

Yield response of vegetables to tillage techniques on a Vertisol of the semiarid region of Puerto Rico¹

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ABSTRACT

Three experiments were conducted on a Vertisol of the southwest region of Puerto Rico to evaluate the effects of no-till vs. three different tillage techniques on the yield of corn, pepper, watermelon, eggplant, bean and tomato. Soil treatments consisted of no till (undisturbed), minimum till (chisel plowing), deep till (disk plowing to 45-cm) and conventional till (15-cm depth). Each treated plot was split into two or three subplots where test crops were planted. A positive response to conventional till was observed for pepper, watermelon, bean and tomato. No statistically significant differences were observed when the yields of all crops grown on minimum-till plots were compared with the no-till treatment. This suggests the possibility that corn and eggplant can be planted in no-till soils similar to Santa Isabel clay without reducing yield at least for 1 year. Bean, tomato, watermelon and pepper, however, might require some type of tillage. Nevertheless, the results in general substantiate the view that production costs can be lowered by decreasing tillage input without reducing yield.

INTRODUCTION

Because Puerto Rico has one of the highest population densities of the world and less land in cultivation, it depends on imports for most of its food. Therefore, it is imperative to improve soil management practices in order to maximize productivity and preserve farm land. Tillage practices are among the main factors that not only affect productivity but also enhance soil conservation.

Conservation tillage is a method defined by the Soil Conservation Society of America as "any tillage system that reduces loss of soil or water relative to conventional tillage; often a form of noninversion tillage that retains protective amounts of residue mulch on surface" (13,17). This method is increasingly applied, especially in the United States (19).

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For example, McGregor et al. observed that the annual amount of erosion was reduced from 17.5 t/ha to 1.8 t/ha when no tillage was used on a highly erodible soil of Mississippi (14). In most cases, these conservation practices have resulted in higher yields in the long run. However, studies over the past 30 years in Senegal, a tropical African nation, indicated that plowing increases crop yield on deep sandy and sandy clay soils by improving soil physical conditions and biological activity while promoting root-system development. Yet, other forms of minimum-tillage have produced good results in different ecological zones of West Africa (5).

It is evident, therefore, that there is no single, specific tillage technique that works equally well under all agroecological conditions. The type of land preparation techniques giving optimal results will depend on the interaction of such factors as soil physical properties, crop species and climate. Specific trials for combinations of soil, crop, and other site factors must be conducted in order to develop appropriate tillage strategies.

In Puerto Rico, Abruña et al. (1) and Lugo et al. (10,11,12) demonstrated that the need for tillage practices varies with crops, soils and location. Lugo et al. (10,11,12) obtained a significantly different response to a specific tillage practice for pepper (plots plowed four times at 45-cm depth), and corn and beans, grown simultaneously on the same plots of a San Antón soil (Cumulic Haplustoll). Conversely, Abruña et al., working on an Ultisol in the mountain region of Puerto Rico, reported that tanager planted without tillage yielded as well as with conventional tillage. But Lugo et al. (10) observed a 75% reduction in yield of the same species grown on undisturbed plots (no till) of Coto soil, an Oxisol in northwestern Puerto Rico. Other researchers had recorded similar interactions between soil, crop species, and location with respect to tillage response (3,4,5,7,8,9,15,16,18,19).

This study was conducted to compare the effects of several tillage techniques versus no till on the yield of corn, watermelon, pepper, bean, eggplant and tomato. Each crop species was grown on a Vertisol of the semiarid southwest region of Puerto Rico.

MATERIAL AND METHODS

Tillage strategies were evaluated in a series of experiments established at the Lajas Research Center from 1983 to 1986. The trials were conducted on a Vertisol, series Santa Isabel clay. This soil is a Udic Pellustert of the fine, montmorillinitic, isohyperthermic family. It is located in a semiarid region (750 to 1000-mm rainfall annually), has a CEC of 52 cmol/kg of soil, and a pH ranging from 6.8 to 7.8. The land used for the experiments had lain fallow for at least 2 years before the initial experiment in 1983.

The experimental design for all trials was a split-plot arrangement of a randomized complete block, replicated four times, with land preparation methods assigned to main plots and the test crop species to subplots. Once treated, each main plot (14 × 6 m) was subdivided into 3 subplots (6 × 4 m). The same treated and nontreated plots were used for all three experiments; that is, the no till, minimum till and conventional till plots used for the first experiment (1983-84) were the same for all subsequent experiments. Fertilization and irrigation, as well as pest and disease control, followed the Agricultural Experiment Station recommendations (6).

Yields were measured and recorded. Chemical and physical soil analyses such as pH, cation exchange capacity (CEC), organic matter and nutrients, N, P, K, Ca and Mg were determined according to Black (2). A recording instrument with a core area of 4 mm² was employed for penetrometer resistance measurements for each plot at harvest throughout the study.

The experimental treatments for the first experiment (1983-84) were as follows: 1) No-till; 2) conventional-till (plowed twice at 15-cm depth and 2-week intervals); 3) deep-till (plowed at 45-cm depth); and 4) minimum-till (chiseling at 30-cm depth). Corn, pepper, and watermelon were used as test crops.

For the second and third trials, the deep till treatment was omitted; that is, no till was compared only with minimum and conventional till. Bean, eggplant, and tomato were assigned to the subplots.

In the third experiment (fall of 1985 to the spring of 1986), plots tilled in the second experiment were split in two subplots, one of which was left undisturbed and the other plowed, as in the 1984-85 experiment. Tomato and bean were then planted in half of each sub-plot. The objective was to measure residual effects of the land preparation technique.

RESULTS AND DISCUSSION

Tables 1, 2 and 3 present the results of the three experiments. Table 1 summarizes the results of 1983-84. The statistical analyses reveal no significant differences among tillage practices when corn and watermelon were used as test crops. However, it is evident that watermelon yields increased with tillage input; for example, the plants grown on deep-tillage plots out yielded the no-till ones by a four to one margin. The absence of statistically significant variation was probably due to the typically great variability of flowering, pollination, and fruit decay before harvesting of this crop, which produced large differences among replicates. On the other hand, peppers planted on conventionally- and deep-plowed land yielded from two to three times more than the no till or minimum till treatments. With pepper, the deep till treatment produced the only statistically significant difference among the tillage methods

TABLE 1.—*Corn, pepper and watermelon yields of the 1983-84 experiment as affected by tillage techniques*

Tillage technique	Yield (kg/ha)		
	Corn	Pepper	Watermelon
No till	11,593 a ¹	6,625 a	9,906 a
Minimum till	9,785 a	6,268 a	21,707 a
Conventional till	9,881 a	11,089 a	37,270 a
Deep till	9,985 a	19,006 b	38,583 a

¹Means (of 4 replicates) followed by the same letter do not differ statistically.

tested. The results agree with those obtained by Lugo et al. (11) on a San Antón soil in Puerto Rico's southern region.

Table 2 presents the results of the 1984-85 trials. Significant increases in yields of marketable tomato and bean were obtained with conventional till as compared with no-till. It appears that the observed yield increases were the result of tillage effects on plant population, since the average number of plants on tilled plots was about 50% higher than with no-till; thus a statistically significant difference for plant population was found between the tillage and no-tillage treatments.

The tillage effect on bean and tomato yields was the opposite of that found by Lugo et al. at Fortuna in a Mollisol (San Antón series). They obtained no statistically significant differences among various tillage practices and no tillage (11,12). Eggplant indicated the same trend, that is, yield increased with tillage, but without attaining statistically significant differences.

Contrary to the 1983 trial, a comparison of the tillage treatments by statistical analysis of combined yields demonstrates a significant response to tillage inputs. As expected, there was a highly-significant climate-soil-crop interaction.

Table 3 summarizes the results of the 1985-86 experiment. Conventional tillage, just prior to planting, increased yields of bean and tomato over those of the other treatments tested. However, bean yield increases from conventional till just prior to planting, was the only response of statistical significance. This not only confirms the 1984-85 results, but

TABLE 2.—*Bean, eggplant and tomato yields of the 1984-85 experiment as affected by tillage techniques*

Tillage techniques	Yield kg/ha		
	Bean	Eggplant	Tomato
No till	182 a ¹	5281 a	4108 a
Minimum till	372 ab	8416 a	5400 a
Conventional till	585 b	7950 a	10,777 b

¹Means (of 4 replicates) followed by the same letter do not differ statistically.

TABLE 3.—*Residual effect of the 1984-85 tillage practices as compared to the same land preparation method performed just before planting the 1985-86 tomato and bean crops*

Treatment	Yield (kg/ha) ¹	
	Bean	Tomato
No till	735 a ²	22,024 a
Minimum till (Previous year)	756 a	17,977 a
Minimum till (Before planting)	585 a	19,408 a
Conventional till (previous year)	652 a	27,972 a
Conventional till	1,235 b	29,306 a

¹ Planted on the same plots used for the 1984-85 experiment.

² Mean of 4 replicates followed by the same letter do not differ statistically.

also indicates that the beneficial tillage effect on this particular soil (Santa Isabel clay) declines after 1 year.

With regard to tomato, it appears that this crop is not as sensitive as beans to the declining tillage effect. The differences between the yield on the conventional-till just before planting and the conventional-till a year earlier were quite small (table 3).

As tables 4 and 5 indicate, the soil used for the study reported herein was in excellent physical and chemical condition. This explains in part the absence of significant differences between minimum till, and in most cases no-till, as compared with conventional till. That is, the typically higher mechanical impedance found in no-till soil was less detrimental because of naturally favorable physical properties and higher concentration of available nutrients.

It is therefore evident, that for most vegetable crops grown with minimum- or even no-till techniques in soils similar to Santa Isabel clay, good yields can be expected. Additional studies are needed, however, to cope with weeds, control of insects and diseases, and with more efficient use of fertilizer. The present results corroborate conclusions from a similar study on a Mollisol soil (San Antón series) of the same region of the island (11,12).

TABLE 4.—*Selected chemical analysis of the experimental plots*

Treatments	pH	Chemical analysis ¹				
		P	K	Ca	Mg	Na
No till	6.13	43	270	3884	1892	129
Minimum till	6.02	93	315	3875	1805	127
Conventional till	6.08	38	211	3913	1907	133

¹ Average of four replicates.

TABLE 5.—Resistance to penetration, % aggregates and bulk density of the experimental plots

Treatment	Resistance to penetration depth (cm)			Aggregates	Bulk density
	7.5	15.0	23.0		
		kg/cm		%	mg/m ³
No till	16.4	27.7	30.0	70.8 ¹	1.33
Minimum till	15.7	36.0	29.3	63.0	1.21 ¹
Conventional till	10.6	25.5	30.8	61.4	1.30

¹ Significant difference (5%) over the other two land preparation methods.

RESUMEN

Rendimientos de algunas hortalizas en varios tipos de labranza en un Vertisol de la región semiárida de Puerto Rico

En tres experimentos en un suelo Vertisol de la región suroeste de Puerto Rico para evaluar el efecto de tres tipos de labranza con cosecha sin labranza en cuanto al rendimiento de maíz, pimiento, melón, berenjena, habichuela y tomate. Los tratamientos fueron sin labranza, labranza mínima, labranza convencional y labranza profunda. Todas las parcelas se prepararon de la manera correspondiente, se dividieron en 2 ó 3 subparcelas en las cuales se sembraron los cultivos de prueba.

Hubo una respuesta positiva a la labranza convencional cuando se comparó con la sin labranza en pimiento, melón, habichuela y tomate, pero hubo diferencias estadísticamente significativas al comparar los rendimientos con labranza mínima y los de la sin labranza.

Estas observaciones sugieren la posibilidad de que el maíz y la berenjena puedan sembrarse en suelos similares a los de Santa Isabel sin arar, sin que disminuya la producción. Pimiento, melón, habichuela y tomate pudieran requerir algún tipo de labranza. En general, los resultados tienden a establecer que se pueden reducir los costos de producción invirtiendo menos en la labranza sin que se reduzca la producción.

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