Effects of N, P, and K on Yield

The use of fertilizers for cassava production in Indonesia is still very limited. Some farmers apply a small amount of urea, once or twice during the growth period (De Bruijn and Dharmaputra 1974).

To study the need of fertilizers for Mukibat cassava NPK experiments were carried out at two locations in East Java in 1974/1976. Only data from one of the locations, Tulungagung, are available. The chemical properties of the soil are as follows: pH = 6.1, organic-C = 0.55%, total-N = 0.04%, 0.03 *N* NH_4F and 0.01 *N* HCl extractable P = 120 ppm, and *N* NH_4-acetate extractable K = 66 ppm.

A split plot experiment was used. There were two varieties, Faroka and Ndoro, which constituted the main plots, while the combinations of N, P, and K fertilizers were arranged factorially in the subplots. P as TSP was applied 15 days after planting, N as urea and K as potassium sulfate were applied in equal split application 15 days and 4 months after planting, respectively.

The only significant effect was the N treatment. On average the application of urea equivalent to 100 kg N/ha resulted in twice the yield of the no N treatment. Further increase of the N rate did not significantly increase the yield.

Discussion

The fact that an increasing number of farmers are adopting the Mukibat system is a strong indication that the system is superior to the normal cassava production system. The preliminary results of the experiments also indicate that the yield of the Mukibat cassava is higher than that of the normal cassava if Mukibat cassava is planted at the right time with proper plant spacing.

Because the response of individual varieties to the Mukibat system varies considerably, the possibility exists of selecting for high yield within varieties that have good eating quality but only produce moderately under the normal system. This is very attractive in Indonesia where almost all cassava is used for human consumption.

The conclusion that making planting holes is not necessary has an important practical implication because labour input for the system can be reduced. This means that the system may be practical for larger fields. Another practical conclusion is that special *M. glaziovii* plantings for obtaining scion material may not be necessary, as the scions taken from the Mukibat plants proved to be as good as those taken from the original *M. glaziovii* tree. However, it is still not known whether scion material repeatedly taken from Mukibat plants without renewal from the original *M. glaziovii* trees will be effective. Further research is needed on this point.

The authors wish to thank the International Development Research Centre, which provided funds for the present research. We are indebted to staff members of the Cassava Research Project and students of the Faculty of Agriculture, Brawijaya University, for their active support and involvement in the cassava research, and to Dr. Graeme D. Swincer for correction of the English.

De Bruijn, G. H., and Dharmaputra, T. S. 1974. *The Mukibat system, a high yielding method of cassava production in Indonesia.* Neth. J. Agric. Sci. 22, 1974, 89–100.

Undersowing Cassava with Stylo Grown Under Coconut

I. M. Nitis and M. Suarna[1]

Three field experiments on undersowing cassava with stylo were carried out in Bali. Stylo drilled under the cassava at diagonal crossing produced tuber dry matter (D.M.) similar to that of cassava sown without stylo. Other methods of sowing stylo (broadcast, windrow, crisscross, and drill midway between the 2 cassava) significantly ($p = 0.05$) decreased the tuber D.M. yield by 32–51%. Windrow sowing the stylo under the cassava by replacing cassava with stylo so that the spacing increased from 40 × 40 cm

[1]Department of Nutrition and Pasture Agronomy, F.K.H.P., Udayana University, Denpasar, Bali, Indonesia.

(without stylo) to 40 × 80 cm (with stylo) and from 60 × 60 cm (without stylo) to 60 × 120 cm (with stylo) increased tuber production by 20 and 22%, respectively. At the wider cassava spacing the replacement significantly decreased tuber D.M. yield by 28%. In the other experiment, windrow sowing stylo under the cassava decreased tuber D.M. yield by 14% ($p = 0.05$). PK or PKT fertilizers could alleviate such yield depression. The cassava + stylo combination produced about 69% more shoot D.M. than that of the cassava sown without stylo. The importance of undersowing cassava with stylo in mixed farming systems is discussed.

In intensively farmed coconut-bearing dry areas in Bali, root crops (cassava, sweet potato), cereal (corn, sorghum), or beans (green bean, dolichos) are grown as cash crop while livestock is integrated into the farming system for draft animals, meat production, and export earnings. Cassava is the cash crop most commonly grown, and undersowing of cassava is rarely practiced. After the cassava crop, the land is either bare because it is too dry for new cultivation, or when enough moisture is available, it is invaded with annuals of low nutritive value. Shortage of livestock feed is not uncommon in this area (Nitis 1967). The tropical legume *Stylosanthes*, which is known for its drought resistance, and which can mix with other species (Humphreys 1969), is showing promise as a livestock feed in Bali (Nitis and Nurbudi 1975).

According to Nitis and Sumatra (1976), cassava undersown with *Stylosanthes* produces 14% more tubers than cassava grown alone. Furthermore, the companion crop *Stylosanthes* produces an additional 5 tons dry matter/ha/year.

This paper reports on a short term field study of the effect of method of sowing, spacing (density), and fertilizer on the yield of cassava and *Stylosanthes* sown under coconut.

Materials and Methods

Site and Land Preparation

The experiments were carried out in 1 ha coconut bearing land in Kuta, 2 km from the sea at 10 m elevation. The average annual rainfall is 1832 mm distributed mainly during the November to April rainy season (Steel and Humphreys 1974). The coconut trees are about 30 years old and are planted at approximately 10 × 10 m spacing. For many years the area has been cropped with cassava, green beans, peanuts, corn, and sweet potato. Recently, some parts have been used to evaluate various tropical legumes introduced to Bali.

The soil is a loamy fine sand (10 YR 3/2) overlaying loamy coarse carolline sand (7.5 YR 4/4) at 80–90 cm, with pH ranges from 6.5 to 8.5 at 0–80 cm depth (Steel and Humphreys 1974). The soil organic matter is 0.27% (Supardjata et al. 1974) and the water table is at 1.5–4.0 m.

The area was ploughed twice at 14 day intervals, hand weeded, and then hand ridged into raised beds (plots) 20 cm high. Spacing between plots was 1 m. Plot size in experiments 1 and 3 was 2 × 2 m, in experiment 2, 3 × 3 m.

Cassava Stick and Stylo Seed

The sticks were cut from 10 month old cassava (*Manihot esculenta* var. *valenca*) obtained locally. Each 25 cm stick was planted perpendicular to the ground at 10 cm depth. Except in experiment 2, the sticks were planted at 80 × 80 cm spacing.

Stylo (*Stylosanthes guyanensis* cv. *schofield*) seeds obtained from Jember (East Java) were used. They were scarified mechanically and sown at the rate of 5 kg/ha. The seeds were not inoculated, and were sown 2 weeks after the cassava planting. Except in experiment 1, the seeds were sown midway between the cassava in a windrow direction at 1 cm depth.

Experimental Design

Each experiment was carried out in a complete randomized design. Measurement of the height and number of leaves was carried out at 4-week intervals. At the same time, density of the stylo was measured in a 0.5 × 0.5 m quadrat. Stylo was harvested at 10 cm height. Plots with cassava without stylo were kept weed-free. The outermost plants were treated as a guard row and were not included in the measurements. After harvest, a proportional sample of leaf, stem, petiole, and tuber was dried at 70 °C to a constant weight for dry matter (D.M.) determination.

Experiment 1 was carried out to compare different methods of sowing stylo in relation to cassava. The treatments consisted of cassava alone and cassava + stylo using five methods of sowing stylo under cassava (broadcast, windrow, crisscross, drill midway between the

Table 1. Effect of method of sowing stylo under cassava on tuber yield and on cassava + stylo shoot.

Method of sowing stylo	D.M. yield of tuber (g/m^2)[a]	Number of tubers/m^2	D.M. yield of cassava + stylo shoot[b] (g/m^2)
No stylo (control)	41.57a	8.22a	224a
Broadcast	21.86b	3.75b	295b
Windrow	20.29b	3.64b	250a
Crisscross	28.14b	5.14f	297b
Drill midway	22.71b	7.14c	243a
Drill at diagonal crossing	45.29a	7.99c	307b
S.E.M.	3.26	0.34	3.19

[a]Values in the same column followed by different letters are significantly different ($p = 0.05$).
[b]Stem + petiole + leaf blade.

two cassava, and drill at diagonal crossing of the four cassava) with seven replications in each treatment. Except for the broadcast, depth of sowing was 1 cm. The cassava sticks were planted on 13 September 1974, the cassava and stylo were harvested when the cassava was 26 weeks old (1 March 1975). Stylo regrowth and volunteer species invading the plot without stylo were harvested 16 weeks later (2 July 1975).

Experiment 2 studied various planting densities of cassava and stylo. The factorial design consisted of three combinations (cassava, stylo, and cassava + stylo), three spacing (40 ×40, 60 × 60, and 80 × 80 cm), and 12 replications. The cassava and cassava + stylo combination resulted in a 40 × 40, 40 × 80, 60 × 60, 60 × 120, 80 × 80, and 80 × 160 spacing with a density of 5.44, 2.67, 2.78, 1.67, 1.78, and 0.89 plant/m^2, respectively for the cassava. The cassava sticks were planted on 15 September 1974, the cassava and stylo were harvested when the cassava was 41 weeks old (27 June 1975). Light intensity under the cassava canopy was measured by photocell light metre and leaf areas of the cassava were measured by planimetre.

Experiment 3 compared the response to nitrogen (N), phosporus (P), potassium (K), and trace elements (T). It consisted of volunteer species (no cassava and no stylo); cassava alone fertilized with nothing, N, NPK, and NPKT; cassava + stylo fertilized with nothing, PK, and PKT; and stylo alone (12 replications each treatment). The elements were applied (kg/ha) as follows: N as urea at 165, P as triple superphosphate at 150, K as KCl at 85, and T as $CuSO_4 \cdot 5H_2O$ at 8, $ZnSO_4 \cdot 5H_2O$ at 8, $MnSO_4 \cdot 7H_2O$ at 21.8, $Na_2MoO_4 \cdot 2H_2O$ at 0.24, and $Na_2B_4O_7 \cdot 10H_2O$ at 4.5. Major elements were mixed thoroughly with soil and then broadcast on the plots. Trace elements Cu, Zn, Mn, Mo, and B were dissolved in water and then applied evenly on the plots. The cassava sticks were planted on 15 September 1974; the cassava and stylo were harvested when the cassava was 41 weeks old (29 June 1975).

Statistical Analysis

Data were subjected to analysis of variance (Snedecor and Cochran 1967). When a significant difference was detected ($p < 0.05$) it was evaluated by the new Duncan multiple range test (Steel and Torrie 1960).

Results

Methods of Sowing Stylo (Experiment 1)

Undersowing cassava with stylo at diagonal crossing did not significantly affect tuber D.M. yield (Table 1). On the other hand, sowing stylo by the other methods reduced tuber D.M. yield by 32.3–51.2% compared with that of the cassava sown without stylo. The crisscross method of sowing exerted the least effect and the windrow method the most.

In terms of cassava shoot growth, cassava undersown with stylo at diagonal crossing yielded 7.9% more shoot D.M. than that of cassava sown without stylo. This was due mainly to the increase in D.M. of the leaf and petiole, whereas the stem D.M. did not significantly vary. The other methods of sowing stylo decreased the shoot D.M. yield of the cassava

Table 2. Effect of plant density and stylo on tuber yield and on cassava + stylo shoot.

Spacing	Cassava density (plants /m²)	Combination	D.M. yield of tuber (g /m²)[a]	Number of tubers /m²	D.M. yield of cassava + stylo shoot[b] (g /m²)
40 × 40	5.44	cassava	614a	8.01a	543a
40	—	stylo	—	—	656bg
40 × 80	2.67	cassava + stylo	737b	9.27b	1006c
60 × 60	2.78	cassava	566a	6.87c	464f
60	—	stylo	—	—	633b
60 × 120	1.67	cassava + stylo	689b	7.96a	904c
80 × 80	1.78	cassava	583a	5.64f	395n
80	—	stylo	—	—	626b
80 × 160	0.89	cassava + stylo	420c	3.91g	705g
S.E.M.			6.74	0.16	18.16

[a]Values in the same column followed by different letters are significantly different ($p = 0.05$).
[b]Stem + petiole + leaf blade.

by 17.4 to 31.3% compared with that of cassava sown without stylo. Of the cassava plant parts, the leaf was affected the most, whereas the stem and petiole varied according to the treatments. Method of sowing has no significant effect on the number of leaves and height of the cassava.

Stylo sown in broadcast produced similar shoot D.M. to stylo sown crisscross, but 86.5, 85.6, and 35.6% more than stylo sown windrow, drill at diagonal crossing, and drill midway, respectively.

Although in most cases, the cassava + stylo combination decreased the shoot D.M. yield of individual species, the combined cassava + stylo shoot D.M. yields were 8.6–37.0% greater than that of cassava sown without stylo. This increase was mainly due to the change in the D.M. of the stem.

Four months after termination of the experiment, the volunteer species invading the plots formerly cultivated with cassava sown without stylo produced 30.7 g D.M./m² and the stylo regrowth produced 7.8–12.7 times this amount.

Plant Density (Experiment 2)

Reducing the cassava density from 5.44 to 2.67 plants/m² by sowing stylo in the location of the cassava row significantly increased the tuber D.M. yield by 20.1% (Table 2). Reducing the density from 2.78 to 1.67 plants/m² resulted in a similar trend, but a further reduction from 1.78 to 0.89 resulted in a 28.0% reduction in tuber D.M. yield. In the absence of stylo, reducing the cassava density from 5.44 to 2.78 and to 1.78 plants/m² did not significantly affect the tuber yield. In the case of the cassava + stylo combination, reducing the cassava density from 2.67 to 1.67 plants/m² had no significant effect, but a further reduction from 1.67 to 0.89 decreased shoot D.M. yield by 39.1%. The change in the tuber D.M. yield was mainly due to the tuber number, whereas the tuber size (length and diameter) did not consistently vary.

Reducing the cassava density from 5.44 to 2.67, 2.78 to 1.67, and 1.78 to 0.89 plants/m² by replacing the cassava with stylo decreased the shoot D.M. yield by 12.2, 7.3, and 30.3%, respectively. The effect of varying density on the D.M. yield of the cassava plant parts (stem, petiole, and leaf) followed the shoot D.M. pattern. The reduction in the leaf D.M. yield was partly due to the reduction in the size and number of leaves.

Increasing the stylo spacing from 40 to 60 and 80 cm did not significantly affect the shoot D.M. yield of the stylo. However, increasing the stylo spacing from 40 to 80, 60 to 120, and 80 to 160 cm by sowing cassava in the row space of the stylo significantly decreased the shoot D.M. yield of the stylo by 19.4, 24.0, and 31.7%, respectively. In the case of the cassava + stylo combination, increasing the spacing from 40 × 80 to 60 × 120 cm decreased the D.M. yield of the stylo shoot by 10.2%, whereas increasing from 60 × 120 to 80 × 160 cm had no significant effect. Number of tillers was not consistently affected by the spacing.

Although the cassava + stylo combination

Table 3. Effect of fertilizer and stylo on tuber yield and on cassava + stylo shoot.

Combination	Fertilizer	D.M. yield of tuber (g/m²)[a]	Number of tubers/m²	D.M. yield of cassava + stylo shoot[b] (g/m²)
volunteer species	none	—	—	90a
cassava	none	729ab	7.37ac	408b
stylo	none	—	—	675g
cassava + stylo	none	628b	6.57b	876c
cassava	N	821ac	8.00a	452b
cassava	NPK	1014c	9.06a	459b
cassava	NPKT	714ab	6.99bc	401b
cassava + stylo	PK	674b	6.92b	989cf
cassava + stylo	PKT	713ab	7.00b	1002f
S.E.M.		2.74	0.72	1.26

[a]Values in the same column followed by different letters are significantly different ($p = 0.05$).
[b]Stem + petiole + leaf blade.

decreased the shoot D.M. yield of the individual species, the combined cassava + stylo D.M. yields were 29.7 to 85.1% greater than that of cassava sown without stylo. The wider the spacing the smaller the D.M. discrepancies.

Fertilizer Response (Experiment 3)

The addition of N and NPK to the cassava plot (without stylo) increased the tuber D.M. yield by 12.6 and 39.1%, respectively, more than that of cassava without fertilizer application (Table 3). The addition of NPKT had no significant effect. Undersowing cassava with stylo reduced the tuber D.M. yield by 13.9% compared with the cassava sown without stylo. Application of fertilizer PK or PKT to the cassava + stylo plots alleviated this yield reduction. The change in tuber D.M. yield was due mainly to the tuber number, to a lesser extent to tuber diameter, whereas tuber length had no significant effect.

Undersowing cassava with stylo resulted in a 12.5% reduction in shoot D.M. yield compared with that of cassava sown without stylo. The addition of either PK or PKT alleviated this yield depression. The height of the cassava and its plant parts (stem, petiole, and leaf) were not consistently affected by these treatments.

The cassava + stylo combination reduced shoot D.M. yield of the stylo by 23.1% compared with that of stylo sown without cassava. The addition of PK or PKT to the cassava + stylo plots did not alleviate this growth depression. Tiller number, but not tiller height, of the stylo was significantly increased by the fertilizer treatments.

The cassava + stylo combination produced shoot D.M. twice that of the cassava sown without stylo, and 9.7 times that of the annual species that grew in the plots without cassava and/or stylo.

Discussion

According to Nitis and Sumatra (1976), sowing stylo under cassava at diagnoal crossing produced 14% more tuber D.M. than cassava sown without stylo. The smaller response (9%) in this study is presumably due to the poorer soil in which nutrient competition started to become important. Method of sowing stylo, plant density, and fertilizer response trials support this suggestion. The coconut trees might not exert any significant effect, because Steel and Humphreys (1974) have shown that pasture growth contiguous to coconut trees is similar to that farther from these trees. Furthermore, Nitis et al. (1975) have shown that coconut trees undersown with improved pasture and grazed by cattle produce 18% more nuts than the coconut trees without pasture and cattle.

Enyi (1973) reported that increasing the cassava density increased the tuber yield and that the calculated optimal density for maximum yield was 1.60 plants/m². The present study confirmed this finding, and showed that tuber D.M. yield can be increased by 26% by increasing the cassava density from 1.78 to 2.67 plants/m^2, provided the latter is undersown with stylo. The stylo might contribute some nitrogen (Anonymous 1967), but not enough to maximize yield. The greater tuber D.M. yield of cassava fertilized with nitrogen than cassava undersown with stylo supports this suggestion.

Cassava undersown with stylo and harvested at 10 months produced 0.17 ton less tuber D.M. than cassava sown without stylo. On the other hand, the cassava + stylo combination produced about 10 tons/ha/year more shoot D.M. than cassava sown without stylo. This roughage would feed 2 or 3 head of Bali cattle. The loss in cassava yield would therefore be compensated for by the additional supply of livestock feed. Farmers, who otherwise cannot afford to keep cattle because of a shortage of livestock feed, would be able to keep one pair of cattle for their mixed farming practices.

Experiments are now underway in Bali to study the effect of livestock manures, different species of tropical legumes, graded levels of potassium and sulfur, and density-fertilizer combinations on the yield of cassava undersown with stylo. Factors such as frequency and height of cutting the stylo merit further study. It is anticipated that knowledge from the cassava-stylo work will contribute to the current research input, which according to Nestel (1974), is still too low in terms of the value of cassava and its growth potential.

The authors wish to express their appreciation to the Governor of Bali province for the CESS Grant for financial support, and the Dean of Faculty of Veterinary Science and Animal Husbandry, Udayana University for facilities. The assistance of Mr Kusumah, Mr Kreped, Mr Wiradnya, Miss Indrawati, and Mr Ngenteg for technical work and Miss Astri for typing are acknowledged with pleasure.

Anonymous. *Nitrogen from tropical legumes.* Rural Res., Commonwealth Scientific and Industrial Research Organization, No. 59, 1967, p. 29.

Enyi, B. A. *Growth rates of three cassava varieties (Manihot esculenta Crantz) under varying population densities.* J. Agric. Sci. Camb. 81, 1973, 15.

Humphreys, L. R. *A guide to better pastures for the tropics and sub-tropics.* Second edition. Wright, Stephenson & Co. Ltd., Melbourne, 1969.

Nestel, B. *Current trends in cassava research.* International Development Research Centre, Ottawa, IDRC-036e, 1974.

Nitis, I. M. *Livestock feed supply and livestock feed requirement in Bali* (English summary). Udayana Univ., Denpasar, Bali, F.K.H.P. Bull. 012, 1967.

Nitis, I. M., and Sumatra, I. G. *The effect of fertilizer on the growth and yield of cassava undersown with Stylosanthes at Penebel, Bali.* Udayana Univ., Denpasar, Bali, F.K.H.P. Bull. 048, 1976.

Nitis, I. M., and Nurbudi, K. D. *The growth of Stylosanthes in the Island of Bali.* Dinas Peternakan Prop. Bali, Report Series, 1975.

Nitis, I. M., Rika, K., Supardjata, M., Nurbudi, K. D., and Humphreys, L. R. *Productivity of improved pastures grazed by Bali cattle under coconuts: a preliminary report.* Dinas Peternakan Prop. Bali, Report Series, 1975.

Snedecor, G. W., and Cochran, W. G. *Statistical methods.* Sixth edition, Iowa State Univ. Press, Ames, Iowa, 1967.

Steel, R. J. H., and Humphreys, L. R. *Growth and phosphorus response of some pasture legumes sown under coconuts in Bali.* Trop. Grassland, 8(3), 1974, 171.

Steel, R. G. D., and Torrie, J. H. *Principles and procedures of statistics.* McGraw-Hill Book Co., New York, 1960.

Supardjata, M., Winaya, D. P., and Nitis, I. M. *Laporan short course on tropical pasture.* Udayana University, Denpasar, Bali, Report Series, 1974.