SOIL FERTILITY IMPROVEMENT THROUGH MANURES AND CROPPING SYSTEMS AND THE EFFECT ON CASSAVA PRODUCTIVITY IN THAILAND

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ABSTRACT

Cassava (*Manihot esculenta* Crantz), is a widely grown field crop in Thailand. In 2000, the cassava planted area was 1.18 million ha, with a total fresh root production of 19.06 million tonnes, having a value of 20,387 million baht after processing into various export products. Over 80% of the soils in the cassava growing area have a sandy or coarse texture with a high rate of leaching; these are naturally infertile soils. However, these infertile soils are becoming even further degraded due to their undulating to rolling topography, an erratic distribution of rainfall, the slow rate of establishment of cassava after planting, and the use of improper cultural practices, which may lead to severe soil erosion. One long-term fertilizer experiment conducted in Khon Kaen indicated that the yield of cassava without any fertilizer application decreased drastically from 27 t/ha in the first year to 8 and 3 t/ha after 12 and 25 years of continuous cropping, respectively.

To improve the sustainability and increase the productivity of cassava, chemical fertilizers and/or manures should be applied. It was found that the root yield of cassava increased between 30 and 119%, and between 13 and 125%, with the application of adequate amounts of chemical fertilizers and animal manures, receptively. Moreover, the annual application of well-balanced NPK fertilizers tended to maintain the level of root yield, whereas, fertilizer application with incorporation of cassava crop residues (stems and leaves) after harvest, tended to gradually increase the yields in the long-run. In addition, including appropriate leguminous crops in the cassava cropping system, either as green manures or as rotation crops, was shown to contribute to an increase in cassava yields. Many long-term experiments have shown that cassava yields declined under continuous monocropping without application of fertilizers or manure, but could be maintained at a fairly high level when adequate amounts of N and K were applied. However, after the first 3-4 cycles of crop rotation, cassava yields gradually increased in subsequent years. Also, these cropping systems resulted in higher net incomes from the leguminous crops, especially when cassava prices were unstable, which is often the case. In addition, the application of adequate fertilizers and manures, the incorporation of crop residues and proper crop and soil management could maintain and even improve the fertility of the soil.

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is widely grown in Thailand, especially in the Northeastern region, which accounts for more than 60% of the total planted area in the country. However, the soil in the cassava growing area is highly infertile, has a sandy or coarse texture, a low buffer capacity, and is characterized by excessive leaching. Besides, many soils become degraded due to an undulating to rolling topography, an erratic distribution of rainfall, and improper practices of crop cultivation; these factors ultimately lead to a reduction in yield potential. Moreover, because of high soil losses caused by erosion, especially at the early growth stage of the crops, there are significant losses of soil nutrients and a reduction in nutrient use efficiency in this region. Making improvements in soil productivity, as done in some small-scale farmers' holdings, revealed that agronomic

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practices such as application of animal manures, the incorporation of green manure crops and cropping system management using leguminous crops, such as sun hemp (*Crotalaria juncea*), pigeonpea (*Cajanus cajan*), cowpea (*Vigna unguiculata*), sword bean (*Canavalia ensiformis*) and verano pasture (*Stylosanthes hamata* cv. *Verano*) could substantially increase cassava yields.

This paper describes some ways to improve soil fertility through fertilizers or manures, and through various cropping systems, and their effect on cassava productivity.

The Effects of Chemical Fertilizer Application and Crop Residue Incorporation

Two long-term cassava experiments, now completing 22 and 25 years, have been conducted on Yasothon infertile sandy soils at Khon Kaen Field Crops Research Center (FCRC). Wongwiwatchai *et al*. (2001) and Nakaviroj *et al*. (2002) reported that annual application of fertilizer at the rate of 50-50-50 kg/ha of N-P_2O_5-K_2O, could maintain cassava yields in the long run, whereas without fertilizers yields decreased drastically year by year (**Figure 1**). Moreover, combining chemical fertilizer application with the incorporation of stems and leaves of cassava after each harvest resulted in a gradual increase in root yields considerably above that obtained with chemical fertilizers alone (**Figure 2**).

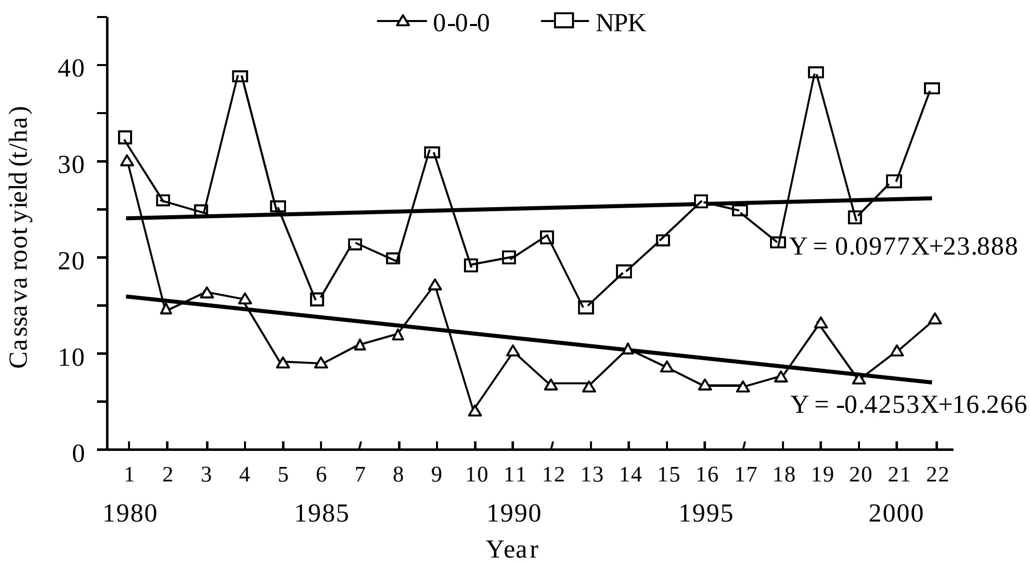

Figure 1. Effect of annual application of chemical fertilizers on the fresh root yield of cassava during 22 consecutive years of cropping at Khon Kaen FCRC from 1980 to 2001.
Note: NPK = 50 kg N+50 kg P_2O_5+50 kg K_2O/ha
***Source:** Wongwiwatchai et al., 2001.*

The Effect of Animal Manures Application

The main purpose of the application of animal manures is to improve the soil's organic matter (OM) content, which results in the release of greater amounts of plant nutrients, a lower bulk density and an increase in buffer capacity of the soil. **Table 1** shows the effect of various rates of animal manure application on the fresh root yield of cassava. In Sakon Nakhon, Chompoonukulrat *et al*. (1996) applied various rates of cattle manure to a cassava field, whereas chicken manure was used by Rammachat *et al*. (2001) in Maha Sarakham. Both manures significantly increased cassava root yields, especially the combination of chemical fertilizer and chicken manure. Moreover, Kokram *et al*. (2002) reported that in Ubon Ratchathani the application of chicken manure mixed with rice husk in the ratio of 1:1 markedly increased the fresh root yield of cassava as compared to the application of chemical fertilizer and the control treatments (**Table 2**).

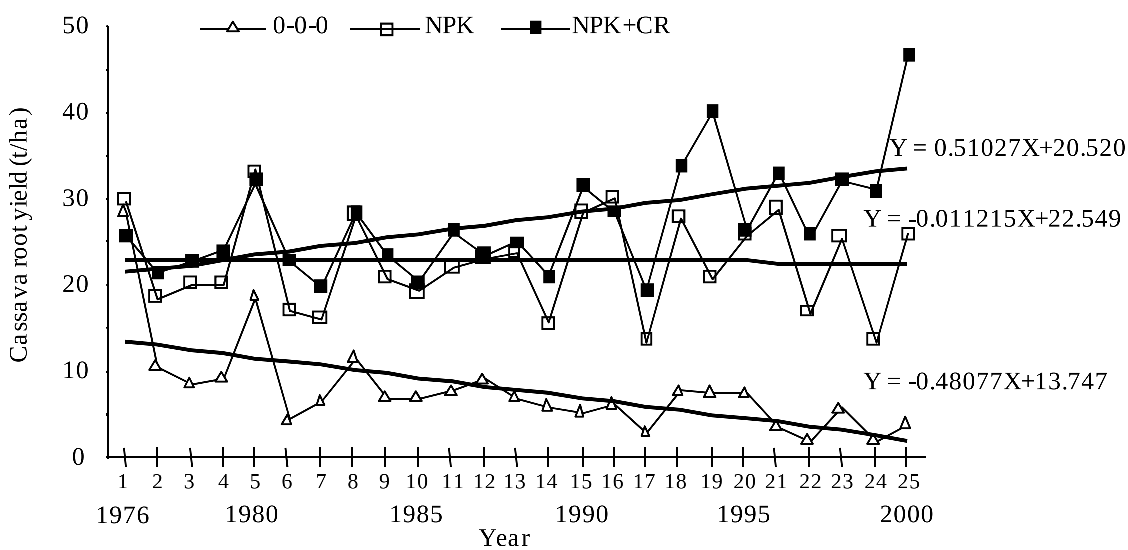

Figure 2. Effect of annual applications of chemical fertilizer, with or without incorporation of cassava stems and leaves, on the fresh root yield of cassava during 25 consecutive years of cropping at Khon Kaen FCRC from 1976 to 2001.
Note: NPK = 50 kg N+50 kg P_2O_5+50 kg K_2O/ha; CR = cassava crop residues incorporated
Source: *Nakaviroj et al., 2002.*

Table 1. Effect of cattle and chicken manure application with or without chemical fertilizers on the fresh root yield of cassava (t/ha) in Sakon Nakhon province[1)] (1996) and in Maha Sarakham province[2)] (average over 3 years, 1999-2001), respectively.

Manure rate (t/ha)	Cattle manure (SN)[1)]		Chicken manure (MS)[2)]		
	-CF	+CF[3)]	-CF	+CF[3)]	**Av.**
0	17.6	-	26.7	48.7	**37.7**
3.12	-	-	48.1	52.6	**50.3**
6.25	21.9	-	53.1	58.4	**55.7**
12.50	23.4	-	-	-	**-**

[1)] Sakon Nakhon (Chompoonukulrat *et al.*, 1996)
[2)] Maha Sarakham (Rammachat *et al.*, 2001)
[3)] +CF application of chemical fertilizer at the rate of 47-47-47 kg N-P_2O_5-K_2O/ha.

Table 2. Effect of the application of chicken manure and chemical fertilizer on the fresh root yield of cassava (t/ha) in Ubon Rachathani province.

Treatments	2000	2001	Av.
Control	14.0	11.6	**12.9**
47-47-47 kg N-P_2O_5-K_2O/ha	28.3	17.8	**23.0**
5 t/ha chicken manure mixed with rice husk (1:1)	31.1	26.2	**28.6**

Source : *Kokram et al., 2002.*

Effect of Green Manures (GM) on Cassava Yields and the Nutrients in the GM residues

Leguminous crops are widely used as green manures for improving the productivity of the soil. Paisancharoen *et al.* (1990) conducted a 5-year (1985-1989) experiment at Khon Kaen Land Development Experiment Station, and found that cowpea was the most promising green manure crop, followed by *Crotalaria* and pigeon pea, for improving the soil and increasing cassava yields, as shown in **Table 3**. This is due to the vigorous early growth of cowpea, which leads to a high amount of biomass being produced within two months before planting cassava. Furthermore, cowpea had a high nutrient content, especially nitrogen and cations such as potassium which is very important for cassava root production. In addition, Jantarak *et al*. (2001) reported that in Maha Sarakham province, the combination of green manure (cowpea) and chemical fertilizers increased the fresh cassava root yields beyond that obtained with chemical fertilizer or the control treatment (**Table 4**).

Table 3. Effect of three green manures on cassava fresh root yields (a), on the biomass of the green manures (b), and on the nutrients in those green manures (c) during five consecutive years (1985-1989) of cassava cultivation in Yasothorn soil in Khon Kaen province.

(a) Fresh root yield (t/ha).

Treatments[1)]	1985	1986	1987	1988	1989	Av.
Cowpea	10.2	13.3	16.2	19.1	14.6	**14.7**
Pigeonpea	5.4	12.9	14.2	13.3	14.2	**12.0**
Crotalaria	5.9	13.4	14.9	17.2	15.2	**13.3**
Control	4.4	14.0	14.1	12.4	14.0	**11.8**

(b) Fresh biomass of leguminous crops (t/ha).

Treatments	1985	1986	1987	1988	1989	Av.
Cowpea	17.9	21.2	10.8	25.8	14.6	**18.1**
Pigeonpea	1.8	10.9	2.7	5.2	4.8	**5.1**
Crotalaria	4.1	18.3	3.2	12.8	13.1	**10.3**

(c) Amount of fresh biomass of leguminous crops at 60 DAP and the amount of nutrients in the biomass in 1986.

Treatments	Fresh biomass (t/ha)	N	P_2O_5	K_2O	Ca	Mg
		(kg/ha)				
Cowpea	21.2	148.8	40.6	194.4	55.6	33.1
Pigeonpea	10.9	103.8	16.9	50.0	22.5	11.3
Crotalaria	18.3	114.4	21.3	56.9	41.9	34.4

1) Leguminous crops incorporated at 60 days after sowing and before planting cassava.

Source: *Paisancharoen et al., 1990.*

Table 4. Effect of incorporation of cowpea green manure and the application of chemical fertilizers on the fresh root yield of cassava (t/ha) during four consecutive years (1998-2001) of cropping in Maha Sarakham province.

Treatments	1998	1999	2000	2001	**Av.**
Control	31.2	23.0	15.0	16.0	**21.3**
Chemical fertilizer[1)]	27.0	28.0	23.0	23.0	**25.2**
Green manure[2)] + chem. fertilizer[1)]	31.0	31.0	31.0	31.0	**30.7**

[1)] Chemical fertilizer at the rate of 47-47-47 kg N-P_2O_5-K_2O/ha.
[2)] Green manure (cowpea) incorporated at 2 months and before growing cassava.
Source: *Jantarak et al., 2001.*

Kokram *et al.* (1996a) conducted an experiment in infertile sandy soils of Warin soil series at Ubon Ratchatani FCRC using verano (*Stylosanthes hamata*) as a living mulch in cassava during 1993-1995. The reported that a living ground cover of verano had a negative effect on the root yield of cassava, even though verano was cut back twice during the cassava growth cycle (**Table 5**). The negative response was due to the severe competition between the two crops.

Table 5. Effect of a living mulch of verano (*Stylosanthes hamata*) on the fresh root yield (t/ha) of cassava during three consecutive years of cropping at Ubon Ratchathani FCRC, from 1993 to 1995.

Treatments	1993	1994	1995	**Av.**
Control	22.4	21.0	22.9	**22.1**
Verano (mowed)[1)]	15.7	20.0	22.6	**19.4**
Verano	10.7	13.5	17.5	**13.9**

[1)] 2 cuttings
Source: *Kokram et al., 1996a.*

Effect of Various Cropping Systems on Cassava Yields and Soil Productivity

A study on the effect of cropping systems on soil productivity for cassava cultivation was conducted using either intercropping or a crop rotation with leguminous crops. Paisancharoen *et al*. (1997) conducted a long-term cassava experiment for nine years (1987-1995) in Khon Kaen FCRC using cowpea and sword bean as intercrops. Intercropping treatments were either without fertilizers (**Figure 3**) or with chemical fertilizer application (**Figure 4**). During the first four years (1987-1990) the intercrops were planted at the same time as cassava; in that case monocropping of cassava resulted in higher root yields than intercropping with cowpea or sword bean. During the following 5-year period (1991-1995) the intercrops were planted 2-3 weeks after cassava; in this case monocropping of cassava resulted in the lowest root yields. With fertilizer application the same relative cassava yield trends were observed, but the absolute yields were much higher than without the application of fertilizers.

Similarly, Kokram *et al*. (1996b) reported the results of a cassava/cowpea trial conducted for four consecutive years (1993-1996) at Ubon Rachathani FCRC, using different sowing dates of cowpea in relation to cassava as the treatments. On average, the root yields of cassava were higher in all intercropping treatments than in monocropping. Planting the intercropped cowpea at 30 days after cassava tended to produce the highest cassava yields (**Table 6**).

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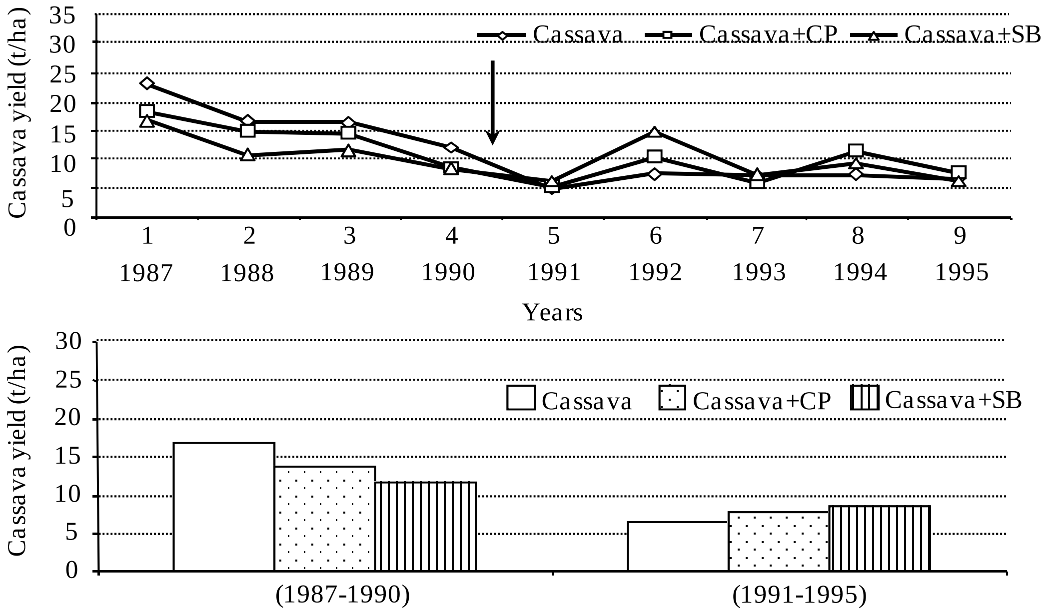

Figure 3. Effect of cassava intercropping with cowpea (CP) or sword bean (SB) on the fresh root yield of cassava during nine consecutive years of cropping without chemical fertilizer application in Khon Kaen FCRC from 1987 to 1995.
Source: *Paisancharoen et al., 1997.*

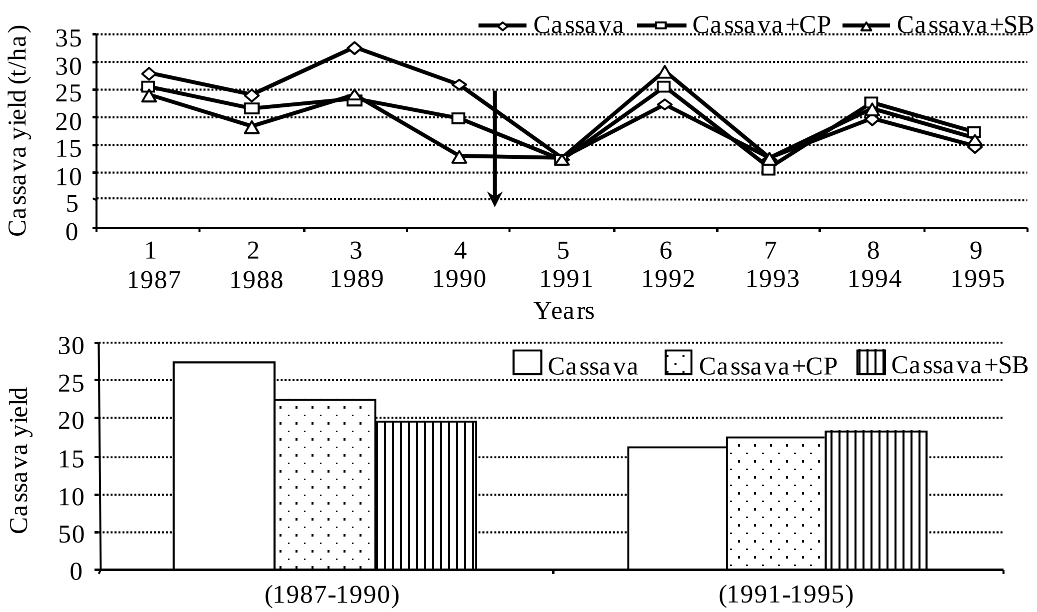

Figure 4. Effect of cassava intercropping with cowpea (CP) or sword bean (SB) on the fresh root yield of cassava during nine consecutive years of cropping with application of 47-47-47 kg/ha of N-P_2O_5-K_2O in Khon Kaen FCRC from 1987 to 1995.
Source: *Paisancharoen et al., 1997.*

Table 6. Effect of the relative time of planting cowpea as an intercrop in cassava on the fresh root yield of cassava (t/ha) during four consecutive years of cropping at Ubon Ratchathani FCRC, from 1993-1996.

Treatments	1993	1994	1995	1996	**Av.**
Cassava monoculture	29.7	17.5	25.5	19.5	**23.1**
Cassava+cowpea (planted at the same time as cassava)	26.5	20.9	28.2	26.9	**25.6**
Cassava+cowpea (planted at 30 days after cassava planting)	32.9	28.3	31.9	25.8	**29.7**
Cassava+cowpea (planted at 60 days after cassava planting)	24.7	22.8	30.9	25.9	**26.1**

Source: *Kokram et al., 1996b.*

Wongwiwatchai *et al*. (2001) reported the results of a long-term experiment on various cropping systems of cassava conducted since 1980 at Khon Kaen FCRC. Treatments consisted of two combination factors of cropping systems and soil improvements. There were three cropping systems: A. continuous cassava monocropping; B. intercropping with groundnut, *Arachis hypogaea*; and C. a crop rotation with cassava alternated yearly with groundnut followed by pigeon pea in the same year; and four methods of soil improvement : 1. control; 2. chemical fertilizer (CF); 3. soil amendment (SM); and 4. CF+SM. Chemical fertilizer applied for cassava was 50 kg N +50 kg P_2O_5 + 50 kg K_2O/ha., whereas, groundnut, grown in the rotation system was fertilized with 19 kg N + 57 kg P_2O_5 + 32 kg K_2O/ha; pigeon pea grown immediately after the harvest of groundnut did not receive fertilizers. The crop residues of all crops were incorporated into the soil before the next planting. The soil amendments (1.25 t/ha of lime, 1.25 t/ha of phosphate rock and 12.5 t/ha of compost) were applied before cassava growing, only on the first, the fifth and the ninth year of the experiment. **Figure 5** indicates that the root yields of cassava, averaged over four soil improvement methods, gradually increased over time in the crop rotation system, whereas in the other two systems yields tended to decrease, especially in the intercropping system.

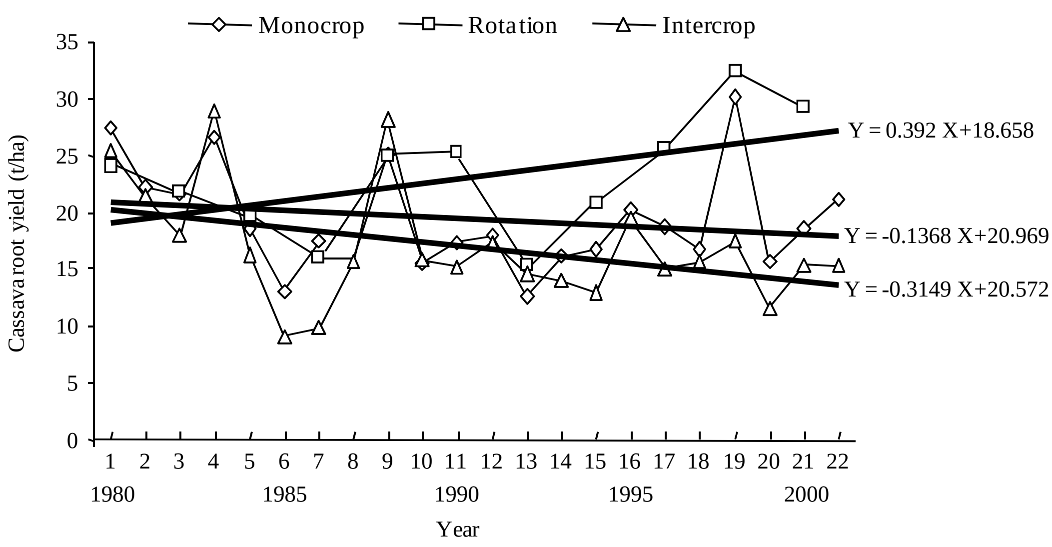

Figure 5. The effect of crop rotation and intercropping with leguminous species on the fresh cassava root yield during 22 years of continuous cropping at Khon Kaen FCRC, Khon Kaen, Thailand from 1980 to 2001.
Source: *Wongwiwatchai et al., 2001.*

Nutrient Management for Sustaining High Cassava Yields

In order to sustain the production of cassava, plant nutrients in the soil should be well managed. A nutrient balance analysis of different cropping systems of cassava was carried out by Paisancharoen *et al*. (2002) in farmers' fields in Khon Kaen, Maha Sarakham and Kalasin provinces. There were five experimental sites in each province. **Figure 6** shows that the most limiting nutrient for cassava was potassium, followed by nitrogen and phosphorus. The analysis, averaged over sites in each province, also revealed that for K the balance was negative in all three provinces, both in monocropping and intercropping systems. This indicates that K removal in the root harvest was greater than the K input in fertilizers or manures; as such, soil K was being depleted. For nitrogen, in the monocropping system inputs and outputs were more or less in balance, whereas in the intercropping system the inputs exceeded outputs leading to a positive balance. However, in case of phosphorus, both cropping systems had a highly positive balance indicating that P inputs far exceeded its removal. In monocropped cassava rather large amounts of nutrients were removed, especially potassium. In contrast, in the intercropping system there was a positive balance of N and P due to the incorporation of crop residues.

CONCLUSIONS

Many researchers have investigated how to improve the management of the infertile soils in the northeast of Thailand, in order to increase soil productivity and make cassava production more sustainable. The results can be summarized as follow:

1. Chemical fertilizers and organic fertilizers such as animal manures and compost, can be directly applied to cassava to increase and maintain high yields. The optimum rates and the N-P-K balance, as well as the best time of application depend on the fertility status of the soil.
2. The planting and incorporation of leguminous crops as green manures before planting cassava is a viable alternative for the farmer. Green manures may supply N and recycle P and K, and improve the soil physical conditions.
3. The choice of cropping system is also very important in soil management. Some research results indicate that intercropping maintains the soil's productivity better than monocropping. Crop rotations, also tended to increase cassava yields in the long-run. Monocropping of cassava, without incorporating crop residues from leguminous crops, could lead to soil degradation. Incorporation of the leaves and stems of cassava after each harvest will also contribute to the maintenance of soil productivity.

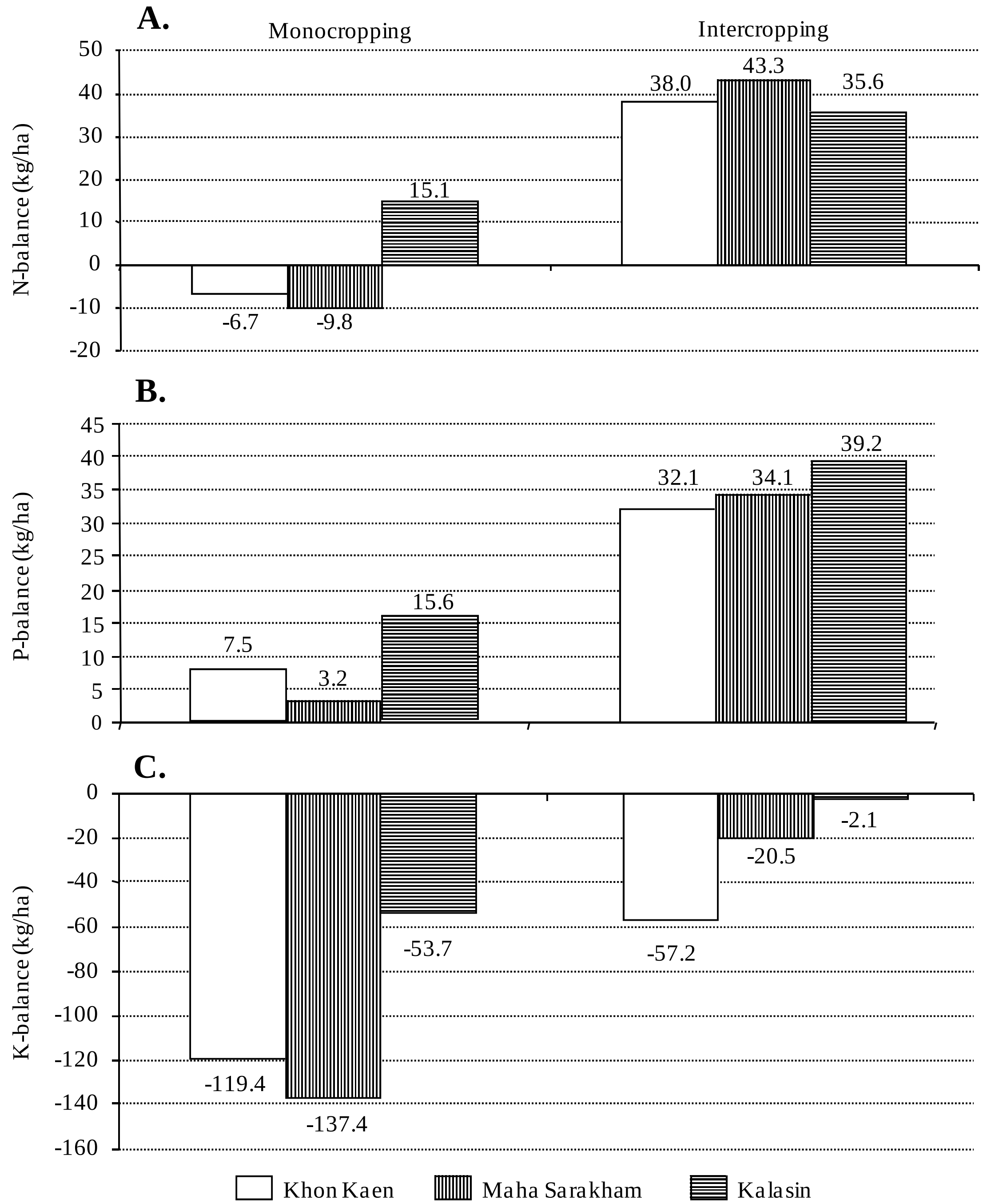

Figure 6. N, P and K balance for monocropped and intercropped cassava cultivation at three locations in northeastern Thailand in 1997/98: (A) Nitrogen; (B) Phosphorus; and (C) Potassium.
Source: *Paisancharoen et al., 2002.*

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