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FORMATION OF PLOWSOLE PANS IN FLORIDA SOILS

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Compaction of the subsoil immediately below the depth of tillage is becoming a problem in certain areas of Florida. This compacted layer is commonly referred to as a "plowsole pan," because it first came to attention where it was associated with the use of moleboard plows. Pounding by the feet of draft horses or pressure of equipment wheels in the bottom of the plow furrow was thought to be the major cause of the condition.

Plowsole pans should not be confused with the brown or brownish-black hardpan commonly found in our palmetto flatwood soils. These brown pans are formed as a result of a natural movement downward and subsequent deposition of soil colloids and materials in solution under the influence of high soil acidity, while plowsole pans are the result of pressure or pounding on the undisturbed subsoil. There is less tendency for pans to develop where a tilled soil cushion is maintained between the maximum depth of tillage and the depth to which equipment wheels penetrate.

The plowsole pan is detrimental because it interferes with the deep penetration of the roots of the crop, and with the free movement of water and air through the soil. As a result the drainage of excess water through the soil is slowed down to the point where an otherwise well-drained soil may become boggy and water-logged after periods of heavy rainfall. This pan also prevents the normal return of subsoil moisture to the surface during dry periods. Coupled with the fact that the crop is necessarily shallow rooted over the pan, this leads to severe drought during periods of limited rainfall.

Plowsole pans also have an effect on the efficiency of various irrigation practices and on the leaching of fertilizer residues. They will tend to prevent the normal deep penetration of water applied by overhead irrigation and will restrict the rise of water applied by sub-irrigation. There is a greater tendency toward the accumulation of soluble salts. This may be a significant factor where heavy fertilization is practiced or where water of marginal salinity must be used.

Formation of tight plowsole pans is associated with certain soil conditions. Dry soil will not compact readily, while wet soils are lubricated by their moisture and result in the tightest pans. Sandy soils compact quite readily when the soil approaches saturation, but clay soils compact the most readily at a moisture content slightly less than that which will make the soil sticky and plastic. At higher moisture levels, a clay soil will ooze out from under the wheels rather than form a compact pan.

Another differentiating characteristic of soils is their ability to recover from pans formed during a given crop season. A clay soil will swell and shrink during wetting and drying. This tends to re-granulate hardpans, so that roots and water can penetrate them. Freezing and thawing are very important factors in bringing about this granulation in the north where frost penetrates to the pan. On the other hand, a sandy soil has little or no swelling and shrinking taking place during wetting and drying. Thus, when a pan forms it tends to remain, and the added pounding it receives each year adds to the tightness of the pan.

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The most impervious pans appear to be formed where there is just enough clay and silt in the sand to be accommodated between the sand grains, yet be insufficient to make the soil plastic or to hold the sand grains apart. In Florida, this condition is most frequently encountered on the border between sandy soil areas and clay soil areas where just the right mixture of sand and clay exists in the transition zone; or where sands overlie clays at certain depths. Another condition that promotes pan formation is the presence of the hard phase of the natural brown pan of the palmetto flatwoods when it lies at about 12 inches below the surface. It forms a base on which a tight impervious pan may be compacted. In some instances it appears that organic matter may take the place of clay in making tight pans.

The formation of plowsole pans probably became significant in Florida with the widespread introduction of tractors and other heavy farming equipment. The steel-tired equipment first used probably had a greater tendency to form pans than does modern rubber-tired machinery, because a steel wheel concentrates the load more and gives a greater jarring shock to the soil than does a pneumatic tire.

The problem of plowsole pans in Florida first came to the attention of the writer in 1940, while carrying on irrigation tests in the Hastings area. It was given no further study until February of 1950, when an area of poor cabbage growth was associated with a well developed plowsole pan in an area of Leon fine sand. Added interest resulted when it was suspected to be a factor in the development of the corky ringspot disease of potatoes, but this latter correlation has not been verified as yet.

It is the purpose of this report to bring the problem of plowsole pans to attention, and to show the degree to which they are developing in certain areas of the peninsula where it is thought the greatest potential for their formation lies. A survey was made of plowsole pans in the Hastings, Sanford, Bradenton, Gainesville and LaCrosse areas. Bearing pressure and density determinations were made wherever the existence of pans was suspected.

A portion of the data obtained by the survey is given in the accompanying table. The bearing pressure determinations were made with a Proctor needle of the type used in earth dam construction. In this instance it measures the resistance to penetration by a flat-pointed needle with an area of .05 square inches. Readings must be made when the soil is at field capacity moisture content, either by selecting a suitable time following a period of rainfall, or by artificially wetting the profile a day ahead of measurement. While this measure does not correlate exactly with pan density, it does give an indication of pan formation and relative resistance to root pene-

EFFECT OF TILLAGE ON SUBSOIL COMPACTION*

Location	Sample Description	Pounds** Bearing Pressure	Soil Volume Weight	Pounds Per Cubic Foot
1—Hastings	Plowsole 10-13″ Bladen lfs	60	1.89	118
2—Hastings	Plowsole 10-13″ Bladen lfs	55	1.90	119
3—Hastings	Plowsole 10-13″ Plummer fs	45	1.77	111
4—Hastings	Plowsole 10-13″ Leon fs	50	1.88	118
5—Sanford	Plowsole 10-12″ Leon fs	55	1.55	97
6—Sanford	Plowsole 11-13″ Leon fs	40	1.57	98
7—Sanford	Plowsole 11-13″ Leon fs	55	1.58	99
8—Gainesville	Plowsole 9-12″ Arredondo lfs	30	1.71	107
9—Hastings	Natural Leon Pan***			
	13-15″ Gray	100	1.97	123
	15-19″ Brown	120+	1.66	104
10—Bradenton	Natural Leon Pan*** 11-13″ Brown	60	1.40	88

* Virgin soils of these types have volume weights between 1.3 and 1.5 (80 to 90 Lb. per cubic foot).

** Pressure necessary to force a flat point with an area of .05 square inches into the plow soil at field capacity moisture content.

*** These are the natural hardpans found in the subsoils of palmetto flatwoods. The high bearing pressure at location 9 is due in part to cementing together of the sand grains.

tration. Areas with no apparent pan formation always measured less than 20 pounds bearing pressure. Density determinations were made by paraffining wet clods of soil, determining displacement in water and then making the proper corrections for wax and moisture.

Virgin soils of the types studied range between volume weights of 1.3 and 1.5 (80 to 90 lb. per cu. ft.). Such soils contain about 40 percent pore space. Well developed plowsole pans such as those found at Hastings will have porosities of about 25 percent. When soils reach this low porosity, the rate of water movement through them is inadequate for drainage or for a significant rate of rise of water from the subsoil during periods of drought or during subirrigation.

The survey showed that pans were the most serious where three conditions occurred. First, the subsoil must be quite moist when tillage usually takes place, as is often the case with our flatwoods soils. Second, the soil must be of a texture such that pans, once formed, remain from year to year. Third—and probably the most significant—pans are most likely to form under the type of tillage where the tractor and equipment wheels ride directly on the subsoil without a cushion of tilled soil in between. The extreme of this condition occurs where high single-row beds are maintained, as with cabbage and potatoes in the Hastings area. These rows usually are 40 inches apart and about 12 inches high. The center of the alley between the rows generally is free of topsoil, and the wheels ride directly on the undisturbed subsoil. The pan is formed directly below this zone of pressure.

Where the rows are maintained exactly in the same place year after year, there are two zones of maximum density of the pan. One lies in the center between the rows and the other directly beneath the row. This is the result of splitting the cash-crop row down the middle and building the summer cover crop row over the old alley. Examinations of these pans showed that root penetration was limited to horizontal growth between the compacted layers laid down from season to season at the extreme top of the pan, with no penetration at the depth at which the pan was permanent.

Areas in the vicinity of Sanford, Bradenton, LaCrosse, and Gainesville were examined in addition to the detailed study at Hastings. In no instance was a well developed pan encountered, although there was some indication of pan development in the Arredondo loamy fine sand studied at Gainesville, and in the Leon fine sand at Sanford. There was no identifiable pan in the Lakeland fine sand areas examined at Gainesville. Part of the reason for the lack of significant development of pans at Sanford and Bradenton may be that some subsoiling had been practiced in the areas. In fact, the incipient pan formation noted at Sanford appeared to be below the depth of such treatment.

Two examples of the natural palmetto flatwoods pan are included in the table to show their wide variation in density and hardness. Apparently the natural pans vary considerably in their permeability to water and should not be assumed to be completely restrictive to its movement.

Conclusions

Dense impervious plowsole pans are developing in certain areas of Florida where soil and cultural conditions are favorable for subsoil compaction, but the areas of potential trouble appear to be quite limited. The problem may arise only under those cultural practices in which the subsoil is exposed to continuous direct traction such as in the Hastings area, and where sands overlie heavier subsoils or the natural hardpans of our palmetto flatwoods. Where tillage is relatively shallow or the subsoil protected by a tilled cushion during the majority of operations, the pans probably will not develop beyond the point to which they can be readily broken up by shallow subsoiling with a wingtip shovel or similar implement set to go a few inches below the normal depth of tillage.

Where pans are fully developed as in affected areas at Hastings, the problem is a serious one in that deep subsoiling may be necessary. Special attention should be given to areas showing droughtiness out of keeping with the surface texture, and to areas that do not respond to subsoil irrigation.

Present conclusions are that any soil containing a pan with a volume weight of more than 1.8 (about 110 pounds per cubic foot) should be given special attention. If they are producing an abnormal crop, then subsoiling should be considered. This is best done just after the spring crop is off when the soil is relatively dry. The summer cover crop will then have an opportunity to grow down into the fractured pan and help to stabilize the granulation that has taken place. The length of time that subsoil chiselling may be effective under our conditions is unknown as yet.

A word of caution is necessary with respect to reduced bearing pressure following subsoil chiselling. Heavy equipment may bog down if put on the area when the soil is wet immediately after such an operation.

EFFECT OF 2, 4-D ON FOUR SWEET CORN HYBRIDS AT DIFFERENT STAGES OF GROWTH

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Sweet corn has become one of the major vegetable crops grown in the Everglades area during the past few years. Research work elsewhere indicates that perhaps herbicidal applications of 2,4-D might be used to reduce hand weeding costs in this crop, particularly in periods of extremely wet weather and after lay-by, to kill rapidly growing sticker weeds, *Amaranthus spinosus,* which interfere with harvesting.

Some growers in the area have applied 2,4-D to sweet corn in the past. In some cases unfavorable responses resulted, reflected in lower yields and poor quality of ears. Reports from these growers were conflicting in regard to susceptibility of varieties and stages of growth at which the plants were damaged when treated with 2,4-D. The main objectives of this study, therefore, were to find (1) the growth stage at which sweet corn is least susceptible to the effects of 2,4-D, and (2) whether there are differences in the tolerance of the four most commonly grown hybrids in the area—Gold Rush, Golden Security, Ioana and Calumet.

Results of extensive study with 2,4-D concerning the hazard of contamination to nearby sensitive vegetable crops indicated that only the sodium or amine salts of 2,4-D should be used in this area. Preliminary work using one pound of 2,4-D as directional spray did not cause noticeable damage to sweet corn plants, although most of the common broad leaf weeds could be killed with one-half pound of 2,4-D. In this study, therefore, 0.75 pounds of the amine salt of 2,4-D was applied to the corn plants at seven stages of growth.

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REVIEW OF LITERATURE

Both field and sweet corn varieties have been found by a number of investigators to differ in their tolerance to 2,4-D (1,2,6,8,9,12, 16,19,24,25) and also in type of reaction to the same 2,4-D treatment. There has also been a considerable amount of study on the effect of 2,4-D on field and sweet corn treated at different stages of growth, whether used as an overall foliage spray, or applied directionally to the base of the plants (3,4,5, 6,7,8,9,12,14,16,17,23,24,25,26,27). Many of these studies were made in combination with different amounts or formulations of 2,4-D.

In general, injury to sweet corn by 2,4-D spraying seems to increase with age of the plant. The critical stage for spraying 2,4-D over the foliage of the corn plant appears to be the 6 to 24 inch stages; however, when directional application of the 2,4-D solution is made only to the base of the stalk of plants 15 to 18 inches or taller, very little or no damage has been done to the corn plants and yields have not been affected (4,9,14,18,26).

Severe damage to corn plants, and in many cases lower yields, have resulted from the use of one pound or more of 2,4-D acid equivalent per acre (16,17,21,24). The safe amount of 2,4-D to be used in sweet corn appears to be from ¼ to ¾ pounds per acre (4,7,9,18,22).

From the various reports, therefore, it is apparent that varieties or lines of sweet corn might react differently to herbicidal application of 2,4-D spray. The degree of reaction is also related to stage of growth at which the corn plants are treated, the amount of 2,4-D acid used, and the method of application of the spray material.

PROCEDURE

A mature Everglades peat soil with a pH of 5.8 was seeded on February 21, 1953 with Gold Rush, Golden Security, Ioana and Calumet varieties of sweet corn in a split plot design, in which varieties were the major treat-