THE EFFECT OF VARIOUS METHODS OF LAND PREPARATION ON SOIL RESISTANCE TO PENETRATION AND YIELD OF CORN (*Zea mays* L.), CASSAVA (*Manihot esculenta* Crantz) AND SWEET POTATO (*Ipomoea batatas* L.) IN ASSOCIATION. II. EFFECT ON YIELD[1] /

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Resumen

La respuesta de maiz, camote y yuca a las varias formas de preparación de suelo fue característica para cada cultivo. En general el rendimiento de maiz respondió negativamente a la humedad del suelo durante el desarrollo del cultivo cuando había un balance hídrico atmosférico positivo grande (lluvia-evaporación de tanque A) y como consecuencia una humedad alta del suelo. La respuesta ocurrió durante los primeros dos meses de crecimiento. El suelo preparado durante la estación seca tuvo una humedad inferior y por lo tanto rendimientos más altos de maíz. Bajo estas condiciones climáticas, la resistencia del suelo no varió lo suficiente para influir significativamente sobre los rendimientos de maiz. El camote respondió durante los primeros dos meses de crecimiento a una discontinuidad de la resistencia en el suelo y no a la resistencia en sí, la cual no varió lo suficiente para afectar los rendimientos. Durante este período hubo una respuesta negativa significativa del rendimiento al cambio máximo positivo de resistencia por 0.1m, el índice de discontinuidad en al capa de 0-0.2m. Durante la época de secamiento antes de la cosecha, hubo una correlación positiva significativa entre la resistencia en la superficie y el rendimiento y esto se atribuye a la reducción en la salida del tubérculo hacia la superficie donde se experimenta insolación y ataques de plagas. La yuca no respondió significativamente a los tratamientos de preparación de suelo y hubo alguna interacción negativa significativa entre los rendimientos de yuca y camote, la cual se considera como producto de la competencia ya que era una siembra en asociación.

Introduction

A previous paper (5) has reported on the effect of various methods of land preparation and cropping systems on a Typic Dystropept of clay loam texture in Turrialba, Costa Rica. The cropping systems were corn (*Zea mays* L.), and cassava (*Manihot esculenta* Crantz) with seet potato (*Ipomoea batatas* L.) in association. This paper reports of the effect of various methods of land preparation and cropping systems on the yield components and their relationship with the induced soil physical properties.

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Materials and methods

With a design of hierarchal classification with 4 replications, 6 methods of land preparation were evaluated, S_1, S_2, S_3, S_4, and S_6 as explained in a previous paper (5) along with 4 sub-treatments of cropping systems CS_1, CS_2, CS_3 and CS_4. Climate, planting procedures and methods of soil physical and chemical analyses have been explained (5).

Corn (CS_3) was planted between 8-15 June, 1975, at a density of 80 000/ha, bending of corn stalks was done between 19 September, 1975 and

10th October, 1975, and reaping between 30 September, 1975 and 30 October, 1975. For each method of soil preparation, corn yields were evaluated. The methods of preparation were as follows, S_1: Preparation with a 60 kW (75hp) D4 Caterpillar track tractor at 0.1m depth, during the dry season; S_2: Preparation with the track tractor at 0.1 m during the wet season; S_3: Preparation with a 50 kW (67 hp) Massey Ferguson tire tractor at 0.1 m during the dry season; S_4: Preparation with the tire tractor at 0.1 m during the wet season; S_5: Preparation with the tract tractor with subsoiler at 0.25 m during the dry season; S_6: No mechanical preparation. Hand weeded and cleaned. Corn yields were evaluated for number of plants/ha, number of ears/plant, grain yield (14% moisture)/plant, and grain yield/ha. Cassava and sweet potato (CS_4) were planted simultaneously between 8-15 June, 1975, at densities of 10 000/ha and 50 000/ha respectively, and reaped on the 8 April, 1976. For each land preparation method the fresh masses of the storage roots of cassava and the sweet potato tuber were determined.

Results and discussion

Table 1 shows the yield components for corn, cassava and sweet potato. In the case of corn S_1, S_3, S_5 and S_6 show significantly creater yields than the other preparation treatments. This response pattern tends to coincide with the gravimetric moisture of these treatments (5, Table 4). The present Table 4 shows high and significant negative correlation coefficients with moisture for grain yield/plant and grain yield/ha during P-1. The general correlation between grain yield/ha for the plots with gravimetric moisture for all depths and sampling periods is –0.08* and represents a dilution of the high correlation obtained in P-1 in Table 4. The general correlations of the adjusted resistance with plants/ha, ears/plant and grain yield/ha are –0.14**, –0.15** and –0.19** respectively. In Table 4 the adjusted resistance has a high negative correlation with grain yield/ha at 0 m depth for P-1.

* Significant at 5% level.

** Significant at 1% level.

Table 1. Averages of yield components for corn, cassava and sweet potato for 6 land preparation methods (S)*

Land Preparation	Corn: Plants/ha (Thousands)	Corn: Ears/Plant	Corn: g Grain/Plant	Corn: kg Grain**/ha
S_1	60.0 ab***	0.82 ab	54.5 a	3 260 a
S_2	62.3 a	0.78 b	27.1 b	1 694 b
S_3	54.3 b	0.87 a	56.2 a	2 999 a
S_4	63.1 a	0.76 b	32.6 b	2 056 b
S_5	58.2 ab	0.80 b	51.7 a	3 021 a
S_6	43.3 c	0.71 c	64.8 a	2 805 a

Land Preparation	Cassava, fresh mass kg/ha	Sweet potato, fresh mass kg/ha
S_1	8 824 a	1 530 b
S_2	8 910 a	6 874 a
S_3	9 083 a	2 597 b
S_4	7 441 a	7 865 a
S_5	7 277 a	6 680 a
S_6	8 992 a	10 195 a

* Preparation methods: S_1 dry soil track tractor, S_2 wet soil track tractor, S_3 dry soil tire tractor, S_4 wet soil tire tractor, S_5 dry soil subsoiled track tractor, S_6 weeding no tillage.

** 14% Moisture

*** Values compared within columns with the same letter are not significantly different at the 5% level (Duncan).

Table 2. Average values of penetration resistance in k Pa (value shown x 10^2) or bars (value alone) for 6 land preparation methods during 2 sampling periods (P), for subtreatment CS_3

Land Preparation	P – 1 (15/Jul 10/Aug/75)	Max + Change per 0.1 m for 0-0.2 m	P – 2 (10/Sept 7/Oct/75)	Max + Change per 0.1 m for 0-0.2 m
Corn (CS_3) at 0 m depth				
S_1	4.7	12.8	10.2	6.0
S_2	9.7	8.2	10.0	7.8
S_3	6.0	8.3	9.2	9.9
S_4	7.3	4.4	12.2	3.5
S_5	6.1	3.0	6.5	2.0
S_6	11.8	7.0	14.6	5.1
0.1 m depth				
S_1	5.6		16.2	
S_2	11.6		12.9	
S_3	14.3		12.2	
S_4	11.7		14.6	
S_5	7.8		8.4	
S_6	18.8		19.8	
0.2 m depth				
S_1	18.4		19.5	
S_2	19.8		20.7	
S_3	18.7		22.1	
S_4	14.9		18.1	
S_5	10.8		9.8	
S_6	19.5		21.1	

* Preparation methods: S_1 dry soil track tractor, S_2 wet soil track tractor, S_3 dry soil tire tractor, S_4 wet soil tire tractor, S_5 dry soil subsoiled track tractor, S_6 weeding no tillage.

The general correlation of resistance with plants/ha is −0.09*. In Table 4 plants/ha negatively correlates (−0.74 significant at 10% level) with resistance at 0.1 m depth during P-1 and this would correspond to the low population density (43 300/ha of S_6 in Table 1 and the higher resistance found 0.1 m and below (Table 2) in that treatment. Adams *et al.* found a similar effect (1). In Table 4 ears/plant negatively correlate highly with resistance at 0 m depth in P-1. The low population density of corn for S_6 was compensated for by the highest yield/plant which resulted in a good yield/ha.

Table 4 suggests that soil conditions during P-1 were more critical for corn yield components that during P-2. The percentage of soil air space between 0-0.1 m, determined by sampling on the 15 December, 1975 after two days of rain, did not significantly correlate with any yield component of corn. The major effect on corn yields in this experiment appears to be soil moisture rather than resistance. The high positive atmospheric water balance which varied between 140 and 313 mm per month during the growing season P-1 and P-2 (5) contributed to the high soil moisture and consequently a relatively small variation in resistance of 4.7-14.6 bars (x 10^2 k Pa) at 0 m, 5.6 - 19.8 bars (x 10^2 k Pa) at 0.1 m, and 9.8 - 22.1 bars (x 10^2 k Pa) at 0.2 m. This weather condition would make soil moisture an important factor to a crop that is sensitive to excess moisture (6). The effect could be intermittent reduced soil air space during rainfall. General surface drainage was good and the minimum water table depth during the rainy season was 0.9 m.

Table 1 shows that S_1 and S_3 gave significantly lower yields of sweet potato than the other treatments. It appears that treatments that left the soil profile with the least discontinuity in resistance between 0-0.2 m during P-1 gave the highest yields. An index of discontinuity is the maximum positive resistance change per 0.1 m between 0-0.2 m, as seen in Table 3. Table 5 indicates a high negative correlation of yield with the maximum positive resistance change, and a high correlation of yield with moisture at 0.2 m, all during P-1. A similar discontinuity effect

Table 3. Average values of penetration resistance in k Pa (value shown x 10^2) or bars (value alone) for 6 land preparation methods during sampling periods (P), for subtreatment CS_4.

Land Preparation	P – 1 (15/Jul-10/Aug/75)	Max + Change*	P – 2 (10/Sept-7/Oct/75)	Max + Change	P – 3 (2-18/Dec/75)	Max + Change	P – 4 (9-25/Mar/76)	Max + Change
	Cassava and sweet potato in association (CS4) 0 m depth							
S_1	7.6	8.0	10.7	2.9	12.4	13.3	29.3	8.9
S_2	8.8	5.6	12.1	9.1	11.3	4.9	36.0	11.6
S_3	8.5	6.3	10.3	5.9	13.2	13.3	36.2	3.1
S_4	9.0	3.3	13.1	7.3	11.5	3.8	45.8	8.0
S_5	7.2	2.3	8.9	2.1	10.4	1.2	38.0	3.3
S_6	10.5	3.6	15.2	4.6	16.0	9.9	43.7	0.7
	0.1 m depth							
S_1	7.7		13.5		9.6		38.2	
S_2	7.8		11.8		13.5		47.5	
S_3	13.4		14.2		12.9		39.3	
S_4	10.9		14.7		14.2		53.8	
S_5	7.3		9.6		11.6		41.3	
S_6	13.9		19.8		25.9		44.4	
	0.2 m depth							
S_1	15.8		13.1		22.9		27.7	
S_2	13.3		20.9		18.4		27.2	
S_3	19.7		20.1		26.2		37.9	
S_4	14.2		22.0		18.0		37.3	
S_5	9.6		11.8		11.5		30.8	
S_6	17.5		21.6		22.5		29.1	

* Maximum + change per 0.1 m for 0-0.2 m.

** Preparation methods: S_1 dry soil track tractor, S_2 wet soil track tractor, S_3 dry soil tire tractor, S_4 wet soil tire tractor, S_5 dry soil subsoiled track tractor, S_6 weeding no tillage.

Table 4. Correlation coefficients for corn of averages of yield components with averages of Gravimetric Moisture percentage (M), Soil Resistance (R), Soil Resistance adjusted to 40% moisture (AR), and Maximum Positive Resistance Change per 0.1 m (MC).

			Plants/ha			
		P – 1			P – 2	
	0 m	0.1 m	0.2 m	0 m	0.1 m	0.2 m
M	0.52	0.24	–0.05	0.41	0.34	0.53
R	–0.56	–0.74	–0.31	–0.50	–0.54	–0.26
AR	0.06	–0.37	–0.24	–0.13	–0.25	–0.10
MC		0.27			–0.08	
			Ears/plant			
	0 m	0.1 m	0.2 m	0 m	0.1 m	0.2 m
M	–0.41	–0.38	–0.39	0.13	–0.40	0.03
R	–0.81 *	–0.46	–0.05	–0.71	–0.57	0.01
AR	–0.41	–0.38	–0.39	–0.38	–0.40	0.03
MC		0.32			0.51	
			g grain/plant			
	0 m	0.1 m	0.2 m	0 m	0.1 m	0.2 m
M	–0.87*	–0.71	–0.54	–0.39	–0.61	–0.26
R	–0.03	0.26	0.06	0.13	0.32	0.02
AR	–0.63	–0.18	–0.26	–0.11	–0.09	–0.04
MC		0.19			0.01	
			kg grain/ha			
	0 m	0.1 m	0.2 m	0 m	0.1 m	0.2 m
M	–0.90*	–0.89*	–0.87*	–0.30	–0.66	0.01
R	–0.49	–0.21	–0.17	–0.24	0.02	–0.20
AR	–0.91*	–0.58	–0.61	–0.31	–0.38	–0.18
MC		0.28			–0.05	

* Significant at 5% level.
** Significant at 1% level

Table 5. Correlation coefficients of averages of yield with averages of Gravimetric Moisture percentage (M), Soil Resistance (R), Soil Resistance adjusted to 40% moisture (AR), and Maximum Positive Change per 0.1 m (MC), for sweet potato.

			kg fresh mass/ha			
Parameters		P – 1			P – 2	
	0 m	0.1 m	0.2 m	0 m	0.1 m	0.2 m
M	0.43	0.67	0.88	–0.09	–0.38	–0.55
R	0.66	0.26	–0.27	0.23	0.40	0.16
AR	0.54	0.50	0.15	0.47	0.23	0.43
MC		–0.80*			0.25	
		P – 3			P – 4	
	0 m	0.1 m	0.2 m	0 m	0.1 m	0.2 m
M	0.67	0.61	0.59	–0.58	–0.07	0.34
R	0.26	0.76	–0.41	0.84*	0.66	–0.10
AR	0.46	0.57	–0.24	0.45	0.54	0.21
MC		–0.58			–0.27	

* Significant at 5% level.
** Significant at 1% level.

on the yield of beans (*Phaseolus vulgaris* L.) was observed by Forsythe and Huertas (4) for soil resistances between 0-10 bars (x 10^2 k Pa). Soil compacted to a uniform value of resistance with depth gave greater yields than soils compacted only in the subsoil. For a wider resistance range of 2-22 bars (x 10_2 k Pa), compaction in the upper layer only had a slight depressing effect on yield. Others have observed a similar type of root behaviour in the field (3, 8).

In the present case of sweet potato, resistance within the range of 7.6 - 19.7 bars (x 10^2 k Pa), did not have a significant effect upon yields, but the discontinuity (maximum positive resistance change) did have a significant effect. It appears that roots of crops with similar behaviour have the ability during initial growth to adapt to certain a value of resistance within a given range, and will continue similar growth as long as the initial value is not exceeded. The percentage of soil air space between 0-0.1 m, did not significantly correlate with sweet potato yields.

Table 5 shows a significant positive correlation of the yield of sweet potato with resistance during P-4. Since P-4 occurs when the soil is drying, the question of the interpretation of resistance for dry soil arises. Studies indicate that soil moisture above the Permanent Wilting Percentage (PWP) does not inhibit the roots' elongation rate capacity (7, 8). As the soil dries out and approaches the PWP, root elongation rate is reduced by the increased soil resistance induced by drying. Once the soil is drier than the PWP all root elongation ceases. Barley (2) has suggested that at the PWP where soil water suction is 15 bars (x 10^2 k Pa) osmoregulation has reached its limit and the root, having lost turgor, can no longer overcome the mechanical resistance of the soil.

Since soil moisture was generally above PWP, one may conclude that root elongation was affected only by increasing resistance and it ceased above values greater than 25-30 bars (x 10^2 k Pa), which is considered limiting. A high correlation of yield with resistance during P-4 may be attributed to soil environmental effects rather than direct soil-plant interaction. A high resistance at O m may have afforded the sweet potato protection against attacks by pests, or reduced the possibility of the tuber being pushed above ground where it would be susceptible to insolation and pest attack such as by *Rhizomatus subcutalus*. Both these effects can reduce yields.

Table 1 shows that the soil preparation treatments had no significant effect on cassava yields. Possibly the tendency towards horizontal growth by the underground reserves makes them less susceptible to soil resistance effects. There was signficant general negative correlation (−0.39**) of the yields of cassava with sweet potato, suggesting an interaction between the crops that were grown in association.

Summary

Response of corn, sweet potato and cassava to soil preparation was characteristic of each crop. Corn yields responded negatively in general to soil moisture during a growing period with a high positive atmospheric water balance and consequently high soil moisture. The response occured during the first 2 months of growth. The soil prepared in the dry season had a lower soil moisture and thus higher corn yields. Under these weather conditions soil resistance did not vary enough to influence corn yields significantly. Sweet potato responded during the first two months of growth to a resistance discontinuity in the soil rather than to resistance per se, which did not vary enough to significantly affect yields. During this period there was a significant negative response of yield to the maximum positive resistance change per 0.1 m, the index of discontinuity in the 0-0.2 m layer. During the drying stage before reaping there was sinificant positive correlation between resistance at the surface and yields, and this is attributed to the reduction of the emergence of the tuber and its consequent exposure to insolation and pest attack. Cassava did not respond significantly to soil preparation treatments, and there was some significant negative interaction between cassava and sweet potato yields, probably due to competition since there were grown in association.

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Reseña de libros

KING, A.B.S., and SAUNDERS, J.L. The invertebrate pests of annual food crops in Central America. Overseas Development Administration. 1984. 166 p.

This book is simply the best thing to happen to entomology in the isthmus since the Biologia Centrali Americani. The 166 pages of concise, carefully researched text is made doubly useful by the inclusion of over 410 well-reproduced, remarkably detailed, full color, close-up photographs of the pests in their natural environment. The inclusion of damage symptoms and natural substrates makes all the difference and the authors should be congratulated for not simply photographing pinned, deformed and discolored specimens.

Chapter 1, which introduces the book, includes a two-page description of Integrated Pest Management which is error-free but so succint that it might best have been left out.

Chapter 2, entitled Key to the More Common Pests of Annual Food Crops, is a beauty. Here, keys are provided for insect pests of 29 different Central American crops. Some keys are comprehensive (eg. maize) while others are preliminary and will need to be enlarged (eg. egg-plant and other horticultural crops of lesser economic importance). In keeping with the practical orientation of the entire book, the keys are divided into sections which deal with each organ (roots, leaves, stems, etc.) and/or phenological stage (seed, seedling, flowering stage, etc.). Characters used will doubtlessly make entomogical systematists cringe, but are very workable and relevant for field-oriented entomologists. Each tentative identification, generally to the generic level, is followed by a number referring the reader to a page in Chapter 3, where a comprehensive, telegraphic description of the pest is provided. Specifically, information is provided on name (English and Spanish), distribution, hosts, life history, description, damage symptoms, pest status, as well as cultural, chemical and biological control. Finally, references are provided. In addition to the 8 insect orders included, the authors provide some information on mites and slugs.

The final chapter is concerned with pesticides and chemical control. While very useful for the moment, there is no doubt that the utility of the preceding chapters will far outlive this one. The categorization of the chemicals by pests group they can effectively control is a useful concept and in the absence of more specific recommendations by national agencies will be helpful over the short term.

Two very easily used and almost entirely error-free indices allow the reader to easily locate discussions of pests and natural enemies. The bibliography contains 192 references.

The text is nicely set, readable, succinct and remarkably free of errors considering that this is a first edition.

Hopefully, the Spanish-language version will be as well done as the English. This book will be useful to anyone with an interest in neotropical entomology. Now, who is going to do a follow-up book on pests of Central American perennial crops?

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NOTA: La versión en español de este libro es distribuida en los países latinoamericanos por el IICA, a través de sus oficinas nacionales.