over tile which no longer function normally because water could not rapidly move through the very dense soil to the tile.**

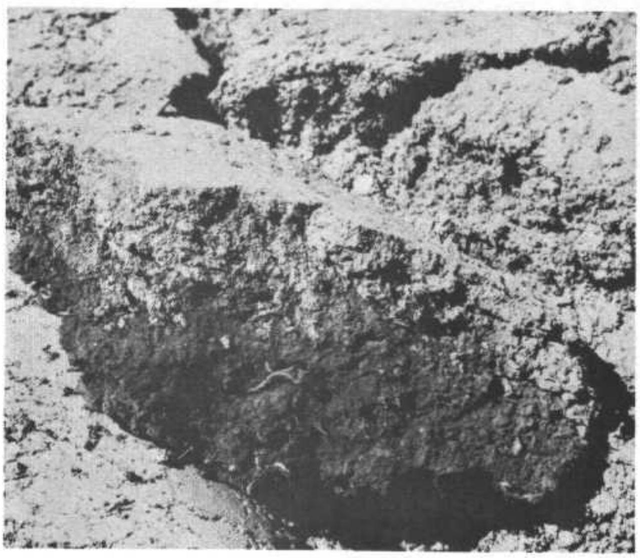

**Fig. 17. Clod strips on fine textured soil are a common sight when soil with a high moisture content is plowed. Maximum compaction occurs in the soil material which makes contact with a moldboard plow. Extra tillage after the soil dries is necessary to reduce the size of the clods.**

winter and spring by repeated freezing and thawing or wetting and drying. The density of the fragmented granules is relatively high, which explains in part why roots frequently grow around the aggregates and not through them.

**Soil crusts** are the most universally distributed and frequently observed symptom of compact soil material. Crusts are the product of interactions between nature and the crop production activities of farmers (Fig. 18).

Crusts represent an undesirable situation, because when dry they are strong and physically limit seedling emergence from the soil. When wet, soil pores are filled with water and the exchange rate of air between the atmosphere and the soil is reduced. Thus, carbon dioxide and other soil gases do not escape from the soil and essential oxygen in the natural atmosphere does not rapidly move into the root zone (Fig. 19).

**Fig. 18. Soil crusts are the most universal and frequently observed symptom of compact soil. Notice the horizontal white stems on some of the bean plants where they developed under a crust. Row widths expanded to more than four inches where the plants had to contact a crack before they could emerge from the soil.**

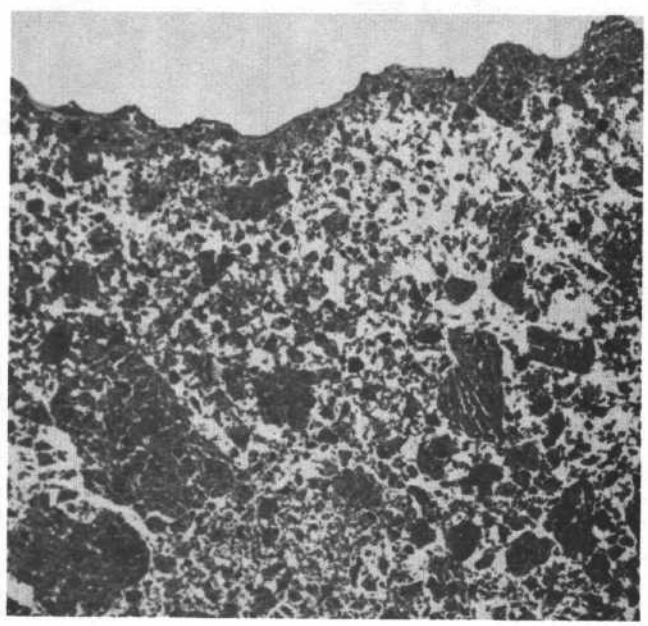

**Fig. 19. Microphotograph of a very thin soil crust on a fine textured soil. The white space in the photograph represents pores in the soil. Notice that no pores extend through the crust. Even the soil aggregates contain some pore space (micropores) which under ideal conditions contain water. The larger white areas represent macropores, those normally filled with air.**

**Soil cracks** in tractor wheel marks are frequently seen in compact fine textured soil. The cracks run parallel to the rows and may not occur between the wheel marks because this area has a different type of structure (Fig. 20).

**Fig. 20. Deep soil cracks, approximately parallel to the row, may reflect soil compacted by farm implements. This symptom has been observed on all row crops and usually occurs in fields where the soil has desirable characteristics except in the wheel marks.**

In wheel tracks the soil is likely to be compacted, while between the tracks soil is granular. These conditions may exist and be observed even after moldboard plowing in the fall. The soil zone that is packed turns over as large clods while the more granular soil turns over in smaller aggregates.

**Soil volumes devoid of roots** can be observed only after digging into the soil. Under extreme conditions, one shovelful of soil may be all that is required to note the absence of crop roots. Under less extreme conditions, it may be necessary to dig a pit and then with a pocket knife or trowel chip away at the soil (Fig. 21).

With this method, roots growing horizontally and failing to penetrate a tillage pan can be observed. If roots are present in all zones to a depth of three or four feet, compact soil is probably not a major yield limiting condition.

**Standing water** in wheel tracks and ponded water in shallow depressions may be a symptom of excessively compact soil (Fig. 22). If water infiltration rates are slow, the condition can be caused by soil crusts or compacted soil materials below the surface. Slow infiltration rates are invariably associated with low total porosity and very small sized soil pores.

Such symptoms are now common in fields of very early planted crops such as spring barley, oats, sugarbeets and corn. Some observations suggest that this condition may be occurring more frequently in fields where dual wheeled tractors have been used. This suggests that some dual wheel tractors are used for field operations at higher soil moisture levels than is possible with other tractors.

**Fig. 21. Soil crack in tractor wheel path. Notice the absence of navy bean roots in the wheel path of this excessively compacted soil. Also notice the numerous roots to the left, growing between the tractor wheel marks.**

**Fig. 22. Temporary flooding or ponding of water is a frequently observed symptom of compact soil. If an ideal soil contains 50% of its volume as pore space and 25% of its volume as water, then a level soil that is plowed to a depth of eight inches should absorb a two inch rain before ponding occurs. Most rains that occur in Michigan during the growing season are much less than two inches.**

**Excessive soil erosion** by water may be a symptom of compact soil. When rain or irrigation water does not rapidly enter the soil due to crusts or compacted soil materials, it collects in low areas as previously described or runs off to another site. If the runoff is great and for an extended period, accelerated water erosion occurs (Fig. 23).

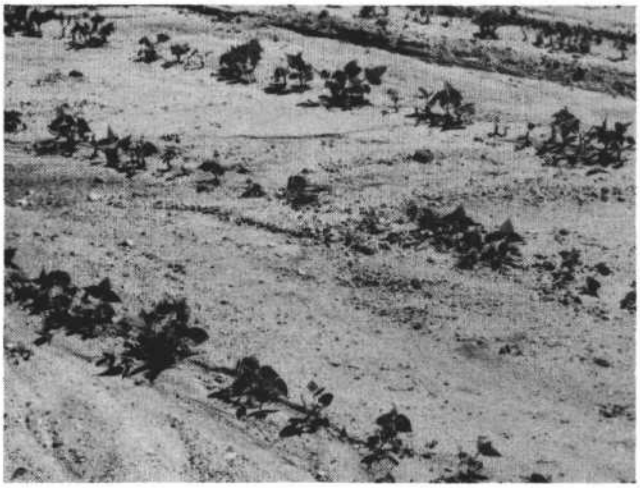

Fig. 23. Excessive soil erosion by water occurs when rainfall rates exceed water infiltration rates. Where water does not penetrate the soil, it moves across the surface causing damage by washing out plants, carrying away soluble plant nutrients or by burying small seedlings.

Fig. 24. Partially decomposed crop residues, especially when observed after incorporation into the soil, are a symptom of compact and waterlogged soil. Oxygen diffusion rates are slow in crusted and waterlogged soil, thus oxygen deficiencies develop and crop residues decompose at a very slow rate.

**Partially decomposed crop residue** observed months after incorporation into the soil is still more evidence of excessively compact soil material (Fig. 24). An inadequate supply of soil oxygen in compact and waterlogged soil creates this symptom which is observed with increasing frequency. Crop residue decompositionis very rapid in soil without physical limitations (Fig. 25).

## SUMMARY

It is not practical for crop producers to use the methods and instrumentation of researchers to identify excessively compact soil, but it is possible to use the researchers' observations and experiences to help interpret the situation in specific areas or fields. A close look at the soil and crops helps to evaluate your soil conditions.

Visual symptoms of compact soils displayed by crops include: Distorted stems, variable plant emergence, variable sized plants, wilted plants, off-colored leaves, shallow rot systems, malformed roots and lodging. Symptoms in soil include: Clod strips, soil crusts, cracks in tractor tire marks, subsurface compact zones, standing water, excessive soil erosion by water and slow decomposition of crop residues.

Fig. 25. Good dry bean roots in soil with few or no physical problems. This crop yielding 2,540 pounds per acre was grown in a rotation that included seven years of alfalfa hay. The field was moldboard plowed after the soil dried. Notice that there is no evidence of excessively compact soil because the roots grew uniformly and in a downward direction.

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