CASSAVA AGRONOMY RESEARCH AND ADOPTION OF IMPROVED PRACTICES IN INDONESIA – MAJOR ACHIEVEMENTS DURING THE PAST 20 YEARS

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ABSTRACT

In Indonesia, annual growth rates for cassava production and yield from 1961 to 2000 were 0.81% and 1.35%, respectively. However, the harvested area decreased at an average annual rate of 0.61%. The average yield of about 12 tonnes of fresh roots/ha is much below the potential yield of 20 to 40 t/ha obtained in experiments, indicating that cassava yields could be further increased by the adoption of improved practices.

Soil preparation using minimum tillage reduced erosion effectively and had no significant effect on root yield compared to that of complete tillage, but the control of weeds was much more difficult. Therefore, most cassava farmers prepare the soil using complete tillage. The quality of planting material used influences the final population and yield. Cuttings of 15-25 cm length planted vertically is used by most farmers even though no significant differences in sprouting capacity and root yield were observed compared to shorter cuttings of 2 to 3 nodes. It means that reducing the stake length from 25 cm to 2 nodes is a way to get more high-quality cuttings when planting material is limited. Maintaining only two stems per plant, as farmers do, produced good planting material and high root yields. Cassava planting time is affected by the cropping system, soil type and water availability. Planting cassava on medium to light textured soils could be done from the beginning to the end of the rainy season without any significant effect on root yield when plants were harvested at 8 to 12 months, since water availability of 35 to 60 mm/10 days could be maintained during the first five months.

Intercropping of cassava can result in a decrease in root yield, but this is generally compensated by the yield of the interplanted crops; therefore, intercropping cassava did not affect total crop value. Most farmers plant intercropped cassava in the early rainy season, whereas monoculture cassava is planted from the early rainy season to the early dry season, especially in areas surrounding cassava factories and near big cities. Plant spacing of cassava was determined by soil fertility, plant type, cropping system and expected yield. The optimum plant population for monoculture cassava using non- or late-branching varieties on poor and better soils are 12,000-14,000 and 10,000 plants/ha, respectively. The best plant population of branching varieties under monoculture on both poor and better soils is 10,000 plants/ha. For monoculture, farmers often use a plant spacing of 100-125 cm between rows and 75-100 cm in the row, while for intercropped cassava they plant at 200-300 cm between rows and 50-75 cm in the row. Intercropping systems of cassava with upland rice and other secondary food crops increased LER to 1.59, increased net income 15%, reduced soil erosion 20% and resulted in a B/C ratio of about 2.80. Therefore, an intercropping system of cassava + maize + upland rice or grain legumes followed by grain legumes is often practiced by farmers which have limited land and capital.

The soil fertility of cassava production areas is rather low; therefore, annual fertilization to increase soil fertility and crop productivity is generally needed. A recommended fertilization to produce 25-35 t/ha of fresh roots for monocropped cassava is 60 kg N+40 P_2O_5+60 K_2O/ha, while that for intercropping systems to produce 20-30 t/ha fresh roots, 2 t/ha dry grain of maize and rice as well as 1 t/ha of legumes is 180 kg N + 90 P_2O_5 + 180 K_2O/ha. When fertilizers were not applied

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annually, cassava yields of 25 t/ha during the first year decreased to 5 t/ha in the 8th year. Applying organic matter annually or every two years could maintain root yields of 20 t/ha, improve both soil fertility and physical conditions and increase fertilizer use efficiency. Annual fertilization of cassava is practiced by most farmers surrounding cassava factories and near big cities who grow cassava commercially, while most other farmers apply a combination of small amounts of inorganic fertilizers and farm-yard manure (FYM).

INTRODUCTION

The main goal of agricultural development in Indonesia is to increase crop production for food, feed, industrial purposes and export, and to increase farmers' income. Rice is the food crop of highest priority in the country since rice is the main staple food.

The annual growth rate in rice production during the past ten years was 1.19%, while that of rice yield was 0.94%. It means that the increase in rice production was achieved both through increasing planted area as well as yield. Increasing the rice-planting area is not easy because about 10% of the lowlands have been used for the development of non-agricultural sectors (CBS, 1998; Rusastra and Budi, 1997).

The importation of 5.8 million tonnes of rice in 1998 indicate that rice production was lower than demand; therefore, food diversification by the utilization of both maize and cassava as a substitute and supplement is the only option to maintain national food security.

The importation of about 600,000 tonnes of maize indicate that the national production of maize is also lower than domestic demand; as a consequence, food diversification depends mostly on cassava.

The annual growth rates for cassava production, harvested area and yield during the past 40 years are 0.81, -0.61 and 1.35%, respectively (FAOSTAT, 2001); thus, a significant increase in yield achieved over the years resulted in an increasing trend in production in spite of a decreasing trend in harvested area. Cassava production and harvested area fluctuated significantly, while yield tended to be more constant, indicating that annual production is mainly a function of the harvested area (Nasir Saleh *et al*., 2001). Increasing the harvested area to increase production is difficult since more than 60% of cassava production areas are located in Java, which is dominated by subsistence farmers with very small land holdings. Therefore, increasing cassava yields, or increasing the planted area in the outer islands, are the only ways to increase national cassava production.

The use of cassava for food, feed, industrial purposes and export accounts for 71, 2, 14 and 12%, respectively, of total cassava production (FAOSTAT, 2001). The national average cassava yield is 12 t/ha, but ranges from 18 to 30 t/ha for farmers that have adopted recommended technologies (Wargiono *et al*., 1995); this indicates that cassava production can be increased significantly through the development of a more intensive production system. Yield is one of the main factors determining farmers' income, so agronomy research to increase cassava yields is very important.

Cassava production areas are generally located in the uplands and are mainly dominated by soils that are low in nutrients and organic matter and susceptible to erosion while crop production is dependent on rainfall. Soil types are mainly Alfisols, Ultisols, Entisols and Inceptisols (Howeler, 1992). Cassava farmers are generally smallholders with limited labor and capital. Therefore, cassava agronomy research that aims to develop technology components that will maximize the utilization of land, labor and capital without affecting the environment is needed to support more sustainable cropping systems. Farmer traditions and socio-economic conditions are also important factors determining the adoption of technologies that will increase cassava yields.

Commercial cassava farmers tend to be more progressive and more willing and more able to adopt new technologies. However, most cassava farmers in Indonesia are subsistence farmers who are not well informed about improved technologies or are not able to adopt these technologies due to lack of technical assistance and capital.

The farmers' situation and needs (**Table 1**) are important considerations in selecting technologies for improving cassava production practices. Intercropping cassava with maize, upland rice and grain legumes are suitable cropping systems; the planting of high-yielding varieties and the use of low inputs are adoptable practices for subsistence farmers because they:

Table 1. Characteristics of cassava subsistence farmers in Central Java and Lampung provinces of Indonesia.

Items	Characteristics		Notes
	Java	Lampung	
1. Land holding			
-Lowland	0.13 ha	0.17	
-Upland	0.6 ha	0.95	60-90% in uplands
2. Family labor	2-3 persons	3-4 persons	
3. Capital	limited	limited	
4. Skill	low	low	
5. Use of fertilizers (low-medium)			
-N	90%	50%	
-N+P	70%	50%	
-N+P+K	4%	40-60%	
-FYM	80%	80%	
6. Use of new recommended clones	20-80%	60-80%	varies among regions
7. Reason for planting cassava			
-Staple food	23%	50%	
-Increase income	13%	75%	
-Low risk cropping system	5%	12%	
-Low investment	9%	20%	
-Traditional system	40%	33%	
8. Way to increase productivity			
-Use fertilizer	90%	80%	subsidies/credit
-Intercropping	89%	50%	
9. Cassava yield			
-Monoculture	11-18 t/ha	17-32 t/ha	
-Intercropping	4-15 t/ha	6-17 t/ha	
10. Adoption of technologies	partial	partial	

Source: *Bagyo, 1990; Wargiono et al., 1995.*

- reduce labor (compared to growing the crop in monoculture)

- control erosion more effectively
- increase income
- distribute income during the year (23-39% at 4, 5-21% at 8 and 45-65% at 10-12 months after planting) (Wargiono *et al*., 1995)
- maintain soil fertility (by reducing erosion and returning intercrop residues to the soil)
- increase land use efficiency (Leihner, 1983)
- reduce N fertilization (when intercropped with grain legumes)
- increase fertilizer use efficiency (Fujita and Budu, 1994)
- enhance the stability of the cropping system (by reducing risks), and
- improve the farmers' well-being (Guritno, 1989).

The objective of commercial farmers is to grow cassava in order to increase income. Therefore, they don't necessarily adopt technologies to maximize yield if the increase in production is not in balance with demand for the product. Cassava grown in monoculture with optimum inputs, as practiced by commercial farmers, can produce fresh root yields of 30 t/ha (Wargiono *et al*., 1995).

Stimulating farmers to adopt new technologies of improved varieties and cultural practices is a way to increase cassava production in order to meet the demand for food, feed, industrial purposes and export, and to increase farmers' income.

AGRONOMY RESEARCH RESULTS

Selected technology components to increase yields and income in each agro-ecological zone are: land preparation, erosion control, planting material, plant growth management through plant population and spacing, planting time, weed control, cropping systems and fertilization.

1. Land preparation

The objective of land preparation is to improve the soil structure, reduce weeds without enhancing soil degradation. Good soil preparation aims to maintain or enhance the circulation of soil O_2 and CO_2 so as to optimize plant growth.

Land preparation by twice plowing or one plowing followed by ridging in the dry season or in the early rainy season when available water is less than 75% of field capacity is recommended (Hudoyo, 1991). Disk plowing of soils that are susceptible to erosion increased soil losses significantly (Suparno *et al*., 1990) (**Table 2**); therefore, a single plowing followed by ridging along the contour is advised to reduce erosion.

Strip tillage controlled erosion effectively and reduced by more than 50% the cost of soil preparation without decreasing root yields significantly when weeds were controlled effectively (Wargiono, 1990) (**Table 2**); however, this is not practiced by farmers because it makes controlling weeds more difficult. Therefore, complete tillage of soils susceptible to erosion should be followed by the adoption of erosion control practices, such as contour ridging, hedgerows, mulching, fertilization and intercropping.

2. Erosion control

Soil erosion is often the main cause of soil degradation and is affected by climate, topography, vegetation and type of soil as well as by human activities (Suwardjo and Sinukaban, 1986). **Table 3** shows that under the climatic and soil conditions of Lampung, Sumatra, cassava grown in monoculture, either with or without fertilizers, caused more serious erosion than two successive crops of maize, peanut, soybean or one crop of rice followed by soybean. Among the various crops, peanut caused the least erosion. Fertilizer application reduced the amount of soil loss in all crops by enhancing rapid canopy formation. Cassava production areas are dominated by soils susceptible to erosion, but most subsistence farmers are not concerned about controlling erosion. Therefore, the development of simple technology components to control erosion, which can be adopted by both subsistence and commercial cassava farmers, is urgently needed.

Table 2. The effect of soil preparation on cassava yields and soil loss due to erosion in Lampung in 1990.

Soil preparation	Cassava yield (t/ha)	Dry soil loss (t/ha)
1. Rome harrow; disk plow followed by contour ridging	25.4 a	89.7 ab
2. Rome harrow; disk plow followed by up-down ridging	25.9 a	88.5 ab
3. Rome harrow; disk plow followed by diagonal ridging	23.8 a	107.8 a
4. Rome harrow; contour ridging	23.5 a	66.8 b
5. Rome harrow; up-down ridging	25.2 a	68.1 b
6. Rome harrow	19.0 b	30.8 c
1. Full tillage (twice hoeing of whole area)	14.3 a	10.3
2. Strip tillage (twice hoeing in 40 cm strips in cassava row	15.0 a	7.6

Source: *Suparno et al., 1990; Wargiono, 1990.*

Table 3. Effect of various crop and cropping systems on dry soil losses due to erosion and on net income during an 8 month cropping cycle on 5% slope in Tamanbogo, Lampung, Indonesia. Data are average values for two years (1994-1996).

	Dry soil loss (t/ha)	Net income (‘000 Rp/ha)
Without fertilizers		
Cassava	41.92	322
Rice-soybean	26.29	570
Maize-maize	30.64	159
With fertilizers		
Cassava	29.06	804
Rice-soybean	24.31	1477
Maize-maize	24.98	892
Peanut-peanut	17.92	2488
Soybean-soybean	27.61	2031
Cassava+maize+rice-soybean	19.60	1301

[1] Net income = total crop value minus fertilizer costs.

Source: *Howeler, 1998.*

The adoption of erosion control technology components practiced by farmers depend on their capability to produce sufficient food, feed or cash income. Technology components that are adopted by most farmers include intercropping, ridging and planting hedgerows with elephant grass. These technology components are able to improve soil physical conditions and soil fertility, increase income, and/or produce biomass for animal feeding (Wargiono *et al*., 1995); therefore, these cropping systems are sustainable. **Figure 1** shows that for the first 1-2 years hedgerows reduced cassava yields, but that after 3-4 years of cropping hedgerows of leguminous tree species, like *Leucaena leucocephala, Gliricidia sepium* or *Flemingia macrocarpum*, resulted in higher yields and less erosion than hedgerows of elephant grass or no hedgerows. Thus, farmers may have to weigh short-term benefits against long-term sustainability.

The capability of crops to minimize erosion depends on the crop's canopy diameter to cover the soil surface, which is affected by soil fertility, cropping system and plant spacing. The greater the canopy diameter and the closer the plant spacing the more the soil is protected from the direct impact of falling raindrops, and the lower the erosion. Therefore, fertilizer application, intercropping with maize, rice and peanut (**Table 4**), and the planting of contour hedgerows (**Figure 1**) are effective erosion control measures. Planting upland rice, maize or peanut with adequate fertilization resulted in 10 and 20% less soil loss than planting cassava, whereas fertilizer application of cassava reduced soil erosion 12% compared to the unfertilized crop (**Table 4**). Even though fertilizer application is very effective in controling erosion and may increase gross return from 40 to more than 400%, most farmers do not apply fertilizers at optimum rates due to limited capital. Therefore, intercropping cassava with peanut (source of biological N fixation) and the application of low to medium rates of fertilizers is an improved practice that is more easily adopted by subsistence farmers. The planting of contour hedgerows of leguminous tree species such as *Gliricidia sepium* or *Leucaena leucocephela* is another practice that is being adopted by some farmers. The capacity of this system to reduce erosion tends to increase over time as the cassava growth rate is increased due to an improvement in soil fertility and soil physical conditions as a result of the addition of hedgerow prunings (Wargiono *et al*., 1998). These hedgerows produce biomass for either feed or mulch and are thus more easily adopted by poor farmers.

3. Planting material

The planting of high-yielding varieties is a technology component that is easily adopted by farmers, as it is cheaper than other technology components for increasing cassava yields. But, only about 20% of subsistence farmers grow new recommended varieties (Bagyo, 1990). The bulkiness of planting material is a serious limitation in the dissemination of new recommended varieties, because the cost of both production and transport of planting material is much higher than that of grain crops. This problem can be partially overcome by the use of planting stakes with only 1-3 nodes (Cock *et al*., 1978).

The quality of planting material influences the final plant population and thus yield (Lozano *et al*., 1977). Sprouting capacity (or germination) depends on the source as well as on the length and size of stem cuttings. Young cassava stems (top parts) have a high water content and dehydrate rapidly when cut for use as planting material; so, the sprouting capacity of stakes produced from young stems is lower than those from older stems (from bottom to middle parts). The sprouting capacity of older stems was not significantly different for stakes ranging from 1.5 to 4.0 cm in diameter (**Table 5**); therefore, farmers are advised to use the middle or lower parts of the stems as planting material.

In case the number of available stakes is limited, stakes of 2-3 nodes could be either planted directly in the field or be transplanted after 7-10 days in the nursery where stakes are placed on wet paper towels to stimulate the growth of roots and sprouts (Wargiono *et al*., 1992).

Table 4. Effect of intercropping systems, cassava plant spacing and fertilizer application on total crop value, net income and dry soil loss due to erosion when cassava was grown on 5% slope in Tamanbogo, Lampung, Indonesia. Data are average values for four cropping cycles (1987-1991).

Treatments[1)]	Total crop value (‘000 Rp/ha)	Net income[2)] (‘000 Rp/ha)	Dry soil loss (t/ha)
A. Without fertilizers			
1. Cassava monoculture (1.0 x 1.0 m)[3)]	744.1	744.1	24.80
2. C+M+R-P (2.0 x 0.5 m)	968.7	938.7	19.02
3. C+M+R-P (2.73 x 0.6 x 0.6 m)[4)]	1,025.6	955.6	20.14
Average	912.8	879.5	21.32
B. With fertilizers[5)]			
4. Cassava monoculture (1.0 x 1.0m)	1,042.6	939.1	21.79
5. C+M+R-P (2.0 x 0.5 m)	1,417.1	1,179.4	18.30
6. C+M+R-P (2.73 x 0.6 x 0.6 m)	1,464.1	1,226.4	19.97
Average	1,307.9	1,115.0	20.02
7. R-C (1.0 x 1.0 m)	494.7[6)]	307.6	17.90
8. M-C (1.0 x 1.0 m)	658.9[6)]	471.8	19.47
9. P-C (1.0 x 1.0 m)	816.1[6)]	661.9	19.02

[1)] C = cassava, M = maize, R = upland rice, P = peanut.
C+M+R-P indicates cassava intercropped with maize within the row, upland rice between rows, which, after harvest is followed by peanut.
R-C indicates monoculture upland rice followed by monoculture cassava.

[2)] Net income = total crop value minus fertilizer costs.

[3)] Planting distance for cassava.

[4)] Cassava planted in double rows, with 0.6 m between rows and 2.73 m between adjacent double rows (3.33 m between centers of double rows).

[5)] Fertilizers: 90-30-90 for cassava/maize; 60-40-60 for rice; 30-30-30 for peanut.
In first year rice and peanut received fertilizers in T_2 and T_3, but not in subsequent years.

[6)] Low total crop value due to very low yields of the cassava relay crop.

4. Plant growth management

Biomass production depends on the crop growth rate (CGR), while CGR depends on the net assimilation rate (NAR), as well as the leaf area index (LAI). The CGR can be increased either through a greater LAI or greater NAR, but when shading occurs as a result of increasing the leaf area index the light interception decreases resulting in a decrease in NAR (Hozyo *et al*., 1984). An optimum LAI of 3.5 could be obtained by the use of an optimum plant population and by controlling the number of shoots as well as the number of leaves per plant (Hozyo *et al*., 1984).

Higher root yields were obtained with two stems/plant compared to either one or three stems/plant (**Table 6**); with two stems the leaf blades overlapped only slightly resulting in an optimum capacity to intercept sunlight. The obtaining of an optimum LAI through plant population arrangement is affected by soil fertility as well as the branching habit of the variety (Wargiono, 1990). When the LAI is higher than 3.5, removing the lower (older) leaves by no more than 25% of the total number of leaves is a way to reduce the LAI and this may result in an increase in yield; the removed leaves can be used as animal feed (Sugito, 1990).

Technology components to obtain high CGR through LAI management are:

- maintaining two stems or shoots/plant (Wargiono and Sumaryano, 1981)
- removing the lower leaves by no more than 25% of the total number of leaves per plant when the LAI is higher than 3.5 (Sugito, 1990)
- using a population of 10,000 plants/ha of branching varieties on both poor and fertile soils; using a population of 12,000 to 14,000 plants/ha of non-branching varieties on poor soil and 10.000 plants/ha on fertile soils (Wargiono, 1990)
- using a plant spacing for monoculture of 100 x 100 cm, 125 x 80 cm or 100 x 80 cm; and 125-300 cm between rows and 50-80 cm in the row for intercropping systems (Wargiono, 1990).

5. Planting time

The maximum crop growth rate (CGR) occurs at about 5-6 months after planting (MAP) (Hozyo *et al*., 1984). As cassava growth depends greatly on water availability, crop productivity is affected mainly by water availability during the first six months as well as during the last two months, just before harvest. Most farmers avoid stand failure by planting cassava at the beginning of the rainy season and harvesting in the dry season; this leads to an excess of cassava roots at that time, resulting in a decrease in price of cassava and thus a decrease in farmers' income. However, the farmer's flexibility is limited as the root starch content will decrease if the harvest is delayed to more than 10 months for early harvestable clones, and to more than 12 months for medium and late harvestable clones, especially when the harvest takes place at the start of the rainy season.

The best way to solve this problem is to move the harvest time by changing the planting time according to the rainfall distribution or soil water availability. The yield of cassava is highly correlated with soil moisture during the first six months; high yields can be obtained when the rainfall is more than 35 mm/10 days and is well distributed up to harvest time (Wargiono, 1991). **Table 7** shows that moving the planting and harvesting time has a significant effect on yield but can improve the year-round supply of cassava roots produced, and result in higher prices paid to the farmer. **Table 8** shows that the yield

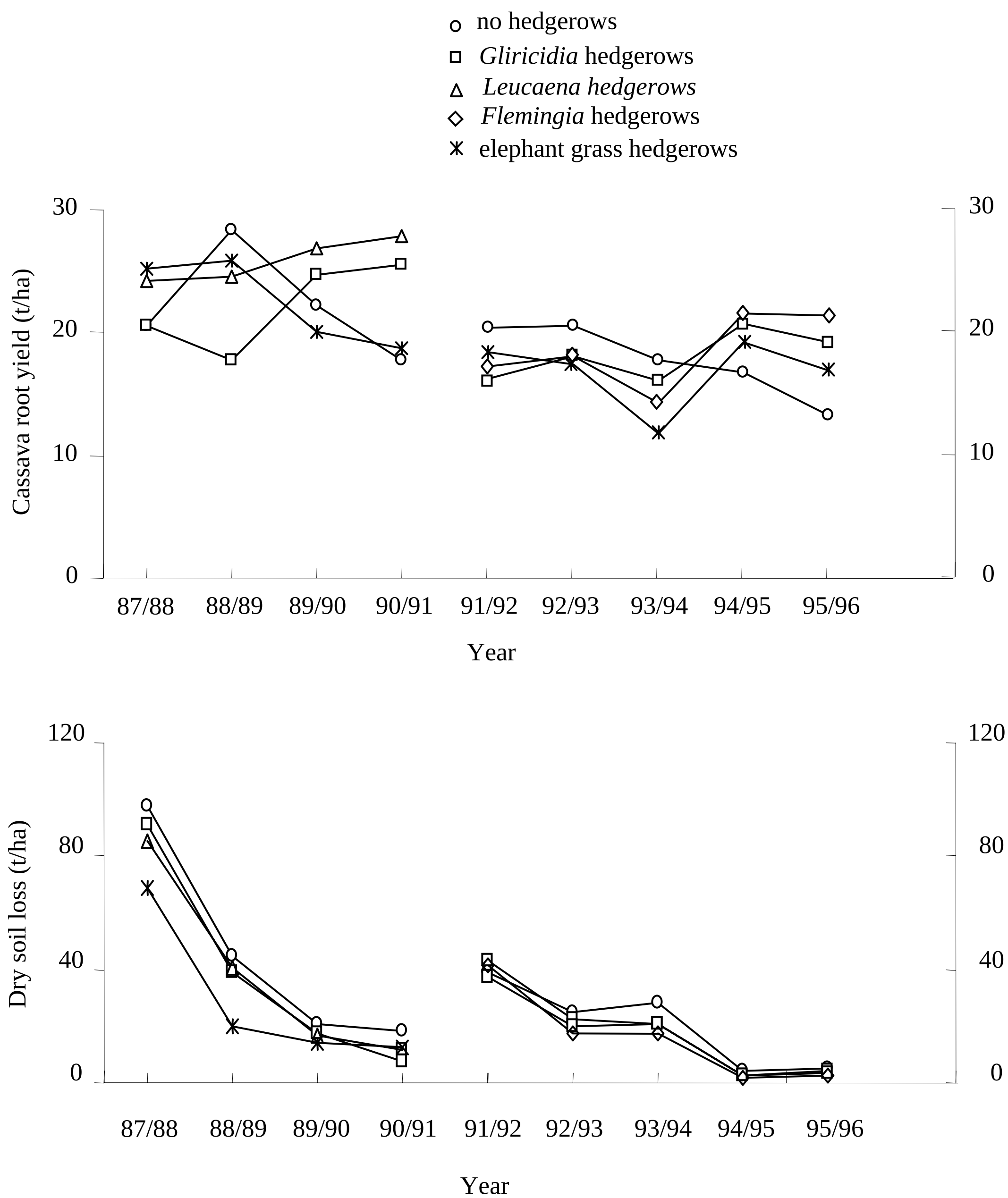

Figure 1. Effect of various types of contour hedgerows on cassava yield and soil loss due to erosion when cassava and maize were intercropped during nine consecutive years on 8% slope in Jatikerto, Malang, Indonesia, from 1987 to 1996.
Source: *W.H. Utomo, personal communication.*

of intercropped cassava decreased with a delay in planting time as the competition from interplanted crops (planted in Dec) increased, resulting in a CGR of cassava during the first two months that was lower than that of the interplanted crops. This decrease in cassava yield was partially compensated for by an increase in the yield of the interplanted crops; however, it was also influenced by the type of soil. Delaying the planting of cassava in intercropping systems in soils that become hard in the dry season (Alfisols in Yogyakarta) is not recommended as the decrease in cassava yield was not compensated by an increase in yield of interplanted crops (**Table 8**). Delaying planting time in lighter soils (Utisols) in Lampung did not significantly affect the total crop value, because the decrease in cassava yield was mostly compensated by an increase in the yields of interplanted crops; therefore, this technology component could be adopted by farmers.

Table 5. Effect of source of planting material and size of stakes on germination and cassava yield in Bogor, West Java, in 1980 and 1989.

Source/size	Germination (%)	Fresh root yield	No of planting stakes produced (# stakes/plant)
Bogor, 1980[1)]			
Stakes diameter (10-12 nodes)		(t/ha)	
1.5-2.0 cm	97-100	26.6	
2.1-2.6 cm	97-100	22.2	
2.7-3.0 cm	97-100	22.5	
3.1-3.5 cm	97-100	25.3	
3.6-4.0 cm	97-100	23.6	
Bogor, 1989[2)]			
Young stem (top part)		(kg/plant)	
one node	10.0 a	1.53 a	6.2 a
two nodes	33.3 b	2.81 ab	8.1 a
three nodes	30.0 b	3.47 ab	9.2 a
Older stem (lower part)			
one node	66.7 c	3.08 ab	11.8 ab
two nodes	96.7 d	3.21 ab	12.6 abc
three nodes	96.6 d	3.92 b	18.2 bc
10-12 nodes	100.0 d	3.85 b	20.3 c

Source: [1)] *Wargiono and Sumaryono, 1981; Wargiono, 1990.*
[2)] *Wargiono et al., 1992.*

6. Weed Control

The growth rate of cassava during the first two months is lower than that of weeds, so weed control is as important as other management practices, such as choice of varieties, stand establishment and fertilizer application. In fact, without adequate weed control the use of other improved cultural practices will generally lead to disappointing yields. Effective weed control is the first step towards reducing competition from weeds for light, water and nutrients, thereby improving cassava yields in the uplands.

Weed control is traditionally done by hand weeding. The number of weedings necessary for cassava varies considerably, depending on the weed population, soil fertility, rainfall, cropping system and the response of particular varieties to competition from weeds. The fact that hand weeding can double root yields compared to that of unweeded plots indicates that effective weed control is a very necessary cultural practice (Bangun, 1990).

The use of herbicides by farmers is increasing in areas with limited available labor; the kind of herbicides used depends on the predominant weed species. Weed populations can also be reduced by increasing the diameter of the cassava canopy so as to increase the plant's light interception through fertilizer application, optimum plant population, and by intercropping or mulching. **Table 9** shows that hand weeding 2 to 3 times increased the root yield 43% compared to the control, whereas using herbicides increased the yield 62 to 100% (Bangun, 1990).

Table 6. Effect of stem number and the removal of leaves on cassava fresh root yield in Bogor, West Java in 1980, and in Malang, East Java in 1988.

Stem number/leaves removed per plant	Cassava fresh root yield (t/ha)
Bogor, West Java[1]	
Number of stems/plant	
-One stem	15.08
-Two stems	20.39
-Three stems	17.95
Malang, East Java[2]	
Leaves removed	
-0%	48.44
-25%	51.07
-50%	49.33
-75%	47.30

Source: [1]*Wargiono and Sumaryono, 1981.*
[2]*Sugito, 1990.*

Table 7. Effect of planting time and age at harvest on cassava yields when planted in monoculture in Lampung in 1988. Data are average values for three varieties.

Planting time	Fresh root yield (t/ha)		
(month)	6 MAP	8 MAP	10 MAP
February	17.2 a	30.7 a	34.6 a
March	17.7 a	27.4 ab	21.2 b
April	15.0 a	24.5 ab	27.0 ab
May	14.6 a	25.2 ab	26.4 ab
June	16.2 a	18.4 b	19.4 c

Source: *Wargiono, 1990, 1991.*

Table 8. Effect of time of planting cassava relative to that of intercropped rice on the yields of cassava and the intercrops when cassava was intercropped with rice followed by mungbean in Yogyaharta, and rice followed by soybean in Lampung in 1991/92.

Planting time of cassava[1]	Yield (t/ha)				Total crop value[2] ('000 Rp/ha)
	Cassava	Rice	Mungbean	Soybean	
A. Yokyakarta					
December	18.46	1.98	0.25	-	1483.4
January	11.07	2.17	0.42	-	1405.3
February	8.03	2.37	0.47	-	1383.7
March	4.74	2.37	0.55	-	1332.1
B. Lampung					
December	39.78 a	1.68	-	0.28	2235.2
January	37.74 a	2.11	-	0.34	2309.1
February	28.95 b	2.17	-	0.36	1988.5
March	21.29 c	2.18	-	0.44	1748.6

[1]Rice intercrop planted in Dec 91 in all treatments; mungbean or soybean planted in April 92 for all treatments; cassava harvested at 8 MAP (Aug-Nov '92)

[2]Prices: cassava: Rp 40/kg fresh roots
rice: 250/kg dry grain
mungbean: 1000/kg dry grain
soybean: 800/kg dry grain

Source: *Wargiono et al., 1997.*

Table 9. Effect of methods of weed control on cassava fresh root yields in two experiments conducted in Lampung in 1985 and in 1989.

Weed control method	Root yield (t/ha)
1. Lampung, 1985[1]	
Control (no weeding)	6.0
Hand weeding at 30, 60, 90 DAP	25.3
Gesapax 80 WP: 1.5 k/ha at 1 DAP	9.3
Laso 4l/ha at 4 DAP	6.4
2. Lampung, 1989[2]	
Control (no weeding)	11.0 b
Hand weeding at 30 and 60 DAP	15.7 ab
Paraquat 1.25 l/ha at 30 DAP	17.8 ab
Paraquat 2.50 l/ha at 30 DAP	17.4 ab
Paraquat 3.75 l/ha at 30 DAP	18.8 ab
Paraquat+Diuron: 1.25 l/ha at 30 DAP	17.8 ab
Paraquat+Diuron: 2.50 l/ha at 35 DAP	17.4 ab
Paraquat+Diuron: 3.75 l/ha at 30 DAP	21.9 a

Source: [1]*Wargiono and Bangun, 1986.*
[2]*Bangun, 1990.*

7. Cropping System

In Indonesia cassava is planted in monoculture only around urban areas and starch factory plantations, as well as in non-productive land, which cannot be planted with other food crops. Most farmers, however, plant cassava intercropped with other food crops, since this will enable them to increase their land use efficiency and income, improve the soil's physical and chemical conditions and reduce erosion (Guritno, 1989; Wargiono, 1993; Wargiono *et al*., 1998). Intercropping systems practiced by farmers yielded 10% and 20% higher gross income under experimental conditions as compared to the monoculture system, with a B/C ratio of more than 2.0; this indicates that intercropping cassava is a feasible and adoptable system for resource poor farmers (Bagyo, 1990; Wargiono, 1993). Therefore, more than 80% of farmers in the main cassava production areas have adopted intercropping systems to increase their incomes (Bagyo, 1990).

Sustainable upland cropping systems can be achieved by choosing suitable varieties and management practices that increase nutrient use efficiency without degradation of the environment.

Adira 1 is a cassava variety which is suitable for intercropping systems as it is characterized by a non-branching or late branching plant type, high starch content, high leaf area index (which could be maintained during 42 weeks) and a high CGR (Hozyo *et al*., 1984; Wargiono, 1991).

The optimum cassava plant population for cassava intercropped with other food crops is 10,000 plants/ha, and the optimum total level of fertilizer application maybe as high as 180 kg N, 90 P_2O_5 and 180 K_2O/ha (Leihner, 1983; Wargiono *et al*., 1995; 1998). The problem is that farmers generally lack capital to buy fertilizers.

N obtained through biological nitrogen fixation (BNF) of the intercropped legumes is an important resource for cassava intercropped with legumes, especially when N-fertilizer or soil-N are limited. It has been reported that interplanted legumes reduced the loss of soil-N by about 50% and fixed 24 kg N/ha (Fujita and Budu, 1994). For that reason, cassava intercropped with maize or upland rice and maize followed by peanut at optimum plant population and fertilization yielded a high Land Equivalent Ratio (LER) and gross income (**Table 10**).

Intercropping cassava with other food crops generally increases LER and total crop value, it reduces both nutrient loss and erosion and it minimizes the risk of crop failure; this indicates that the adoption of this technology component would considerably improve the sustainability of the cropping system, optimize the use of land, water and sunlight, and increase farmers' income.

8. Fertilization

Cassava growth is often inhibited and leaves may show deficiency symptoms when the contents of available nutrients in the soil are below the critical level. Wargiono *et al*.,(1997) reported critical levels of 3.3 to 5.2 ppm for available P and 0.13 to 0.19 me/100 g for exchangeable K. When this is the case, crop growth can be improved by adding nutrients to the soil. The crop’s ability to absorb soil nutrients is affected by the type of soil and the fertilizer applied, the responsiveness of the variety, the crop's general condition, the cropping system and the availability of other nutrients (Howeler, 1981; Wargiono, 1988; Widjaya *et al*., 1990).

Table 10. Land use efficiency and total crop value with different intercropping systems of cassava in CIAT, Cali, Colombia (1979) and in Bogor, W. Java, Indonesia (1991).

Cropping system[1)]	Cassava[2)] planting time	Cassava population ('000/ha)	Fertilization[3)]	Land Equivalent Ratio
Colombia[4)]				
C+Cp	-3	10	F	1.5
C+Cp	0	10	F	1.8
C+Cp	+3	10	F	1.4
Bogor[5)]				
C+P-Mb	0	10	UF	1.9
C+P-Mb	0	10	F	2.1
C+R+M-P	0	10	UF	1.6
C+R+M-P	0	10	F	2.1

[1)]C=cassava; Cp=cowpea; M=maize, P=peanut; Mb=mungbean
[2)]-and +: months before and after intercrop planting, respectively; 0:planted at the same time
[3)]F=fertilized; UF=unfertilized
Source: *[4)]Leihner, 1983; [5)]Wargiono, 1991.*

The amounts of nutrients removed by cassava roots are generally rather low compared to those removed by other crops (Howeler, 2001), but can be relatively high when yields are high or when stems and leaves are also removed (Wichmann, 1992; Howeler, 2001). For that reason, soil fertility will decrease with time if cassava is planted continuously without any addition of nutrients to the soil. Potassium is the nutrient removed by cassava in greatest quantities, so the amount of K added to the soil should be higher than those of other nutrients. However, if K is added to the soil in very large amounts this may decrease Mg and Ca uptake and *vice versa*, due to antagonism among these three cations; therefore, if inorganic NPK fertilizers are applied continuously this may reduce the available Ca and Mg in the soil (Nayar *et al*., 1995). Addition of organic manure or compost and application of balanced NPK fertilizers minimized this antagonistic effect among the cations (Nayar *et al*., 1995) and resulted in a significant increase in yield (**Table 11**). Application of farm-yard manure (FYM) is practiced by most farmers, but that of balanced NPK fertilizers is not yet widely practiced. Adoption of this technology component is a way to increase cassava production and farmers' income (Bagyo, 1990, and Wargiono, 1993).

The amounts of nutrients removed by food crops intercropped with cassava is relatively high, but part of these nutrients (46% of N, 33% of K, 85% of Ca, and 73% of Mg) may be returned to the soil with the crop residues (Wichmann, 1992). Therefore, harvesting and removing all plant parts will increase the soil fertility decline over time if no fertilizers are applied. Fertilizer application and reincorporation of crop residues of both cassava and interplanted crops can maintain the fertility status of the soil. If the level of soil K is low this could be improved by returning the residue of interplanted rice, since 93% of K absorbed by rice is concentrated in the straw (Wichmann, 1992).

Table 11. Effect of application of organic matter and inorganic NPK fertilizers on the Total crop value in two different cropping systems in Lampung, 1993.

Treatment	Total crop value ('000 Rp/ha)	
	Monoculture	Intercropping
Without organic matter		
-Without NPK	480	525
-With NPK	653	702
With organic matter		
-Without NPK	778	1,008
-With NPK	1,037	1,253

Source: *Wargiono, 1986.*

Application of organic matter in each growing season also improved the soil physical conditions, such as bulk density, infiltration rate and aggregate stability (Wargiono *et al.*, 1995). Reincorporation of crop residues is, therefore, a technology component that will help maintain soil fertility and increase fertilizer use efficiency.

For soils that are low in P and K, the application of a balanced NPK fertilizer is an effective way to increase cassava yields and farmers' income. Intermediate levels of application, such as 90 kg N, 25 P_2O_5 and 60 K_2O/ha for cassava grown in monoculture (Wargiono *et al.*, 1998) and higher rates, such as 90-120 kg N, 50 P_2O and 90-120 K_2O/ha for cassava grown in intercropping systems will tend to maintain stable yields of both cassava and interplanted crops (**Figure 2**), provide the highest gross and net income (**Figure 3**), and can generally maintain soil fertility (**Figure 4**). The B/C ratio of this technology component is usually above 2.0, and is, therefore, a feasible and adoptable practice.

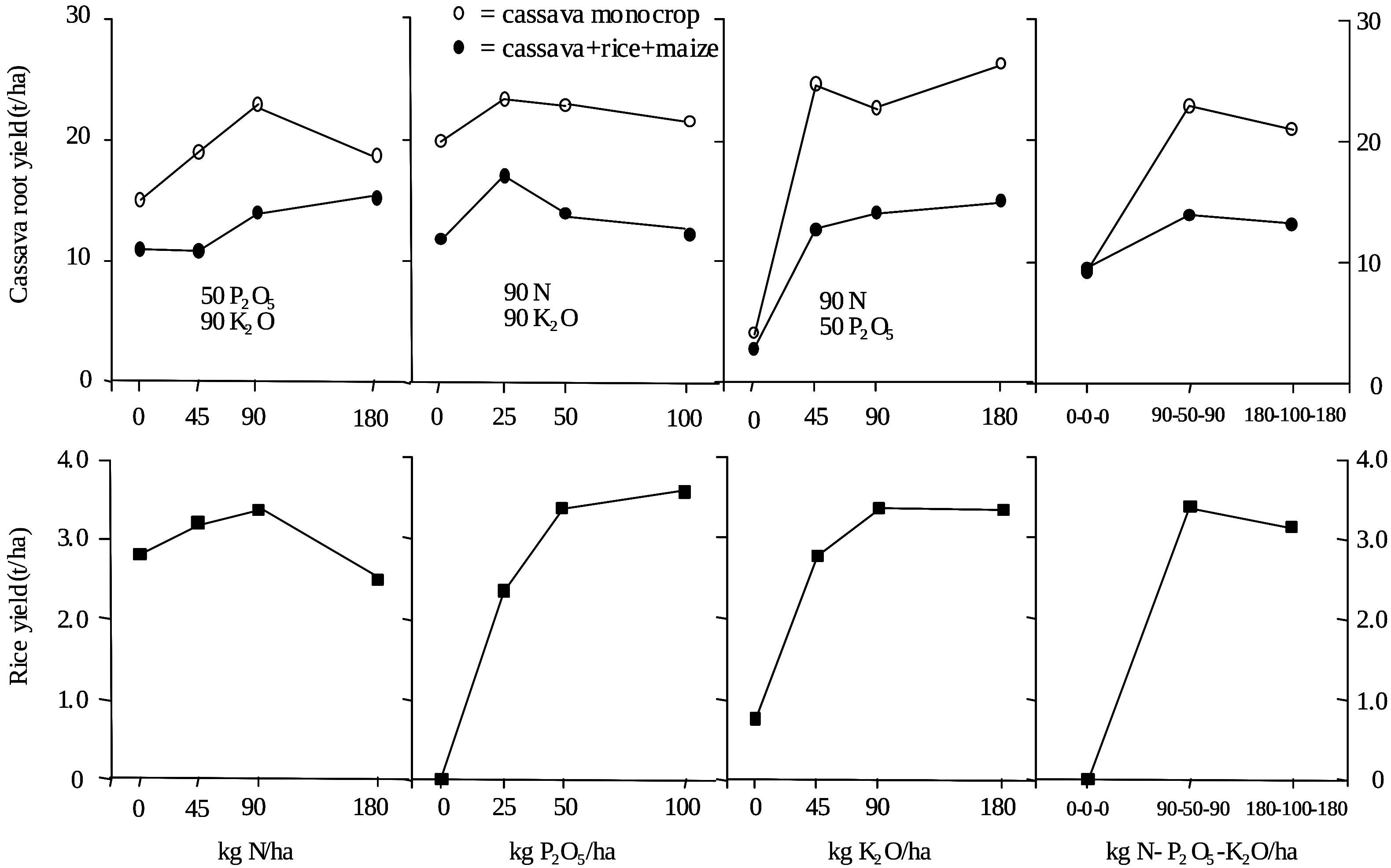

Figure 2. Effect of annual applications of various levels of N, P and K on the yields of cassava (both monocropped and intercropped with rice and maize) and upland rice during the 9th consecutive cropping cycle in Tamanbogo, Lampung, Indonesia, in 1999/2000. Note: maize yields were zero.

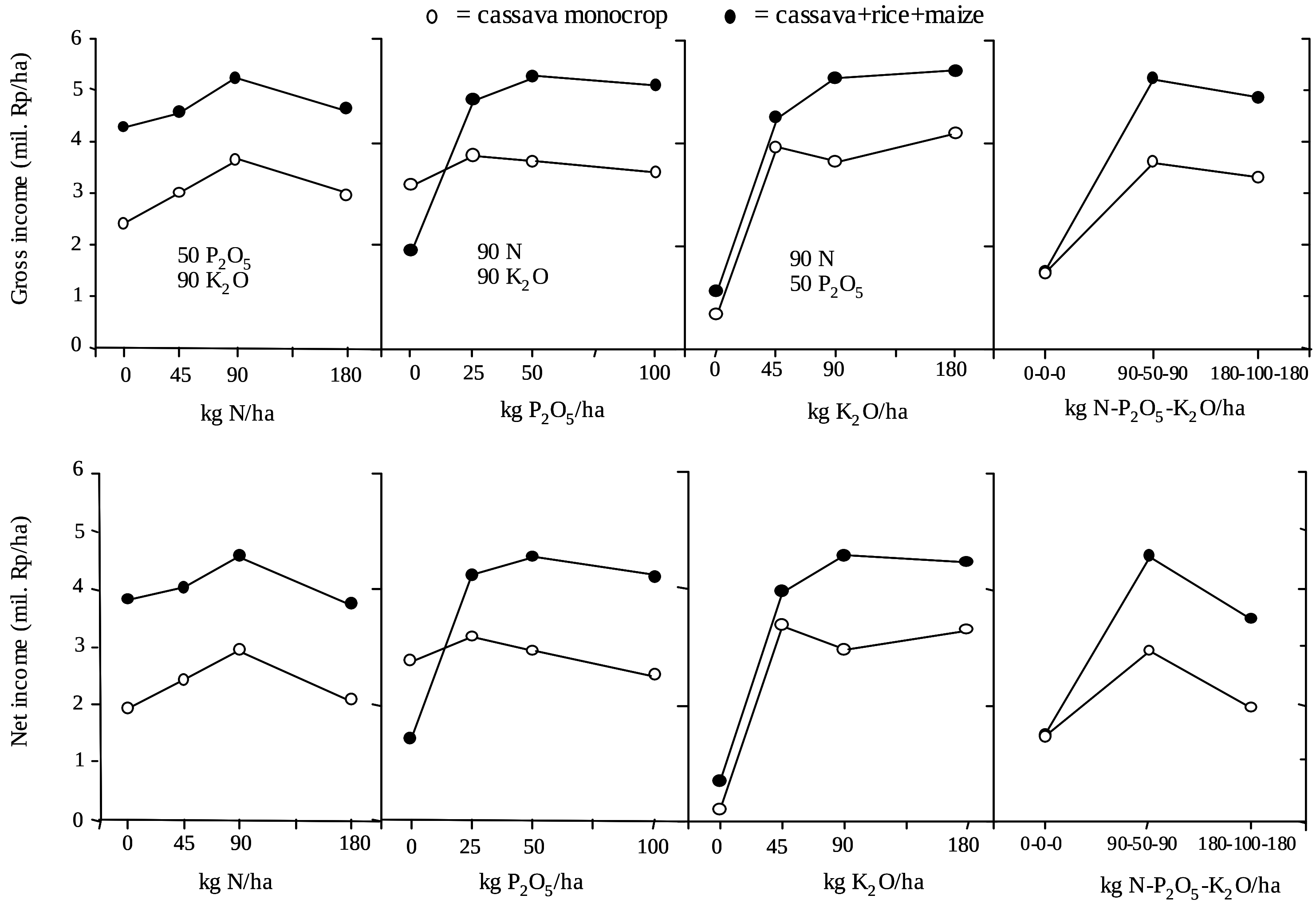

Figure 3. Effect of annual applications of various levels of N, P and K on the gross and net incomes obtained when cassava was monocropped or intercropped with rice and maize during the 9th consecutive cropping cycle in Tamanbogo, Lampung, Indonesia, in 1999/2000. Note: maize yields were zero.

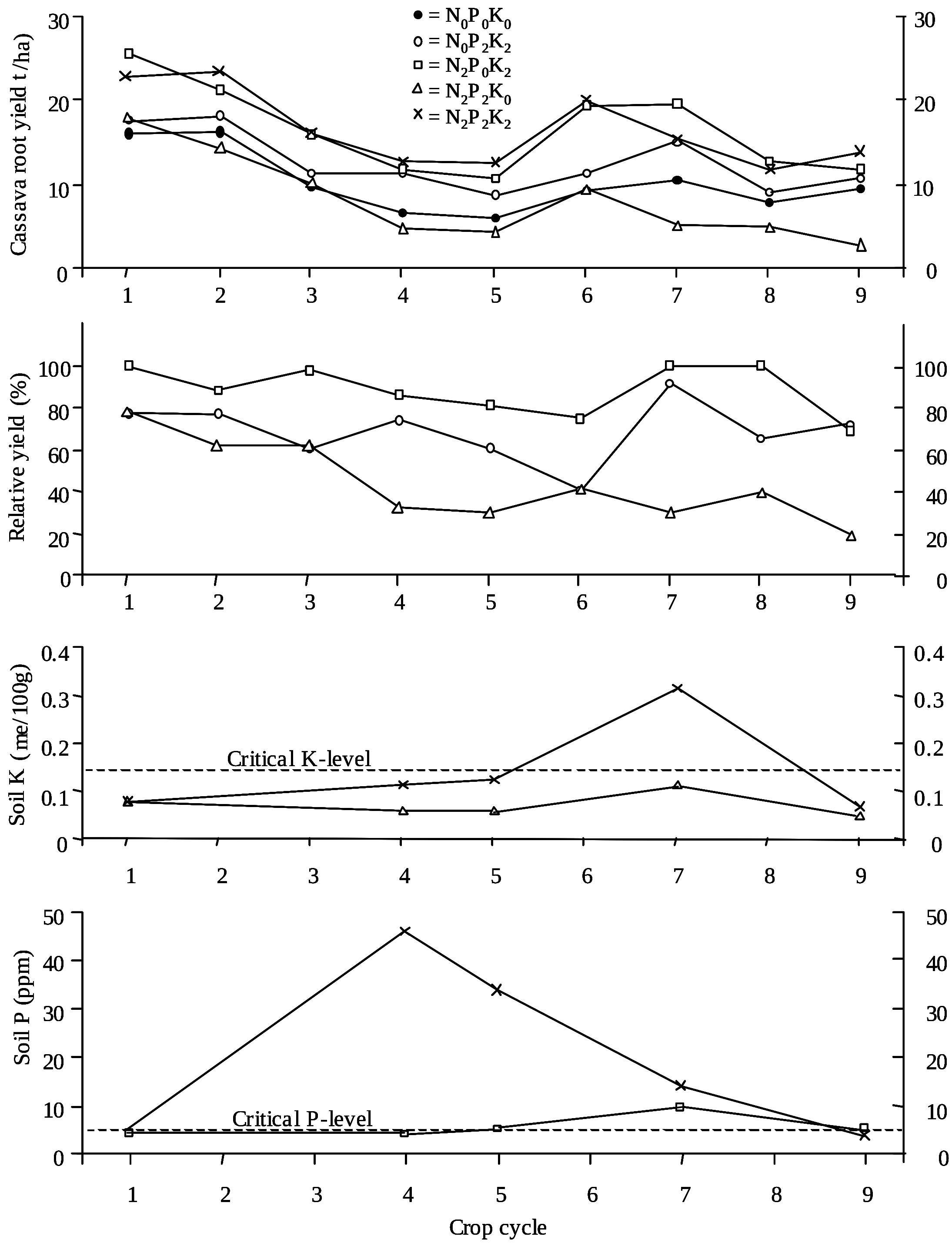

Figure 4. Effect of annual applications of N, P and K on cassava root yield, relative yield (yield without the nutrient over the highest yield with the nutrient) and the exchangeable K and available P (Bray 2) content of the soil during nine years of continuous cropping (cassava intercropped with upland rice and maize) in Tamanbogo, Lampung, Indonesia.

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