TILLAGE TESTS

I. EFFECT OF SUBSOILING AND MOLE DRAINAGE UPON THE MINIMUM INFILTRATION CAPACITY OF A HEAVY CLAYPAN SOIL OF THE TROPICS

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Introduction

There are probably more than 250,000 acres of cultivated land in Puerto Rico on which internal drainage could be improved considerably by the use of better tillage practices. This area includes a great variety of soil types of the inner and river flood plains, coastal lowlands, and the terraces and alluvial fans. Large areas of soils of the Caguas, Candelero, Sabana Seca, Mabí, Moca, Coloso, Vega Baja, Yabucoa, Josefa, Maunabo, Las Piedras, Camaguey, Santa Clara, Lares, and other series have tight subsoil layers which interfere with root penetration, water movement, and aeration (6).[2] Unless these areas are properly tilled, the roots of plants growing on them are restricted to small volumes of soil, thus reducing the available nutrients and moisture. Yields are considerably lower in these places than in the better drained sections. A regular feature of these areas, which are mostly devoted to sugarcane cultivation, is the large number of ditches required to dispose of run-off waters (3).

In other regions with similar problems attempts have been made to improve the situation by using deep-tillage practices, drainage, and subsoil fertilization (7). Subsoiling has been a regular practice in some Puerto Rican plantations of moderately heavy soils but in others, with claypan layers underneath the surface, the practice is virtually unknown (4). No experimental measurements have been performed properly to evaluate the effect of these practices upon soil tilth or crop yields. Mole-drainage systems have been installed in the past to a very limited extent, but the practice never became generalized and disappeared without apparent reason.

Following a preliminary survey of many farm lands a plan was outlined to evaluate tillage practices currently used and to test experimentally others that might prove more practical. The improvement of soils by techniques that promote better internal drainage and aeration may lead to reduced farm expenses, more efficient land utilization, and increased crop yields.

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[2] Numerals in parentheses refer to Literature Cited. p. 185.

Soil Characteristics

The area selected for establishing the first tillage test is located in Colonia Preston, a large sugar estate of east-central Puerto Rico. The experimental field was located near road 28, km. 12 H. 9. Various pits were dug at different parts of a 10-acre field to study the morphological characteristics of the soil. In addition, soil cores for laboratory studies were obtained with a Kelley (Utah) soil-sampling machine (2). The soil was previously mapped in the Soil Survey of Puerto Rico (6), as Vía silty clay, but field examinations indicated that it approached more a Caguas silt loam.

The soil was in native pasture, mostly carpet grass mixed with some native legumes and many weeds. The root development was rather weak all the way down, thinning out considerably with depth, being practically none below the 16-in layer. A soil profile examined on September 26, 1950, was as follows:

0–7″	Light grayish-brown silt loam with some admixture of yellowish subsoil. Many large, dark concretions, some ½″ in diameter, mostly about ⅛″. Indefinite and rather fine granular structure. pH 6.6.
7–16″	Highly mottled, predominantly yellow clay. Well-developed fragmental-blocky structure. pH 6.0. Transition layer.
16–26″	Highly mottled, gray color predominant, clay. Fragmental-blocky structure coarser than above. Cut like putty. Concretions in the upper 16–22″ section. pH 5.3 in gray material, 4.7 in brown material.
26–50″ +	Gray, mottled brown and reddish-brown silty clay. Material that looked like colloidal films along the cleavage planes. Prismatic structure, coarse, with tendency to vertical cleavage. pH 5.0.

The slope of the field ranged from about 4 to 10 percent. The tight layer appeared closer to the surface in approaching the higher parts of the field. Permeability measurements made on undisturbed cores gave slow rates of only 0.19 inches of water per hour for the 23- to 26-inch layer indicating that this was a very tight layer. The layer above it had a moderate rate of percolation of 3.90 inches of water per hour and the permeability of the surface layer was only 1.31. The total exchange capacity ranged from 9.5 to 12.5 m.e. per 100 gm. of dry soil, the higher values corresponding to the deeper layers.

Experimental Lay-out and Procedure

An incomplete block design, the triple lattice, was used for the experimental lay-out (1). This type of design has proved to be very precise, especially when using a large number of treatments. The plots were rather large, 200 feet times 20 feet wide, to facilitate the operation of heavy equipment.

Land preparation was started on October 11, 1950, by passing a disk harrow twice to cut the sod. From November 8–15 the land was plowed and harrowed three times with disks to a depth of about 12 inches. Furrows were made every 5 feet, four to each plot. Although the field was ready for treatments and planting, these operations were deferred to a later date because of unusually heavy rains. The soil was too wet for several weeks. On January 10, 1951, after a few days of intense sunlight, a fourth disking was performed and the furrows were prepared over again. Surface drainage was provided by ditches every 25 feet at right angles to the furrows and leading to larger drainage ditches dug to follow the topography of the land. From January 17 to 24, 1951, the treatment differentials were established

TABLE 1.—*Treatment differentials established on the experimental field on a heavy claypan soil in east-central Puerto Rico, showing other treatments occurring in the same group according to design used*

Treatment No.	Description	Other treatments in the same group[1]
1	Check	2, 3, 4, 5, 7, 9
2	Subsoiling	1, 3, 5, 6, 7, 8
3	Subsoiling + fertilizer on subsoil	1, 2, 4, 6, 8, 9
4	Subsoiling + lime on subsoil	1, 3, 5, 6, 7, 8
5	Subsoiling + fertilizer and lime on subsoil	1, 2, 4, 6, 8, 9
6	Subsoiling and mole drainage	2, 3, 4, 5, 7, 9
7	Subsoiling and mole drainage + fertilizer on subsoil	1, 2, 4, 6, 8, 9
8	Subsoiling and mole drainage + lime on subsoil	2, 3, 4, 5, 7, 9
9	Subsoiling and mole drainage + lime and fertilizer on subsoil	1, 3, 5, 6, 7, 8

[1] Refer to table 3 for the grouping system.

as described in table 1. In this table also are shown those treatments which occurred in same group with each respective treatment.

For these treatments an International TD-9 Diesel Crawler Tractor, wide-tread model (60-inch width center to center of tracks), 16-inch track shoes; heavy-duty equalizer spring; with extended tracks and track frame, was used. A hydraulic system consisting of pump, valve, tank, and hoses, to operate "International-Universal" tool bar (basic) was directly connected to the tractor. The tool bar floated and was hinged for horizontal movements. On this bar was mounted a heavy-duty standard with subsoil point with a removable mole attached. A fertilizer attachment for subsoil was mounted so as to be motivated by the tractor's power take-off which stopped automatically when the tool bar was in the raised position for turning and transporting the tractor; it started automatically when the tool bar was lowered. The standard was graduated so that the subsoil point would penetrate 30 inches.

In treatments 3, 5, 7, and 9 a 13–3–12 fertilizer was applied to the subsoil at the rate of 1,000 pounds to the acre. In treatments 4, 5, 8, and 9 an application of limestone at the rate of 1,000 pounds to the acre, as indicated by lime-requirement tests, was made at the subsoil breakpoint. Each treatment was replicated nine times. Cane variety POJ 2878, standard for the region, was planted from February 7–21. Two applications of fertilizer were made later to a total of 2,000 pounds to the acre. The first and second surface applications of fertilizer were at only half the rate for plots that received fertilizer at the subsoil as for those that had not previously received this subsoil treatment. Other agronomic practices were conducted as was customary for the region.

During the period from September 17 to October 10, 1951, 8 months after establishing the treatment differentials, infiltration tests were conducted on each plot. Four tests were also conducted on an adjoining plot devoted to pasture which had not been plowed for many years. The buffer-compartment technique as outlined by Nelson and Muckenhirn was used (5). The procedure is as follows:

Three concentric iron rings, each 5 inches in height, and 9, 18, and 27 inches, respectively, in diameter, are driven into the ground 2 or 3 inch surface. The soil inside the two outside rings is kept saturated with water while the test is running. The infiltration test is run in the soil within the inner 9 inch ring, over which hangs a calibrated 2,000 ml. burette, the water reservoir. A volume of 1,043 ml. in this burette is equivalent approximately to one inch of water added to the 9-inch soil core. A pinchcock serves as a valve at the rubber hose that connects the tip of this burette to a small glass tube. The burette is filled with water to the 2,000 ml. mark and is stoppered. The stopcock is opened and the starting time recorded. Water infiltrates rapidly at first, into the soil, until the thin film of water that collects on the top soil touches the end of the small tube. This film serves as a regulator for the water to run from the burette as fast as the soil requires it. The time is recorded every time the burette is emptied to the zero mark. At this time the pinchcock is closed rapidly and the burette is refilled with water. The outfit is kept covered with a canvas.

The tests were run for eight consecutive hours, the quantity of water used every hour being recorded. The results of the eighth-hour run were analyzed statistically according to the design used.

Results and Discussion

The results of the statistical study of the infiltration rate obtained for the eighth hour are presented in tables 2 and 3. Table 2 shows the analysis of the total sum of squared deviations of the infiltration data. The values for *B* and *E* are 198.9 and 126.1 respectively. These values were used in correcting the mean infiltration rates obtained in the field. Table 3 gives the corrected mean infiltration rate of water at the eighth hour for each tillage treatment. The form of presentation facilitates the comparison between treatments to detect their significance.

The mean infiltration rates of all plots where either subsoiling or subsoiling and mole drainage were practiced are significantly higher than that of the check plots. The mean differences between them and the check are significant at the 1-percent level in all cases, excepting differences between

TABLE 2.—*Analysis of total sum of squared deviations of infiltration-rate data from the experimental field in east-central Puerto Rico*

Source of variation	Degrees of freedom		Sum of squares		Mean square
Replications		8		3,681,46	
Component a	12		2,386.40		198.9 = *B*
Component b	6		519.10		
Blocks (eliminating treatments)		18		2,905.50	
Treatments (eliminating blocks)		8		3,015.28	126.1 = *E*
Error (intrablocks)		46		5,800.32	
		80		15,402.56	

TABLE 3.—*Corrected mean infiltration rate of water at the eighth hour in plots undergoing different tillage treatments*

Treatment	1(a)[1]	2(b)	3(c)
Inches of water per hour	5.6	26.7	21.5
Treatment	4(c)	5(a)	6(b)
Inches of water per hour	18.9	23.1	22.4
Treatment	7(b)	8(c)	9(a)
Inches of water per hour	25.3	19.6	23.1

[1] Respective letters in parenthesis refer to the *Z* grouping in the statistical analyses. For other treatments within the same group see table 1.

L.S.D. for treatments within the same group:
at the 5-percent level 11.18
at the 1-percent level 14.91
L.S.D. for treatments not within the same group:
at the 5-percent level 11.77
at the 1-percent level 15.70

treatments 4, 8, and 1, which are significant only at the 5-percent level. No significant differences could be observed between any other treatments.

From the standpoint of water infiltration subsoiling is a very eflective practice in areas of heavy claypan soils. Soils treated in this way, even when saturated, can readily absorb four or five times as much water as soils the claypan layers of which remain undisturbed by ordinary tillage practices. The following tabulation shows the infiltration rate of water at four sites in a pasture plot adjoining the experimental field which had not been disturbed by plowing operations for many years.

Treatment	*Eighth-hour infiltration rate Inches per hour*
Undisturbed	0.70
Do.	1.10
Do.	.02
Do.	.03
Plowed and harrowed 4 times	5.60

For establishing comparisons readily the mean rate of infiltration of the nine control plots is also given. The mean rate at the eighth hour of all four undisturbed sites is only 0.5 inch of water per hour. By ordinary plowing and harrowing only, the infiltration capacity of this soil was increased tenfold. These facts show the effectiveness of the ordinary land-preparation operations.

A rate of infiltration of more than 5 inches per hour is very rapid and should indicate no drainage problems. However, it must be remembered that areas of these soils usually occur in flat lands where large volumes of run-off waters coming from the adjoining hills and mountains must be disposed of quickly. Thus, even with rains of small intensities, large quantities of water collect on low fields which may be very harmful to growing crops unless internal drainage is very good. Subsoiling and subsoiling plus mole drainage assure a very rapid rate of infiltration.

The permeability measurements reported previously indicated a very slow rate of percolation of only 0.19 inches per hour for the tight subsoil layer. This suggests the possibility that most of the water entering the soil of the check plots through the immediate surface, moved laterally after reaching the tight layer, rather than downward in the profile. In the treated plots where the tight layer was disturbed by the subsoil standard, the water probably moved downwards through the disturbed tight layer, thus accounting for the excessively rapid rates of infiltration measured in these plots.

The period during which the various tillage practices will be effective remains yet to be determined. It will be interesting to find out whether the subsurface tillage will remain more effective with passage of time than surface tillage. The indirect effects of subsoil fertilization and liming, through better developed and more extensive root systems, may be measurable in the next few years.

Summary

Data are presented here on the minimum infiltration capacity of a heavy claypan soil under different tillage treatments. The experiment was laid out following a triple lattice design. The mean rate of infiltration at the

eighth hour of an undisturbed pasture plot was 0.5 inches per hour. The minimum infiltration capacity of the check plots which were plowed and harrowed four times was 5.6 inches per hour. This rapid rate of infiltration in the check plots suggests the possibility of lateral flow instead of downward movement of water in the plots where the tight claypan layer was disturbed either by subsoiling or by subsoiling and mole drainage. The plots that received the subsoiling and subsoiling and mole-drainage treat ments had significantly higher rates of infiltration than the control plots.

Resumen

Se presentan datos aquí sobre la capacidad de infiltración de un suelo con un "claypan" sometido a varios tratamientos durante las operaciones de la preparación del terreno. El experimento se estableció siguiendo un diseño de enrejillado triple. La velocidad promedio de la infiltración del agua a la octava hora en un lote dedicado a pasto, donde no se hicieron operaciones de preparación o cultivo, fué de 0.5 de pulgada por hora. La capacidad mínima de infiltración de las parcelas testigo, que se araron y rastrillaron cuatro veces, fué de 5.6 pulgadas de agua por hora. Esta infiltración tan rápida en estas parcelas, se puede explicar, quizás, a base del movimiento lateral del agua en vez de vertical, como en el caso de las parcelas donde se pasó un arado de subsuelo para romper el "claypan" o en las que se estableció un sistema de desagüe subterráneo, además de pasar el arado de subsuelo. En las parcelas donde se pasó el arado de subsuelo y donde se instaló el sistema subterráneo de desagüe, se obtuvieron valores significativamente más altos, para la capacidad de infiltración, que en las parcelas testigo.

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