CASSAVA LONG-TERM FERTILITY EXPERIMENTS IN THAILAND

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ABSTRACT

Cassava in Thailand is normally planted on flat or undulating land (0-10% slope), having sandy or sandy loam soils of low fertility. In some areas cassava has been cultivated continuously for more than 50 years; in that case the soil's productivity has steadily declined resulting in a decrease in growth and yield.

In 1975 and 1976, long-term fertility experiments for cassava were initiated in three locations, i.e. at Rayong Field Crops Research Center (clayey, mixed, Typic Paleudult; Huay Pong soil series); at Banmai Samrong Field Crops Experiment Station (fine-loamy, siliceous, Oxic Paleustult; Korat soil series); and at Khon Kaen Field Crops Research Center (fine loamy, siliceous, Oxic Paleustult; Yasothon soil series). The treatments consisted of the application of different combinations of N, P and K, as well as municipal compost, with or without incorporation of cassava stalks (stems and leaves) after each harvest.

The results of 31 years of continuous cassava cropping at Rayong and Banmai Samrong, and 30 years at Khon Kaen show a clear response of cassava to annual fertilizer applications in all three locations. Without fertilizer application, cassava growth and yields decreased, and the soil's fertility status declined, especially in Khon Kaen. The omission of K reduced the growth and yield of cassava more than the omission of either P or N, while the annual incorporation of cassava stalks after harvest resulted in a marked increase in growth and yield. The complete chemical fertilizer application of 100 kg N, 50 P_2O_5 and 100 K_2O per ha, combined with 12.5 t/ha of municipal compost or with about 18 t/ha of incorporated cassava stalks, resulted in better growth and higher cassava root yields than the application of only complete chemical fertilizers; these treatments were able to maintain roots yields of 20-40 t/ha and to maintain or improve the fertility status of the soils. Based on these results, it can be concluded that long-term productivity of cassava can be sustained with the application of adequate N, P and K fertilizers in combination with crop residues or other organic materials.

INTRODUCTION

Thailand is presently among the world's major producers of cassava roots, and is the biggest exporter of cassava products. About 70% of the total cassava production is exported, mainly as pellets, chips and starch (TTTA, 2003). Most cassava in Thailand is grown on coarse textured soils, with sandy clay loam and sandy loam textures and having low fertility (Duangpatra, 1988). These soils have rather unfavorable physical and chemical properties, having a very light texture, low levels of organic matter, low contents of available phosphorus (P) and potassium (K), and low clay content. Moreover, due to their rather poor soil aggregate stability and their frequent occurrence in areas of undulating and rolling topography, soil loss due to erosion by heavy rain can be very severe. And the cultural practices used by almost all cassava farmers is continuous cassava cultivation without fertilizer application or soil erosion control measures. These factors have caused the soil's productivity to steadily decline, resulting in a decrease in cassava growth and yield.

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It has long been recognized that certain nutrient elements are essential for plant growth and normal development. It has also been known that the lack of one or more of the essential elements leads to abnormalities of one sort or another. Lack of one or another of the essential elements in available form in the soil solution may lead to disease symtoms, reduced growth, lower yields and inferior quality products. Moreover, organic materials such as compost, plant biomass and manures can improve soil properties and the soil's biochemical properties, especially in infertile acid soil.

Three cassava long-term fertility experiments were initiated in major cassava growing areas. The main objective of these experiments is to study the effect of chemical fertilizers, compost and the return of cassava crop residue on cassava growth and root yield, and soil fertility status for cultivation in Thailand

MATERIALS AND METHODS

A randomized complete block design of 8 treatments and 4 replications was used. The plot size was 8 x 10 meters and plant spacing was 1 x 1 meter. Stem cuttings of cassava were planted vertically during the early rainy season (May-June) and plants were harvested at about 11 months after planting. Chemical fertilizers were applied at about 1-2 months after planting in moist soil. In one treatment, compost was applied and incorporated before planting. In most treatments cassava stems and leaves were removed from the field after harvest, but in two treatments these tops were left on the plots and incorporated during land preparation. Weeds were controlled by 4-5 times hand weeding during the crop cycle.

Locations and Soils

The same experiment was conducted in three agro-ecological zones of Thailand:

1. Rayong Field Crops Research Center; Huay Pong soil series, sandy clay loam; clayey, mixed, Typic Paleudult, in the eastern seaboard region.
2. Banmai Samrong Field Crops Experiment Station; Korat soil series, sandy loam; fine loamy, siliceous, Oxic Paleustult, in the southwestern part of the northeastern region.
3. Khon Kaen Field Crops Research Center; Yasothon soil series, sandy loam; fine loamy, siliceous, Oxic Paleustult, in the central part of the northeastern region.

Treatments

1. $N_0P_0K_0$
2. $N_1P_0K_0$
3. $N_1P_1K_0$
4. $N_1P_0K_1$
5. $N_1P_1K_1$
6. $N_1P_1K_1$+municipal compost (12.5 t/ha)
7. $N_1P_1K_1$ +tops incorporated
8. $N_0P_0K_0$ +tops incorporated

From 1975 to1998: N_1 = 50 kg N/ha, P_1 = 50 kg P_2O_5/ha and K_1 = 50 kg K_2O/ha
From 1999 to 2005: N_1 = 100 kg N/ha, P_1 = 50 kg P_2O_5/ha and K_1 = 100 kg K_2O/ha.
In two treatments tops were incorporated at 18.75 t/ha after each harvest.

Varieties

From 1975 to 1992 all three trials were planted with the local variety Rayong 1; later Rayong 1 was gradually replaced by the higher yielding new varieties Rayong 90, Rayong 5 and Rayong 72, as indicated in **Table 1.**

Table 1. Cassava varieties planted in the long-term fertilizer trials conducted from 1975 to 2005 in three locations in Thailand.

Variety	Rayong FCRC	Banmai Samrong	Khon Kaen FCRC
Rayong 1	1975-1992	1975-1995	1976-1996
Rayong 90	1993-1995		
Rayong 5	1996-2005	1996-2005	1997-1999
Rayong 72			2000-2005

Duration

The two experiments in Rayong and Banmai Samrong were initiated in 1975 and the one in Khon Kaen in 1976; they have been replanted in the same plots with the same treatments every year until the present.

RESULT AND DISCUSSION

1. Effect on Cassava Yields

The results of 31 years of continuous cassava cropping in Rayong and Banmai Samrong and 30 years in Khon Kaen show a clear response of cassava to annual fertilizer applications in all three soils.

In the two soil series of Yasothon and Huay Pong in Khon Kaen and Rayong, respectively, the growth and root yields of cassava decreased rapidly during the first 10-15 years of cassava cultivation in the treatments without any chemical fertilizer or in treatments without K; thereafter, the yields remained low in Khon Kaen, but improved slightly in Rayong (**Figure 1** to **3**). The growth and yield of cassava cultivated in Korat soil series in Banmai Samrong did not show a major response to fertilizer application, but yields varied from year to year due to fluctuations in rainfall. The application of NK and NPK fertilizers resulted in better growth and higher cassava root yields than the application of N or NP fertilizers without K, in a similar fashion in all three soil series. Hence, potassium appeared to be the most limiting nutrient, followed by nitrogen.

The application of complete chemical fertilizers of N, P and K with an additional 12.5 t/ha of municipal compost, or with about 18.75 t/ha of incorporated cassava stalks (stems and leaves), resulted in the best growth and highest cassava root yields of 30-50 t/ha; this is considerably higher than the yield of 20-30 t/ha obtained with only complete chemical fertilizers (**Figures 1** to **3**). The continuous application of compost or cassava stalks over many years improved the soil nutrient status resulting in higher yields. Yields obtained after 1993-1996 may also have increased due to the use of new higher-yielding varieties (**Table 1**).

Both with and without chemical fertilizer application, the incorporating of cassava stalks at about 18.75 t/ha resulted in better growth and higher yields than when these crop residues were removed from the field (**Figures 1 to 3**).

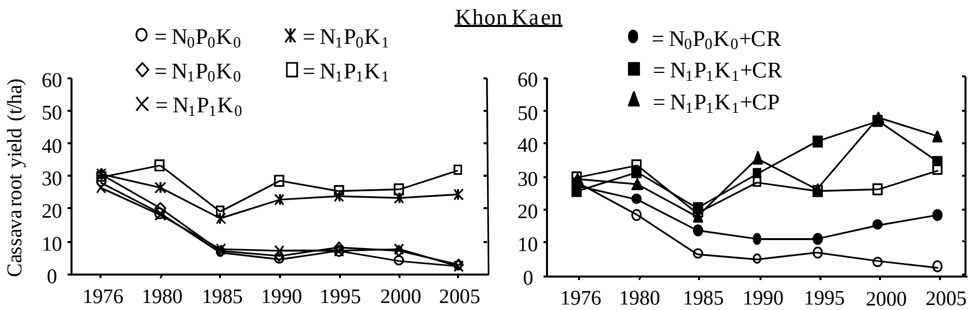

Figure 1. Effect of annual application of fertilizers and compost (CP), and crop residue (CR) management on cassava root yields during 30 consecutive crops grown in Khon Kaen.

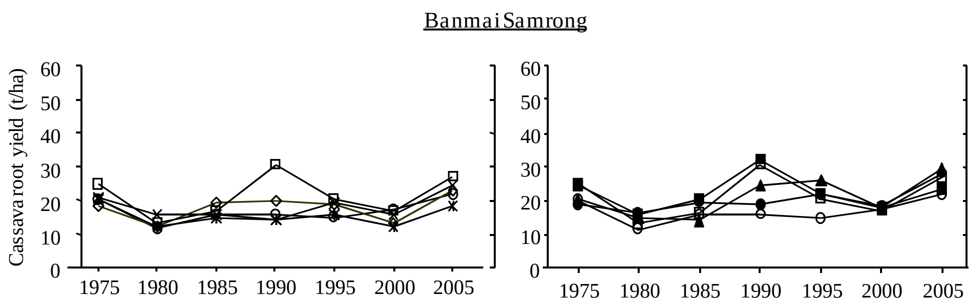

Figure 2. Effect of annual applications of fertilizers and compost (CP), and crop residue (CR) management on cassava root yields during 31 consecutive crops grown in Banmai Samrong.

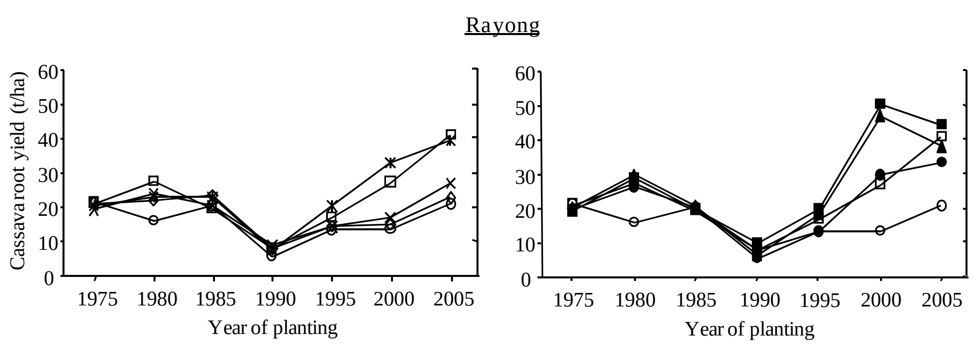

Figure 3. Effect of annual application of fertilizers and compost (CP), and crop residue (CR) management on cassava root yields during 31 consecutive crops grown in Rayong.

The average starch yield of cassava grown in all three sites were significantly higher in the treatments of complete chemical fertilizers combined with 12.5 t/ha of compost or with 18.75 t/ha of incorporated cassava stalks, than in that of the complete chemical fertilizer alone (**Table 2**). This is partly due to the higher root yields obtained in those two treatments but also due to the higher starch contents of the roots. The three treatments without K application and with crop residues removed had the lowest root starch contents and starch yields in all three soil series indicating the importance of K application for obtaining high yields and high starch contents. In contrast, application of N alone tended to decrease the starch contents and starch yields, while P application had little benefial effect (**Table 2**).

Table 2. Effect of annual applications of various combinations of N, P, K and municipal compost as well as cassava crop residue management on the average fresh root yield, starch content and starch yield during the last five years (2001-2005) in long-term (>30 years) fertilizer trials conducted in three locations in Thailand.

Fertilizer treatments[1)]	Root yield (t/ha)	Starch content (%)	Starch yield (t/ha)
Khon Kaen			
$N_0P_0K_0$	4.81	14.3	0.69
$N_1P_0K_0$	4.06	10.8	0.44
$N_1P_1K_0$	4.12	10.7	0.44
$N_1P_0K_1$	30.31	16.3	4.94
$N_1P_1K_1$	33.12	16.6	5.50
$N_1P_1K_1$ + CP	47.62	20.2	9.62
$N_1P_1K_1$ + CR	43.25	18.6	8.06
$N_0P_0K_0$ + CR	19.62	15.0	2.94
Banmai Samrong			
$N_0P_0K_0$	18.56	23.9	4.44
$N_1P_0K_0$	18.44	21.0	3.88
$N_1P_1K_0$	22.19	22.3	4.94
$N_1P_0K_1$	20.12	23.6	4.75
$N_1P_1K_1$	24.00	24.0	5.75
$N_1P_1K_1$ + CP	26.94	24.8	6.69
$N_1P_1K_1$ + CR	25.38	23.8	6.06
$N_0P_0K_0$ + CR	23.75	24.5	5.81
Rayong			
$N_0P_0K_0$	12.69	23.2	2.94
$N_1P_0K_0$	15.25	19.3	2.94
$N_1P_1K_0$	17.88	19.2	3.44
$N_1P_0K_1$	30.00	22.7	6.81
$N_1P_1K_1$	29.88	21.4	6.38
$N_1P_1K_1$ + CP	31.94	24.1	7.69
$N_1P_1K_1$ + CR	38.81	22.0	7.44
$N_0P_0K_0$ + CR	22.56	22.7	5.12

[1)] N_1 = 100 kg N/ha as urea; P_1 = 50 kg P_2O_5/ha as TSP; K_1 = 100 kg K_2O/ha KCl
CP = 12.5 t/ha of municipal compost
CR = cassava stems+leaves incorporated in soil before next planting; in all other treatments CR are removed every year.

2. Effects on Soil Fertility Status

There were significant changes in many soil properties after continuous cultivation of cassava in infertile acid soil, such as in pH, organic matter content, plant nutrient availability and biological activity in the soils. The results of soil analysis indicate that the Yasothon soil in Khon Kaen had a much lower soil fertility status than the Huay Pong soil in Rayong and the Korat soil in Banmai Samrong.

In spite of this, with adequate fertilization, cassava yields tended to be higher in the Yasothon and Huay Pong soils than in the more fertile Korat soil; in the latter, cassava yields may have been depressed by severe Zn deficiency in these high-pH calcareous soils.

The pH of the Yasothon soil decreased from 5.2 to 4.0-4.5 in the treatment of no chemical fertilizer and the treatments of different combinations of N, P and K fertilizers; and slightly decreased in the treatment of incorporating cassava stalks after each harvest. The treatment of combining complete fertilizers with compost increased the pH to about 7.0 in the 10th to 30th year (**Figure 4**). Similar results were obtained in Huay Pong soils with an initial pH of 4.8 which increased to 6.3 with application of compost (**Figure 6**). Also, the initial pH of 6.7 of the Korat soil slightly decreased initially in all treatments with and without chemical fertilizer application but later increased again (**Figure 5**). The application of complete chemical fertilizers with compost or with cassava residues incorporated, and that of cassava residues alone, slightly raised the pH value to 7.0-7.2.

Under regular field crop cultivation, the soil organic matter (OM) content in tropical regions usually declines leading to a reduction in soil pH. The results from all three experiments on continues cassava cultivation indicate that without organic materials incorporated, the soil OM content decreased more in Yasothon soils than in Korat and Huay Pong soils (**Figures 7** to **9**). However, the application of the combination of complete chemical fertilizers with 12.5 t/ha of compost maintained the soil OM content. There was a trend of a slight increase in soil OM content when 18.75 t/ha of cassava residues were incorporated.

With the application of phosphate fertilizer, and even more so with the addition of compost or cassava residues, soil P increased significantly in all soil series (**Figures 10** to **12**).

The exchangeable soil K content increased significantly in the Yasothon and Huay Pong soils (**Figures 13** to **15**). In the Korat soil, however, the soil K content declined over the years from the very high initial value of 198 ppm to less than 100 ppm, without K application and to 130-145 ppm with K fertilizer application. The soil K level was always higher with K than without K application and much higher with the addition of compost. Crop residue incorporation tended to increase the exchangeable-K level of the soil, but this was not consistent.

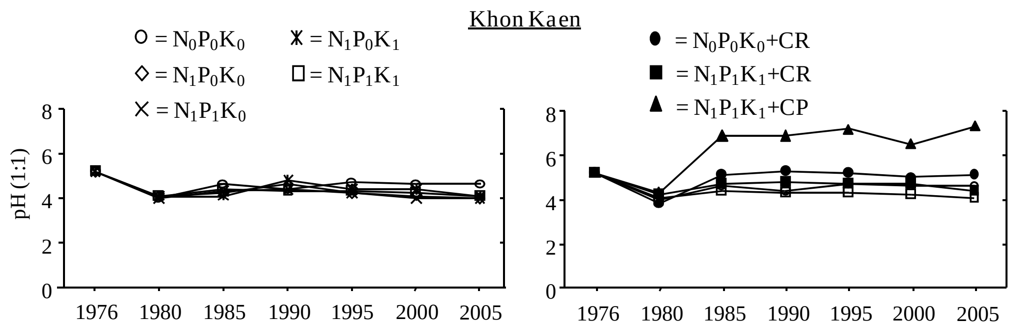

Figure 4. Effect of annual application of fertilizers and compost (CP) ,and crop residue (CR) management on soil pH in Khon Kaen during 1976-2005.

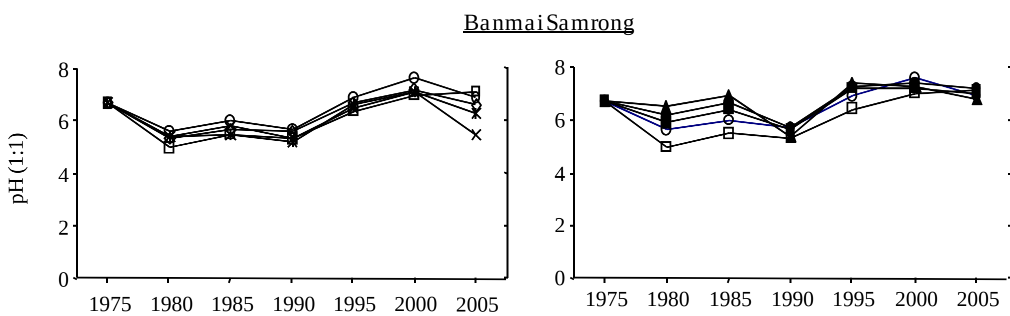

Figure 5. Effect of annual application of fertilizers and compost (CP), and crop residue (CR) management on soil pH in Banmai Samrong during 1975-2005.

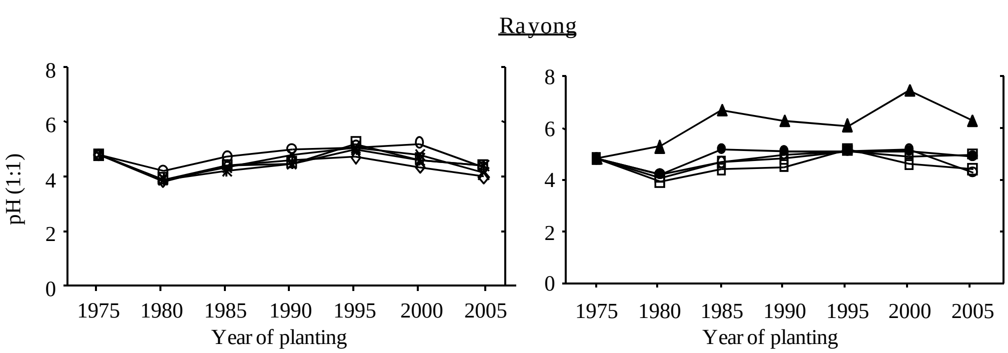

Figure 6. Effect of annual application of fertilizers and compost (CP), and crop residue (CR) management on soil pH in Rayong during 1975-2005.

Khon Kaen

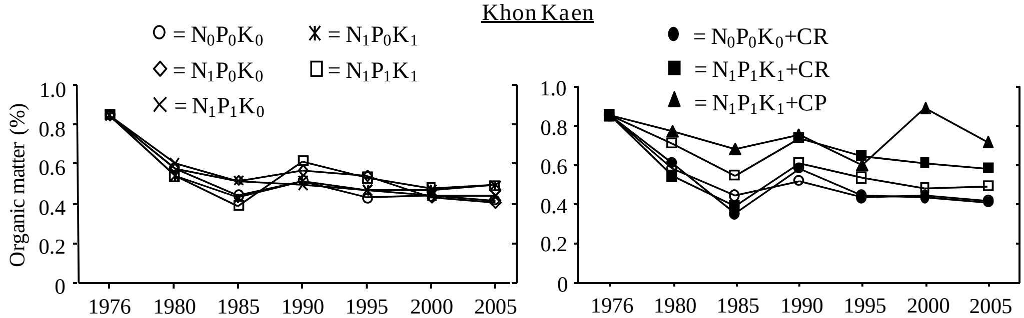

Figure 7. Effect of annual application of fertilizers and compost (CP) ,and crop residue (CR) management on soil organic matter in Khon Kaen during 1976-2005.

Banmai Samrong

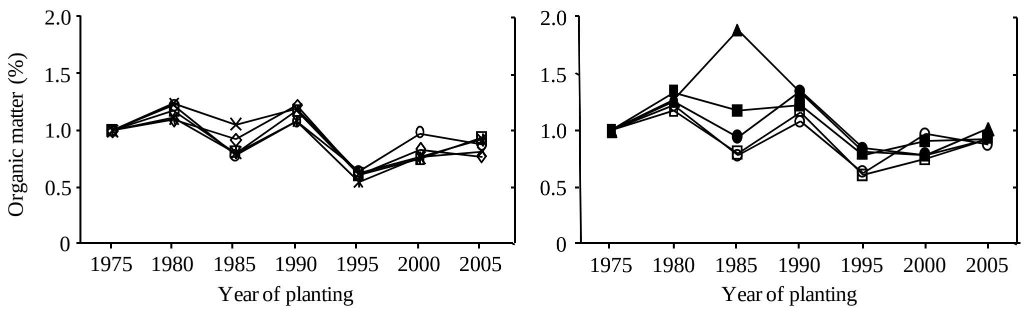

Figure 8. Effect of annual application of fertilizers and compost (CP), and crop residue (CR) management on soil organic matter in Banmai Samrong during 1975-2005.

Rayong

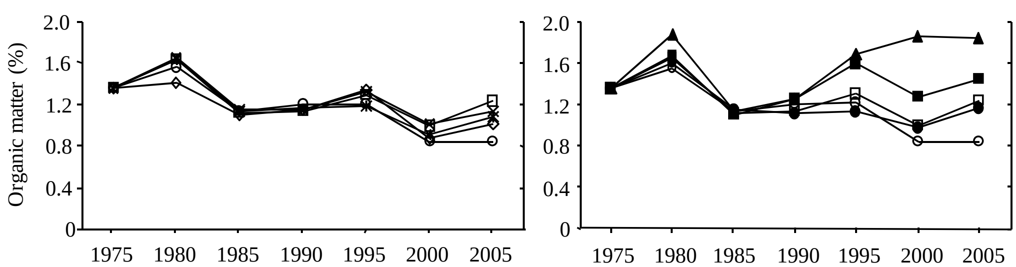

Figure 9. Effect of annual application of fertilizers and compost (CP), and crop residue (CR) management on soil organic matter in Rayong during 1975-2005.

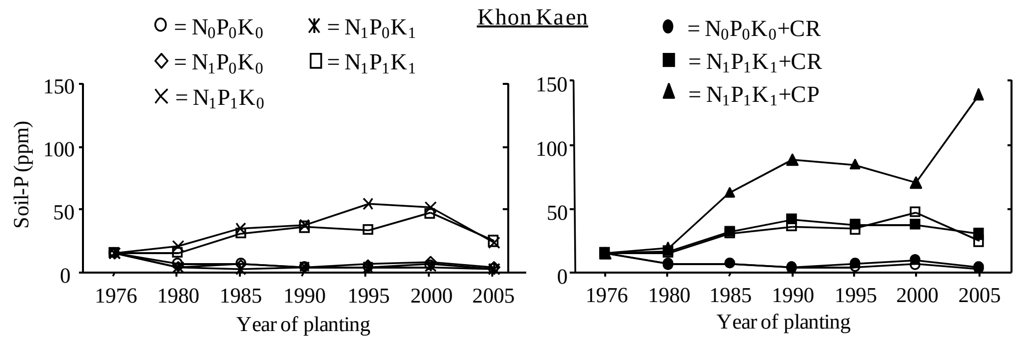

Figure 10. Effect of annual application of fertilizers and compost (CP), and crop residue (CR) management on soil-P in Khon Kaen during 1976-2005.

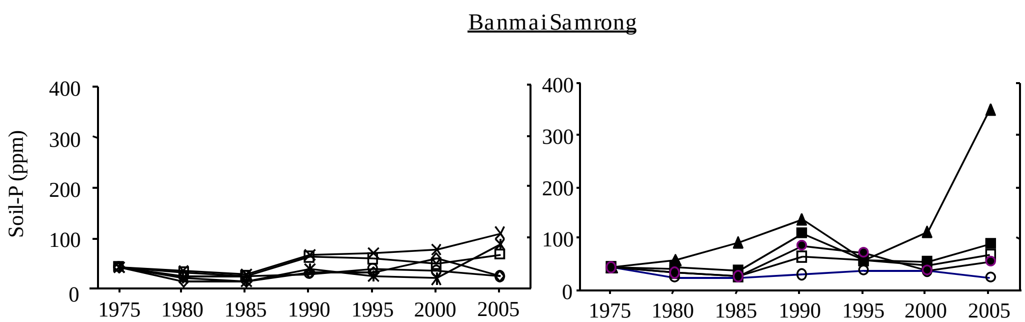

Figure 11. Effect of annual application of fertilizers and compost (CP), and crop residue (CR) management on soil-P in Banmai Samrong during 1975-2005.

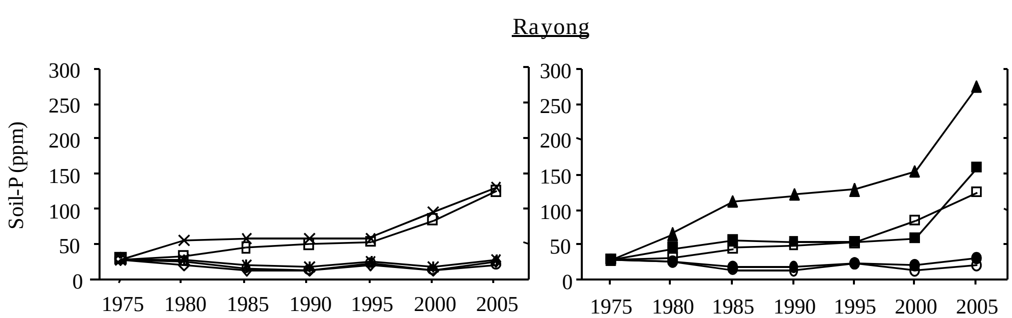

Figure 12. Effect of annual application of fertilizers and compost (CP), and crop residue (CR) management on soil-P in Rayong during 1975-2005.

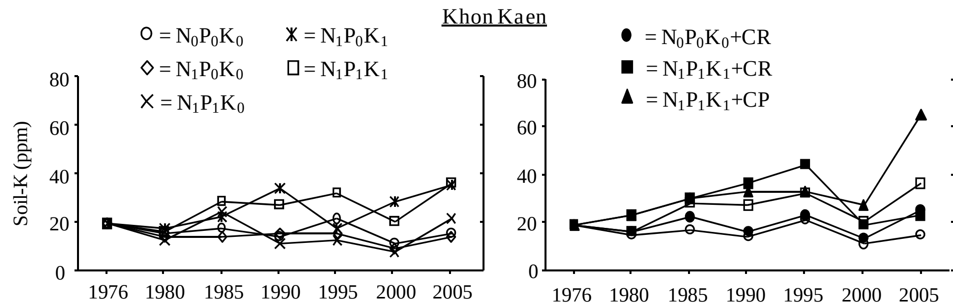

Figure 13. Effect of annual application of fertilizers and compost (CP), and crop residue (CR) management on soil-K in Khon Kaen during 1976-2005.

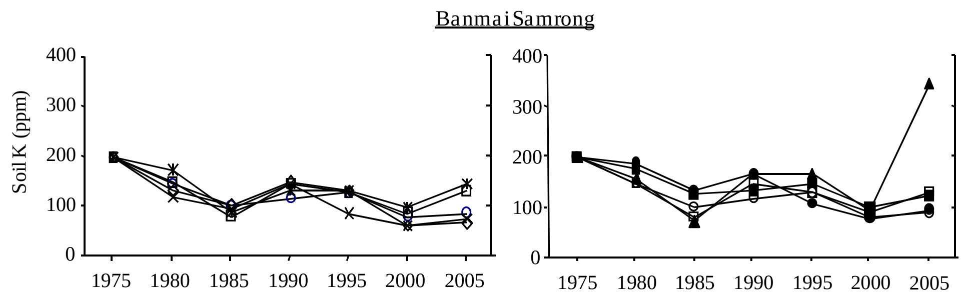

Figure 14. Effect of annual application of fertilizers and compost (CP), and crop residue (CR) management on soil-K in Banmai Samrong during 1975-2005.

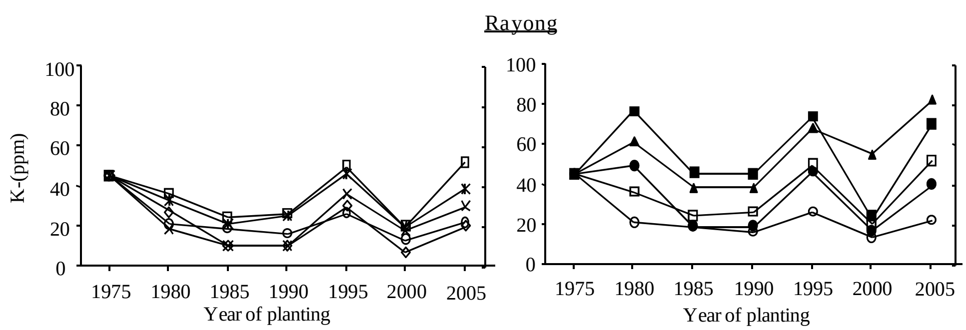

Figure 15. Effect of annual application fertilizers and compost (CP), and crop residue (CR) management on soil-K in Rayong during 1975-2005.

CONCLUSIONS

1. Without fertilizer application, cassava growth and yield, as well as the soil fertility status declined very markedly over the years as a result of continuous cassava cultivation.
2. With the optimum chemical fertilizer application of 100 kg N, 50 P_2O_5 and 100 K_2O/ha, cassava yields could be maintained or increased during 30 years of continuous cassava cultivation on all three soils.
3. To sustain long-term cassava production, 100 kg N, 50 P_2O_5 and 100 K_2O/ha combined with 18 t/ha of cassava tops incorporated after each harvest, or combined with 12 t/ha of compost is recommended.
4. When P or K were applied every year, these two nutrients tended to accumulate in the soil, resulting in a steady increase in available P and exchangeable K.
5. The annual chemical fertilizer application for cassava of 100 kg N, 50 P_2O_5 and 100 K_2O/ha, combined with 18 t/ha. of cassava tops incorporated after each harvest, or combined with 12 t/ha of compost, improved the fertility status of the soils, even after 30 years of continuous cropping.

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