MINIMUM TILLAGE FOR CASSAVA IN THAILAND

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ABSTRACT

This paper presents the results of four experiments. The first experiment was conducted from 1992 to 1995 on Huay Pong soil series in Rayong province, and studied the effect of land preparation on the cassava yields of Rayong 90 and Rayong 5, comparing various methods. The results indicate that the best land preparation for Rayong 90 was two times plowing using a 3-disk plow followed by 7-disk plow, which gave a yield of 20 t/ha, whereas the use of a 7-disk plow or a 3-disk plow followed by 7-disk plow gave the highest yield of Rayong 5.

The second experiment studied the interaction between land preparation and the incorporation of soil amendments and was conducted in 1999/00 at Rayong Field Crops Research Center. The trial had a split plot design with various land preparation treatments in main plots and soil amendments in sub-plots. The results indicate that land preparation of two times plowing using a 3-disk plow followed by 7-disk plow produced the highest cassava root yield of 36.9 t/ha.

The third experiment is the comparison between no-tillage and conventional tillage, combined with three levels of N (0, 50, 100 kg N/ha) and the effect on the fresh root yield of cassava (cv. Rayong 72). The field trial has been conducted since 2000 on Satuk soil series (fine loamy, siliceous, Oxic Paleustult). Under no-tillage the soil's physical properties were improved compared to conventional tillage. The soil's structural parameters, such as soil porosity and saturated hydraulic conductivity, increased in the no-tillage plot, while soil bulk density decreased compared to conventional tillage. During the first year of the experiment higher yields of fresh cassava roots were obtained in the no-tillage plot. But, in the second year, the two tillage systems had no significant effect on fresh root yield. With respect to N application, yields increased as the N supply increased, but the effect was not statistically significant.

The fourth experiment studied the effect on cassava yields of several land preparation methods, from zero tillage to complete tillage (traditional practice in Thailand). The trials were conducted in 2001/02 and were located in three sites, i.e. Khaw Hin Sorn, Rayong and TTDI. Results indicate that on average the use of a 3-disk plow followed by a 7-disk plow and either contour or up-and-down ridging resulted in the highest yields compared to other treatments. This is probably because the ridging may have helped in the early control of weeds. The soil's physical properties had probably not yet improved as the data represented only the first year results. With respect to varieties, at the Rayong site, cassava yields decreased in the following order: Rayong 5>KU 50>Rayong 72>Rayong 90, whereas at the TTDI site Rayong 90 produced the highest and KU 50 the lowest yields; there were no significant differences among varieties in Khao Hin Sorn.

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INTRODUCTION

In tropical regions, soil ecosystems are often constrained beyond their natural capacity. Consequently, the soils are reduced in productivity and sustainability. The traditional methods of farming in Thailand have resulted in soil quality deterioration as they seldom considered soil improvement. Continuous cultivation at constant depth creates a zone of high compaction in the sub-surface soil. The depth of this zone will depend on the farmer's practices (Spoor, 2000). Thus, soil management will be responsible for important changes in soil quality parameters, particularly those related to soil structure and water movement. Most cassava in Thailand is grown in light- textured soils, which are very susceptible to erosion. In most cases, cassava farmers prepare their land by plowing with a 3-disk plow followed by a 7 disk harrow, which in turn is followed by a ridger. This results in a very loose soil which is free of weeds and easy to plant. It also makes the soil highly susceptible to erosion, while the direct exposure of the soil to sun and rain will cause rapid decomposition of organic matter, leaving many soils almost devoid of organic matter and with very poor structure. Minimum tillage is thought to be a more appropriate technique for these soils. A broad range of minimum tillage systems is used to conserve soil and water, and to enhance and sustain agricultural productivity. No-till is one type of this system whereby crops are sown directly into an untilled seedbed without any primary or secondary tillage. Previous crop residues are left on the surface, and weeds are generally controlled by herbicides. This system is also called "zero-tillage" or "no-tillage" (Lal, 1995). Roth *et al*. (1988) reported that in a Brazilian Oxisol the bulk density at 20-30 cm depth was significantly lower in no-tillage and minimum tillage systems compared with the conventional tillage system. Accordingly, the total porosity was significantly higher in minimum tillage and no-tillage compared with conventional tillage systems. Despite the large amount of information available on no-tillage practices, there is still a lack of information related to the use of these systems in sandy soils on which cassava is generally grown.

The objective of these experiments is to develop "no-tillage" or "minimum tillage" management systems for cassava production, in order to reduce production costs and improve the soil's physical condition.

MATERIALS AND METHODS

Experiment 1. The effect of various land preparation methods on the yields of Rayong 90 and Rayong 5.

The trial was conducted at Rayong Field Crop Research Center, Rayong province, from 1992 to 1995 using Rayong 90 as the test variety. The experimental design was a Randomized Complete Block design with 3 replications. The treatments were as follows: no-tillage, two times with 7-disk plow, one time with 7-disk plow followed by animal ridging, two times plowing with 3-disk plow followed by one time with 7-disk plow, two times of animal ridging, one time of subsoiler followed by 7-disk plow, and one time of cassava harvester followed by 7-disk plow.

The trial was repeated for one more year at Rayong Field Crop Research Center in 1995/96 using Rayong 5 as the test variety. The experimental design was again a Randomized Complete Block design with 3 replications. The treatments were the same as for Rayong 90 above.

Experiment 2. The interaction between various land preparation methods and the use of several soil amendments.

The trial was conducted at the Rayong Field Crop Research Center in 1999/00. The experimental design was a split-plot in RCB with 3 replications. Four land preparation treatments were established in main plots: no-tillage, two times plowing with 7-disk plow followed by ridging, one time with 3-disk plow, and two times plowing using a 3-disk plow followed by 7-disk plow. The sub-plots had the following four soil amendments: control, chemical fertilizer 15-7-18 N-P_2O_5-K_2O at the rate of 312.5 kg/ha, rock phosphate (RP) plus chicken manure at the rate of 6.25 t/ha, and RP + chicken manure + chemical fertilizer. The test variety was Rayong 5. Plants were harvested at 12 months after planting. The fresh root yield and starch content were measured.

Experiment 3. The interaction between two-tillage systems, and three levels of N.

This experiment was established in 2000 at the Japan International Research Center for Agriculture Science (JIRCAS), in Khon Kaen, Thailand. The soil belongs to Satuk series (fine, loamy siliceous, Oxic Paleustults). The experimental design was a split plot in RCB with 4 replications. Main plots comprised of two tillage systems: no-tillage (NT) and conventional tillage (CT). There were three levels of nitrogen application in sub-plots: 0, 50 and 100 kg N/ha. In addition, all plots received 50 kg P_2O_5 and 50 K_2O/ha. Prior to planting cassava, a herbicide was sprayed for weed control in the NT plot. Cassava, cv. Rayong 72, was used as the test crop.

Two undisturbed soil samples were collected at each depth within the profile (0-10, 10-20, 20-30, 30-50 and 50-70 cm) for physical soil analysis before the start of the trial and after the first year harvest. Soil bulk density was determined by the method described by Black (1965). Porosity was calculated using the equation $\varepsilon = 1- \rho b/\rho s$: where ρb is the measured bulk density and ρs is the density of soil particles taken as 2.65 Mg/m^3. This is a generally accepted figure for soil particle size density, as it represents an average figure that is sufficiently exact for the majority of mechanical analyses (Baver *et al*., 1972). Changes in the water profile through the experimental period were measured by pressure plate. The other parameters, i.e. soil saturated hydraulic conductivity, were measured by the method of falling head (Klute, 1986). Soil texture was determined by the pipette method (Gee and Bauder, 1986). For chemical soil analysis, a composite soil sample was collected at the start of the trial at 0-10, 10-20, 20-30, 30-50 and 50-70 cm depth for measuring the pH (1:1 soil:water) , organic matter (Walkley and Black), available P (Bray II) and exchangeable K (NH_4OAc). The data obtained were statistically analyzed using IRRI STAT version 92-1 used in the Thai Department of Agriculture.

Experiment 4. The effect of several land preparation methods, from zero tillage to complete tillage, on cassava yield.

The same experiment was conducted in 2001/02 in 3 sites: in a farmer's field near Rayong Field Crop Research Center, in Huay Pong, Rayong; at Kasetsart University Research Station in Khaw Hin Sorn, Chachoengsao; and at TTDI Research and Training Center in Huay Bong, Nakhon Ratchasima. The experimental design was a split-plot in RCB with 4 replications. The following ten land preparation treatments were established in main plots:

1. no tillage; initial weed control by spraying with Glyphosate
2. tillage by chisel plow, spaced at 50 cm; initial weed control with Glyphosate
3. tillage by subsoiler, spaced at 50 cm; initial weed control with Glyphosate
4. tillage by subsoiler followed by chisel plow, both spaced at 50 cm; initial weed control with Glyphosate
5. tillage by cassava harvester; initial weed control with Glyphosate
6. tillage by one pass of 3-disk plow
7. tillage by subsoiler followed by 3-disk plow
8. tillage by one pass of 3-disk plow, followed by 7-disk plow
9. tillage by one pass of 3 disk-plow, followed by 7-disk plow and contour ridging
10. tillage by one pass of 3-disk plow, followed by 7-disk plow and up-and-down ridging

The following four cassava varieties were planted in subplots: V1 = KU 50; V2 = Rayong 5; V3 = Rayong 72 and V4 = Rayong 90. Stakes were planted at a spacing of 100x80 cm. Chemical fertilizer was applied at the rate of 312 kg/ha of 15-7-21 or 15-15-15 N-P_2O_5-K_2O at one month after planting. The plants were harvested at 10-11 months. Main plots were 10 x 19.2 m and subplots 10 x 4.0 m.

RESULTS AND DISCUSSION

Experiment 1. **Table 1** shows the effect of six land preparation methods on the fresh root yield and starch content of Rayong 90, averaged over three years. The results indicate that the various land preparation methods had a highly significant effect on the fresh root yield of cassava but not on the root starch content. Two times plowing with 3-disk plow followed by one time with 7-disk plow resulted in the highest fresh root yield of 20.43 t/ha, whereas the no-tillage system produced the lowest fresh root yield of 13.63 t/ha. The low yield obtained under no-tillage may be due to the fact that the soil at the start of the experiment might be very compacted from the previous cultivation practices. As such, using a 3-disk plow followed by 7-disk plow loosened the soil and incorporated weeds and crop residues. Adequate loosening of the soil during land preparation will generally improve drainage and soil aeration. Moreover, the soil was very poor in fertility; in particular it had a very low organic matter content. The use of no-tillage systems generally requires an adequate level of soil fertility at the beginning of the trial.

Table 2 shows similar results for Rayong 5. Land preparation by two times plowing with a 7-disk plow, resulted in the highest fresh root yield, but this yield was not significantly different from those obtained using two times of plowing with 3-disk plow followed by 7-disk plow, or using a cassava harvester followed by 7-disk plow, or two times ridging with a cattle-drawn plow. Again, no tillage systems produced the lowest fresh root yield of only 10.66 t/ha.

Experiment 2. In Experiment 2, the results of two years were combined, as neither the fresh root yields nor the starch contents were significantly different between the first and the second year (**Table 3**). Among the various land preparation treatments, the standard practice of using a 3-disk plow followed by 7-disk plow produced the highest fresh root yield of 33.03 t/ha; this was not significantly different from twice plowing with a 7-disk

plow followed by ridging, which resulted in a yield of 28.86 t/ha. The no-tillage treatment produced the lowest yield of 25.54 t/ha, while the roots also had the lowest starch contents. Overall, the land preparation methods tested had a highly significant affect on yield and a significant effect on starch content. Similar results were also reported by Tongglum *et al*. (1992). There were also highly significant differences among soil amendments in terms of fresh root yield. The application of rock phosphate + chicken manure + chemical fertilizer produced the highest fresh root yield of 30.2 t/ha. The control treatment without any of these soil amendments produced the lowest root yield of 22.5 t/ha. There was a highly significant interaction between land preparation methods and soil amendments in terms of root yield, but no interaction in terms of starch content. The starch contents of the roots significantly increased by the various tillage treatments as compared to that of plants growing under the no-tillage system.

Table 1. The effect of various methods of land preparation on the average fresh root yield and root starch content of Rayong 90, planted for three years at Rayong FCRC from 1992/93 to 1994/95.

Land preparation treatments	Fresh root yield (t/ha)	Starch content (%)
No-tillage	13.63 d	26
Two times with 7-disk plow	17.86 b	25
One time with 7-disc plow followed by animal ridging	16.86 bc	26
Two times plowing with 3-disk plow, followed by 7-disk plow	20.43 a	26
Two times of animal ridging	15.22 cd	26
One time of subsoiler followed by 7-disk plow	15.54 cd	25
Cassava harvester followed by 7-disk plow		
F-test	**	NS
cv.(%)	14.32	6.74

Table 2. The effect of various methods of land preparation on the fresh root yield and starch content of Rayong 5 at Rayong FCRC in 1995/96.

Land preparation treatments.	Fresh root yield (t/ha)	Starch content (%)
No-tillage	10.66 c	21.67
Two times with 7-disk plow	19.28 a	21.22
One time with 7-disk plow followed by animal ridging	14.46 bc	22.25
Two times plowing with 3-disk plow, followed by 7-disk plow	16.31 ab	24.27
Two times of animal ridging	16.06 ab	22.80
One time of subsoiler followed by 7-disk plow	13.63	20.29
Cassava harvester followed by 7-disk plow	15.96 ab	22.15
F-test	*	NS
cv. (%)	19.75	9.16

Table 3. The interaction between land preparation and the incorporation of soil amendments on the fresh root yield and starch content of cassava (combined analysis for two years).

	Cassava root yield (t/ha)	Starch content (%)
Year		
1 st year	27.57	24
2 nd year	28.02	26
F-test Year	NS	NS
Land preparations (LP)		
No-tillage	25.54 b	24 b
Two times plowing with 7-disk plow followed by ridging	28.86 a	26 a
One time plowing with 3-disk plow	27.08 b	25 ab
Two times plowing with 3-disk plow followed by 7-disk plow	33.03 a	25 ab
F-test LP	**	*
Soil amendments (SA)		
Control = no amendments	22.50 c	25
Chemical fertilizer 15-7-18 at 312.5 kg/ha	28.59 b	25
Rock phosphate + chicken manure at 6.25 t/ha	26.92 b	25
Rock phosphate + chicken manure + chemical fertilizer	30.20 a	25
F-test SA	**	NS
F-test Year x LP	**	NS
F-test Year x SA	**	**
F-test LP x SA	**	NS
F-test Year x LP x SA	NS	NS

Experiment 3. At the start of the experiment the soil texture was classified as loamy sand with a bulk density of 1.645 Mg/m^3, to a depth of 50 cm. **Table 4** shows the other base measurements taken before the trial. The soil was rather acid with a pH of 4.97, it had a very low organic matter (OM) content of 0.57%, while the available P was adequate and exchangeable K very low. The soil's physical and chemical characteristics indicate that the soil used in this trial was low in fertility and had poor physical properties. **Figure 1** and **2** show that in the surface soil (0-10 cm) the soil porosity was higher and the bulk density was lower than those in the no-tillage (NT) and conventional tillage (CT) plots taken at the end of the two year trial. That is probably a result of soil disturbance by the cultivation of cassava. In the NT plot certain structural parameters improved, such as an increase in soil porosity (**Figure 1**), particularly at the depth below 20 cm, as compared to the CT plot and at the start of the trial. There was also an improvement in soil bulk density; the values in the NT plots at each depth were lower than those in CT plots (**Figure 2**). This could be attributed to the *in situ* mulching of plant residues in the NT plots. Numerous studies have shown that crop residues decrease soil compactibility (Gupta *et al*., 1987; Ohu *et al*., 1985). In addition, in the CT plot the soil was further compacted during the cultivation practice. Another parameter that was improved was the saturated hydraulic conductivity. The results indicate that soil saturated hydraulic conductivity values in the NT plot were higher than those obtained in the CT plot at each depth interval (**Table 5**). Although at this time the

soil saturated hydraulic conductivity in the NT plot was lower than that obtained at the beginning of the experiment, in the long term this value might be improved. Probably, the soil porosity and bulk density were improved and made it possible for soil particles to produce a greater value of soil saturated hydraulic conductivity. In addition, it also could be the influence of *in situ* mulching on soil water content. Unger (1994) pointed out that a major advantage of maintaining crop residues on the surface soil is improved soil water conservation as a result of reduced runoff of surface water and improved soil conditions. Concerning soil water retention, in general, the retained soil water at the beginning of the trial seemed to be lower than those of the CT and NT plots, with the exception of the values from pF0, in particular at 0-20 cm depth (**Figures 3A-3C**). In most cases the water contents in the soil under NT and CT plots were not much different from each other at each soil water potential and depth. That might be as a result of root penetration into the subsoil of the CT and NT plots, leading to the downward movement of water.

Table 4. Soil properties at the start of the land preparation trial conducted at the JIRCAS Research Center in Klon Kaen in 2000/01 (average to 50 cm depth).

pH	4.97
Organic matter (Walkley and Black, 1934)	0.57%
Available P_2O_5 (Bray and Kurtz, 1945)	17.52 cmol(+)/kg
Exchangeable K_2O (Peech *et al*., 1947)	21.12 cmol(+)/kg
Texture (Pipette method)	Loamy sand
Bulk density (Black, 1965)	1.645 Mg/m^3

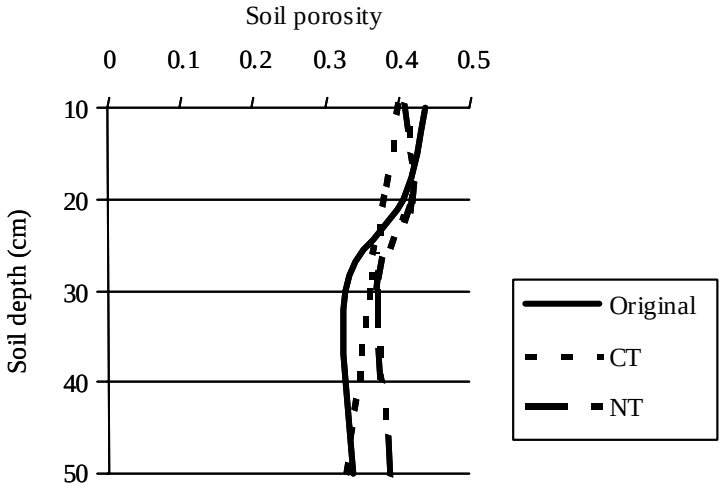

Figure 1. Effect of tillage systems on the soil porosity.

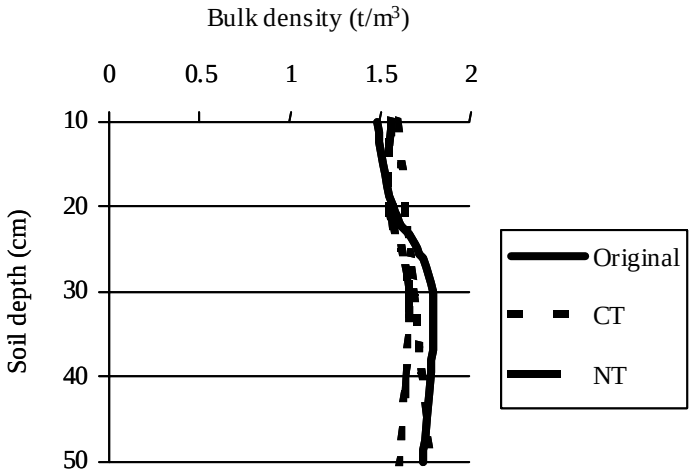

Figure 2. Effect of tillage systems on the soil bulk density (t/m^3)

Table 5. Effect of tillage system on soil saturated hydraulic conductivity compared to the original soil (at the start of the experiment) at four depths at the JIRCAS Center in Khon Kaen, Thailand in 2000/01.

Soil depth (cm)	Soil saturated hydraulic conductivity (Ksat. mm./hr)		
	Original (at start)	CT	NT
0-10	139.68	13.70	20.15
10-20	29.09	10.30	13.91
20-30	2.38	4.28	15.33
30-50	3.61	0.54	1.64

As the results of both years indicate, there were no interactions between the tillage system used and the level of nitrogen application. For the first year (2000/01), the fresh root yield of cassava grown under the no-tillage system was significantly higher (59.38 t/ha) than that of cassava grown using conventional tillage (47.13 t/ha) (**Table 6**). Considering the soil physical properties after the first year harvest, most soil parameters were improved under the no-tillage system. It was also found that the cassava fresh root yield tended to increase as the level of nitrogen application increased. The average yields were 48.94, 50.50 and 60.31 t/ha at the N rates of 0, 50 and 100 kg N/ha, respectively (**Table 6**). In the second year (2001/2002), the two different tillage systems resulted in similar cassava fresh root yields. In the no-tillage plot the average yield was 49.13 t/ha, which was slightly lower than that obtained using conventional tillage 54.00 t/ha (**Table 7**). As in the first year, cassava yields increased consistently but not significantly with increasing levels of N application.

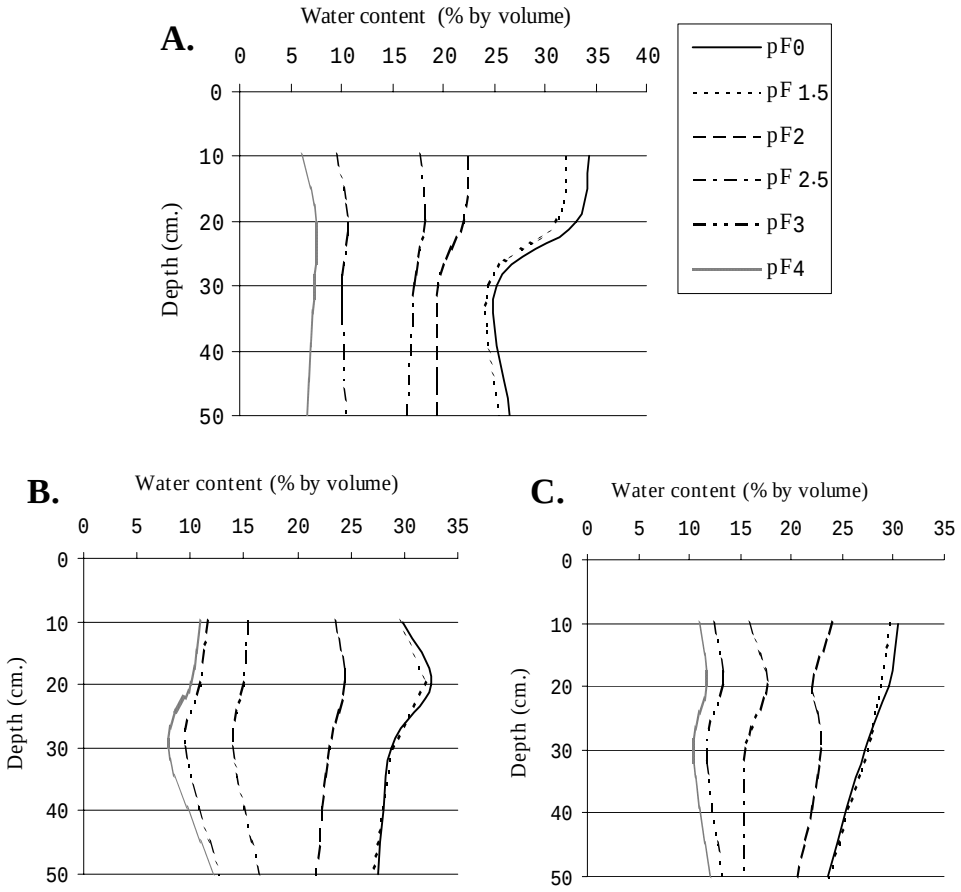

Figure 3. The relationships between soil water content and soil in depth at each soil water potential (pF): (A) the beginning of the trial, (B) under conventional tillage and (C) under no-tillage, in a land preparation trial conducted at the JIRCAS Center in Khon Kaen, Thailand in 2000/01.

Experiment 4. In Experiment 4 there were no interactions between tillage treatments and cassava varieties in terms of fresh root yield and starch content in the three sites of the experiment. In the farmer's field near Huay Pong **(Table 8),** tillage treatments had a significant effect on the fresh root yield of four cassava varieties. Using a 3-disk plow followed by 7-disk plow and up-and-down ridging produced the highest fresh root yields of 19.5 t/ha, while the no-tillage system produced the lowest fresh root yield. Among the reduced tillage treatments (T2-T5) the fresh root yields were not significantly different. Among the four varieties, KU 50 and Rayong 5 had higher yields than Rayong 72 and 90. The yields were rather low due to a very poor soil, severely deficient in Mg (personal communication), and with very low organic matter content, as well as due to lack of rain after planting and initial weed competition. Averaged over four varieties, the highest yield was obtained using a 3-disk plow followed by 7-disk-plow and up-and-down ridging, a

subsoiler followed by 3-disk plow, and 3-disk plow followed by 7-disk plow and contour ridging. Ridging may have helped in early weed control. The lowest fresh root yield in the no-tillage treatment was due to flooding. There were no significant differences among treatments in terms of starch content (**Table 8**).

Table 6. Effect of tillage system and nitrogen application rate in the first year on the fresh root yield of cassava, cv. Rayong 72, grown on Satuk soil series at the JIRCAS Center in Khon Kaen, Thailand in 2000/01.

Chemical fertilizer rate (b)	Fresh root yield (t/ha)		
	Tillage system (a)		
N-P_2O_5-K_2O in kg/ha	CT	NT	**Average**
0-50-50	42.75	55.13	**48.94**
50-50-50	44.94	56.06	**50.50**
100-50-50	53.69	67.00	**60.31**
Average	**47.13**	**59.38**	**53.25**
CV 21%	F (a) *	F(b) NS	F(axb) NS

Table 7. Effect of tillage system and nitrogen application rate in the second year on the fresh root yield of cassava, cv. Rayong 72, grown on Satuk soil series at the JIRCAS Center in Khon Kaen, Thailand in 2001/02.

Chemical fertilizer rate (b)	Fresh root yield (t/ha)		
	Tillage system (a)		
N-P_2O_5-K_2O in kg/ha	CT	NT	**Average**
0-50-50	51.31	42.69	**47.00**
50-50-50	54.81	52.19	**53.50**
100-50-50	55.75	52.44	**54.13**
Average	**54.00**	**49.13**	**51.56**
CV 12.8%	F (a) NS	F(b) NS	F(axb) NS

At the Khaw Hin Sorn site, neither tillage treatments nor cassava varieties had significant effects on the fresh root yield (**Table 9**), but the variety of cassava had a significant effect on root starch content.

At the TTDI site, there were significant differences among tillage treatments with respect to fresh root yield (**Table 10**). Using a subsoiler followed by chisel plow produced the highest fresh root yield of 21.86 t/ha, but this yield was not significantly different from that obtained in the no-tillage treatment. Using various combinations of 3-disk and 7-disk plows produced rather low fresh root yields of about 16-18 t/ha. Among the four varieties tested, Rayong 90 produced the highest yield and KU 50 the lowest.

Table 8. Effect of various tillage treatments on the root yield and starch content of four cassava varieties[1)] planted in a farmer's field in Huay Pong, Rayong, Thailand in 2001/02.

	Cassava root yield (t/ha)					Starch content (%)				
Tillage treatments	V_1	V_2	V_3	V_4	**Av.**	V_1	V_2	V_3	V_4	**Av.**
1. No tillage; Glyphosate	10.72	12.42	12.41	10.29	**11.46c**	20.4	20.7	17.6	22.0	**20.2**
2. Chisel plow; Glyphosate	12.13	13.36	12.58	10.05	**12.03bc**	23.2	20.1	17.3	23.3	**21.0**
3. Subsoiler; Glyphosate	16.82	16.77	9.97	11.25	**13.70bc**	21.3	19.4	15.6	22.5	**19.7**
4. Subsoiler+Chisel; Glyphosate	16.59	16.69	14.42	11.69	**14.85abc**	23.5	20.7	19.3	24.2	**21.9**
5. Cassava harvester; Glyphosate	12.29	19.22	14.48	12.42	**14.60abc**	21.4	18.8	17.2	22.1	**19.9**
6. 3 disk plow	13.29	15.86	14.63	10.62	**13.66bc**	23.1	20.6	19.3	22.3	**21.3**
7. Subsoiler+3 disk plow	16.40	20.08	19.35	14.45	**17.57ab**	22.0	21.2	19.7	21.9	**21.2**
8. 3 disk+7 disk plow	13.41	14.14	10.65	9.51	**11.93bc**	23.2	20.0	17.1	23.8	**21.0**
9. 3 disk+7 disk+contour ridges	21.43	17.14	15.86	15.44	**17.47ab**	20.0	19.7	17.1	22.9	**19.9**
10. 3 disk+7 disk+up/down ridges	19.40	22.92	18.75	16.93	**19.50a**	19.9	18.2	16.6	20.0	**18.7**
Average	**15.27ab**	**16.86a**	**14.31b**	**12.26c**	**14.68**	**21.8a**	**19.9b**	**17.7c**	**22.5a**	**20.5**
CV (%)					27.57					7.7
Tillage treatment (T)					*					NS
Variety (V)					**					**
TxV					NS					NS

[1)] V_1 = KU 50; V_2 = Rayong 5; V_3 = Rayong 72; V_4 = Rayong 90

Table 9. Effect of various tillage treatments on the root yield and starch content of four cassava varieties[1)] planted in a farmer's field in Khaw Hin Sorn, Chachoengsao,Thailand in 2001/02.

	Cassava root yield (t/ha)					Starch content (%)				
Tillage treatments	V_1	V_2	V_3	V_4	**Av.**	V_1	V_2	V_3	V_4	**Av.**
1. No tillage; Glyphosate	23.45	19.53	20.54	22.27	**21.45**	19.8	17.5	13.9	21.2	**18.1**
2. Chisel plow; Glyphosate	18.06	25.10	18.75	20.35	**20.56**	19.7	16.8	14.1	20.8	**17.8**
3. Subsoiler; Glyphosate	22.17	17.14	17.01	20.49	**19.20**	20.9	17.8	14.9	21.6	**18.8**
4. Subsoiler+Chisel; Glyphosate	20.03	19.48	18.89	17.90	**19.07**	20.2	18.3	16.3	23.2	**19.5**
5. Cassava harvester; Glyphosate	20.31	18.89	16.06	18.98	**18.56**	20.3	16.8	14.9	22.6	**18.6**
6. 3 disk plow	20.69	18.49	21.22	14.83	**18.81**	20.1	16.8	14.8	20.9	**18.2**
7. Subsoiler+3 disk plow	23.43	24.57	23.40	27.43	**24.71**	21.6	18.1	14.4	22.3	**19.1**
8. 3 disk+7 disk plow	22.81	23.96	19.13	19.18	**21.27**	20.2	17.5	14.4	22.0	**18.5**
9. 3 disk+7 disk+contour ridges	25.42	23.02	25.90	25.17	**24.88**	21.7	18.6	13.8	21.7	**18.9**
10. 3 disk+7 disk+up/down ridges	21.67	22.57	22.50	26.28	**23.25**	21.3	18.2	13.9	21.6	**18.8**
Average	**21.80**	**21.28**	**20.35**	**21.29**	**21.18**	**20.6b**	**17.6c**	**14.5d**	**21.8a**	**18.6**
CV (%)					14.72					5.65
Tillage treatment (T)					NS					NS
Variety (V)					NS					**
TxV					NS					NS

[1)] V_1 = KU 50; V_2 = Rayong 5; V_3 = Rayong 72; V_4 = Rayong 90

Table 10. Effect of various tillage treatments on the root yield and starch content of four cassava varieties[1)] planted in TTDI, Huay Bong, Nakhon Ratchasima Thailand in 2001/02.

	Cassava root yield (t/ha)					Starch content (%)				
Tillage treatments	V_1	V_2	V_3	V_4	**Av.**	V_1	V_2	V_3	V_4	**Av.**
1. No tillage; Glyphosate	14.14	21.80	19.97	23.72	**19.91ab**	22.0	25.8	25.0	28.3	**25.3**
2. Chisel plow; Glyphosate	15.77	18.11	16.80	20.44	**17.78bc**	21.8	26.0	26.9	25.4	**25.0**
3. Subsoiler; Glyphosate	14.03	16.19	15.16	19.87	**16.31c**	24.3	25.8	25.8	24.9	**25.2**
4. Subsoiler+Chisel; Glyphosate	20.36	20.94	22.21	21.95	**21.86a**	26.1	27.2	26.2	30.4	**27.5**
5. Cassava harvester; Glyphosate	11.74	17.50	17.66	17.42	**16.08c**	25.5	26.1	25.6	27.9	**26.3**
6. 3 disk plow	17.03	20.39	17.45	17.13	**18.00bc**	23.7	25.0	27.2	21.0	**24.2**
7. Subsoiler+3 disk plow	16.95	15.10	19.51	14.82	**16.59bc**	24.0	26.9	27.2	28.6	**26.7**
8. 3 disk+7 disk plow	19.95	15.26	17.37	20.02	**18.15bc**	23.4	26.5	25.3	25.6	**25.2**
9. 3 disk+7 disk+contour ridges	16.09	19.11	17.94	20.15	**18.19bc**	24.9	26.5	24.3	29.3	**26.2**
10. 3 disk+7 disk+up/down ridges	14.75	18.16	17.45	19.71	**17.52bc**	25.5	24.9	27.8	29.4	**26.9**
Average	**16.08a**	**18.46a**	**18.15a**	**19.52a**	**18.05**	**24.1b**	**26.1a**	**26.1a**	**27.1a**	**25.9**
CV (%)					20.67					11.1
Tillage treatment (T)					*					NS
Variety (V)					**					**
TxV					NS					NS

[1)] V_1 = KU 50; V_2 = Rayong 5; V_3 = Rayong 72; V_4 = Rayong 90

CONCLUSIONS

The standard practice of using a 3-disk plow followed by 7-disk plow, with or without ridging generally resulted in the highest fresh root yields. There were no significant interactions between the tillage treatments and cassava varieties in terms of both fresh root yield and root starch content. No-tillage systems generally produced low cassava yields but seemed to have improved the soil's physical conditions as compared to conventional tillage; the porosity and soil saturated hydraulic conductivity increased in the no-tillage plot and the bulk density was reduced. Fresh root yields tended to increase with increasing levels of applied N.

REFERENCES

Baver, L.D., W.H. Gardner and W.R. Gardner. 1972. Soil Physics, 4th Edition. John Wiley and Sons, Inc. , New York. London, Sydney, Toronto. 498 p.

Black, C.A. 1965. Methods of Soil Analysis. Part A. American. Soc. Agronomy Inc., Madison, Wisconsin, USA.

Bray, R.H. and L.T. Kurtz. 1945. Determination of total, organic and available forms of phosphorus in soils. Soil Sci. 59: 39-45.

Gee, G.W. and J. W. Bauder. 1986. Particle size analysis. *In:* A. Klute (Ed.). Method of Soil Analysis, Part I. American Soc. Agronomy, Madison, WI. pp.383-411.

Gupta, S.C., E.C. Schneider, W.E. Larson and A. Hadas. 1987. Influence of corn residue on compression and compaction behaviour of soils. Soil Sci. Soc. Am. J. 51: 207-212.

Klute, A. 1986. Water retention: Laboratory methods. *In*: A. Klute (Ed.). Methods of Soil Analysis, Part I. American Soc. Agronomy, Madison, WI. pp. 635-662.

Lal, R. 1995. Minimum tillage systems. *In*: N.S. Jayawardane and B.A. Stewart (Eds.). Advances in Soil Science. Subsoil Management Techniques. Lewis Publishers, Boca Raton. FL. pp. 1-33.

Ohu, J.O., G.S.V. Raghavan and E. McKeys. 1985. Peatmoss effect on the physical and hydraulic characteristics of compacted soils. Trans. ASAE 28: 420-424.

Peech, M., L. T. Alexander, L. A. Dean and J.F. Leed. 1947. Methods of Soil Analysis for Soil Fertility Investigations. US Dept. Agric. Circular. 757 p.

Roth, C.H., B. Meyer, H.G. Frede and R. Derpsch. 1998. Effect of mulch rates and tillage system on infiltrability and other soil physical properties of an Oxisol in Parana, Brazil. Soil and Tillage Research 11: 81-91.

Spoor, G. 2000. Compaction characteristics of swelling clay subsoils. *In*: R. Horn, J.J.H. van der Akker and J. Arvidsson (Eds.). Subsoil Compaction Distribution, Processes and Consequences. Advances in GeoEcology 32: 427-434.

Tongglum, A., V. Vichukit, S. Jantawat, C. Sittibusaya, C. Tiraporn, S. Sinthuprama and R.H. Howeler. 1992. Recent progress in cassava agronomy research in Thailand. *In:* R.H. Howeler (Ed.). Cassava Breeding, Agronomy and Utilization Research in Asia, Proc. 3rd Regional Cassava Workshop, held in Malang, Indonesia. Oct 22-27, 1990. pp. 199-223.

Unger, P.W. 1994. Residue management - What does the future hold. *In:* P.W. Unger (Ed.). Managing Agricultural Residues. Lewis Publishers, Boca Raton, FL. 464 p.

Walkley, A. and C.A. Black. 1934. An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci. 37: 29-38.