Cassava Planting for Biomass Production and Soil Quality in the Cassava + Maize Intercropping System

Wani H. Utomo[1], Erwin I. Wisnubroto[2], and R. H. Howeler[3]
[1]Research Centre for Tuber and Root Crops, Brawijaya University, Malang, Indonesia
[2]Tribhuwana Tunggadewi University, Malang, Indonesia
[3]CIAT Emeritus, Cali, Columbia
Email: wanihadi@ub.ac.id

***Abstract*—Three years of cassava + maize intercropping experiments were conducted to study the effect of planting cassava for forage production on cassava forage and root yields and on soil quality. The experiments were also designed to minimize the decrease of soil quality due to planting cassava for forage production. The experimental treatments include two cassava plant spacings (1.0×0.8m and 1.0×0.4m) and four different level of nitrogen fertilizer application (135; 180; 235 and 270kg N/ha). As the control treatment, cassava was planted without any pruning during the cassava crop cycle. These nine treatments were arranged in a Randomized Block Design with three replications. The results indicate that regular pruning of cassava plants for forage production decreased soil quality, especially soil carbon and soil nitrogen. Application of nitrogen fertilizer increased forage yield; however, the increase in nitrogen rate from 225 to 270kg N/ha did not further increase forage yield. The application of additional nitrogen fertilizer did not maintain soil quality. Indeed, application of nitrogen fertilizer could minimize the decrease of soil nitrogen, but it could not avoid the decline of crop yield. With the highest nitrogen rate, after three years of planting cassava + maize in an intercropping for forage production system, the crop yields obtained at 1.0×0.8m spacing were: 3.24t/ha for the intercropped maize; 14.08t/ha for cassava roots; and 6.48t/ha cassava forage. The yield of the first year of these treatments was: 3.97t/ha for maize; 18.09t/ha for cassava roots; and 7.73t/ha cassava forage.**

***Index Terms*—soil carbon content, nitrogen fertilizer, maize yield, mixed cropping**

I. Introduction

Cassava is one of the most common crops planted in Indonesian upland agriculture. Under normal conditions, this crop has a comparative economic advantage over other crops like sugarcane cultivated on the same land [1]. However, due to oversupply of cassava production, the price of cassava is sometimes very low resulting in farmers suffering losses in their agricultural business. To minimize this risk, some researchers have developed other uses of cassava. Ref. [2] used hay of cassava leaves for ruminant feeding during the dry season. In Central Vietnam, [3] used cassava leaves as a protein source for pig feeding.

Studies by [2] and [4] indicate the positive prospect of planting cassava for both root and leaf production. Ref. [1] reported that planting cassava for forage production in a cassava + maize intercropping system increased farmers' income. However, these authors found that the yield of maize, cassava roots and cassava forage decreased markedly during the second year. The decrease in crop production is reasonable because cassava removes a large amount of plant nutrients from the soil, especially potassium (K) and nitrogen (N) [5], [6]. The additional harvest of cassava biomass (in this case cassava leaves for forage) would increase the removal of plant nutrients from the cassava farming system, especially nitrogen. The harvesting of 6 tons of cassava dry leaves having an N-concentration of about 4.5% [1], would result in the removal of an additional 240kg N/ha.

Considering these phenomena, it is clear that N fertilization is very important in planting cassava for forage production. The application of nitrogen is expected to not only increase the yield of the various crops, but also to minimize the decline in soil quality, and therefore, that the yields of the following year crops could be maintained at their normal level. To test this hypothesis, an experiment of planting cassava for forage production with various nitrogen fertilization treatments in a cassava + maize intercropping system was conducted for three consecutive years at the Brawijaya University field station at Jatikerto, Malang, Indonesia.

II. Materials and Method

A. Experimental Setup

The experiments were conducted for three consecutive years on the same field at the experiment station of Brawijaya University, in Jatikerto, Malang, East Java, Indonesia. The soil is classified as an Alfisols and has a clay-loam texture, pH of 6.95, soil organic matter of 2.79%, and total nitrogen content of 0.18%.

The experimental treatments include: 1.) cassava plant spacing (1.0×0.8m and 1.0×0.4m) and 2.) N fertilizer

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application (135; 180; 235 and 270kg N/ha). As a control treatment, cassava was also planted without any leaf pruning, but with leaves (with the young branches) was harvested at the time of the root harvest and weighed as a source of cassava leaf forage. These individual treatments (total of 9 treatments) were arranged in a Randomized Block Design with 3 replications.

B. Cassava Intercropping System

Cassava was planted in an intercropping system with maize as the intercrop in a plot of 6.0×4.0m. In accordance with the treatments, stakes of the cassava variety UB 1442 were planted either at a distance of 1.0×0.8m or at 1.0×0.4m. The hybrid maize, variety Pioneer P 21 was planted (1 plant/hole) in between cassava rows, at a distance of 1.0×0.25m. The cassava and maize were both planted at the same date.

The plants were fertilized with 100kg P_2O_5/ha and 100kg K_2O/ha, and N fertilizer in accordance with the corresponding treatments. All dosage of P, K, and ¼ of N were applied at the time of planting. The rest of the nitrogen fertilizer was given at 30 days after planting (¼ dosage), at the harvest of maize (¼ dosage), and after the second cassava prunning (¼ dosage).

Excluding the control treatment, all cassava plants were pruned four times: the first prunning was done at the same time with harvesting the maize intercrop (at 110 days after planting), the second and third pruning were done at 30 and 60 days after the first prunning. The fourth pruning was done at the same time with the cassava root harvest (the first year cassava was planted at 305 days after planting, the second year cassava at 315 days after planting, and the third year cassava at 310 days after planting) Pruning was done by cutting the whole plant tops at a height of 20cm from the ground; this included mainly the newly sprouted young stems and leaves with petioles.

C. Plants Measurements

Yield data were collected of total cassava dry forage (sum of four pruning or one cut in case of the control treatment), fresh cassava roots and dry maize grain yield (t/ha), as well as soil quality indicators. To study the changes of soil qualities, the soil carbon (C) and N contents was measured before the start of the experiment and after the third year cassava harvest. Soil samples were taken to a depth of 20cm, with about 0.5kg taken from 5 sub-samples from each plot. The samples were then processed for soil organic matter and nitrogen analysis in the laboratory. Soil organic matter was determined by the method of Walkley and Black [7], and soil N was determined with the Kejldahl method [8].

III. Result and Discussion

A. Cassava

The cassava forage yield was significantly influenced by plant spacing and the rate of nitrogen application (Table I). Increasing the nitrogen application rate significantly increased the forage yields at both plant spacings and in all years of planting. However, the extent of the increase was different. In the first year, the cassava forage yield increased with increasing N application rate up to 225kg N/ha; the further increase in application rate did not significantly influence the cassava forage yield. For the third year crop, on the other hand, an increase in N application rate up to 270kg N/ha still significantly increased the cassava forage yield. It seems that in the first year the soil nitrogen content was still relatively high, and therefore the application rate of 225kg N/ha was enough to fulfill the nitrogen requirements of the crops. There was a decrease in soil nitrogen content in the third year, and as a consequence, the N fertilizer requirement increased.

The decrease in soil nitrogen content decreased the yield of cassava forage in all treatments. The results in Table I also show that increasing the nitrogen application rate decreased the decline of the cassava forage yield. In the treatment of 135kg N/ha application, the decrease in forage yield of the third year crop was about 32% (for both plant spacing) compared to the first year yield. Increasing nitrogen rate to 270kg N/ha application the forage yield decrease was only 16% at the plant spacing of 1.0×0.8 m, and 29% at the spacing of 1.0×0.4m. The decrease of the forage yield for the control treatment was about 14%.

TABLE I. Effect of Nitrogen Rate on Dry Cassava Forage in Cassava + Maize Intercropping for Forage Production

Treatments		Dry forage yield (t/ha)		
Cassava plant spacing (m×m)	Nitrogen rate (kg/ha)	First year	Second year	Third year
1.0×0.8	135	3.14 c	3.40 c	2.15 e
	180	4.32 c	4.25 c	3.90 cd
	225	6.27 b	5.90 b	5.84 ab
	270	7.73 ab	6.90 ab	6.48 a
1.0×0.4	135	4.18 c	3.38 c	2.85 de
	180	5.19 b	4.27 c	2.80 de
	225	6.32 ab	6.35 b	4.38 bc
	270	9.07 a	7.90 a	6.40 a
Control (1.0×0.8; no pruning)	135	2.27 d	2.10 d	1.95 e

*) value means followed by the same letters in the same column are not significantly different (*P*>0.05)

The results presented in Table II show that the root yields of cassava planted for forage production were significantly lower than in the control treatment. In the first year the root yield of the control treatment was 35.48t/ha; this was far higher than the yield of cassava planted for forage production, i.e. 12.27t/ha for the 1.0×0.4m plant spacing and 10.11t/ha for the 1.0×0.8m spacing. Pruning of cassava leaves will decrease the plant parts used for photosynthesis, and this practice will therefore decrease the root yield [9]. Application of more N fertilizer in cassava for forage production increased the root yield, but this still remained far below that of the control treatment. The root yield of the 270kg N/ha treatment was only 20.57 for the 1.0×0.4m plant spacing and 18.09t/ha for the 1.0×0.8m spacing. The root yield of the control treatment for the same year (third year) was 35.48t/ha.

TABLE II. EFFECT OF NITROGEN RATE ON CASSAVA YIELD PLANTED FOR FORAGE PRODUCTION IN CASSAVA + MAIZE INTERCROPPING SYSTEM

Treatments		Tuber yield (t/ha)		
Plant spacing (m×m)	Nitrogen rate (kg/ha)	First year	Second year	Third year
1.0×0.8	135	10.11 d	8.46 d	5.75 d
	180	13.62 cd	10.25 d	7.38 cd
	225	15.82 c	16.86 bc	12.84 b
	270	18.09 bc	16.30 bc	14.08 b
1.0×0.4	135	12.27 cd	8.35 d	6.28 cd
	180	15.81 c	14.30 c	8.35 c
	225	19.02 bc	18.26 bc	14.34 b
	270	20.57 b	19.38 b	15.85 b
Control (1.0×0.8; no pruning)	135	35.48 a	34.24 a	28.40 a

*) value means followed by the same letters in the same column are not significantly different (*P*>0.05)

Previous studies have shown that planting cassava continuously on the same field resulted in a significant decrease in cassava root yield [5], [10]. This phenomenon also occurred in these experiments. The results in Table II show that for the control treatment, the root yield of the first year cassava crop was 35.48t/ha, and decreased to 28.40t/ha for the third year cassava crops. Planting cassava for forage production accelerated the decrease of cassava root yield. The yield decrease could be as high as 43% (for plant spacing 1.0×0.8m, 135kg N/ha treatment). Harvesting cassava forage would increase the removal of nitrogen from the soil and applied fertilizer. To produce 3.14-4.18t/ha dry cassava forage (see Table I), with a nitrogen concentration of about 4% [1] will remove an additional amount of about 120-160kg N/ha.

Furthermore, the results in Table II also show that in addition to increasing the root yield, increasing the rate of nitrogen application also decreased the yield decline of the following year cassava crop. The yield decrease of the 270kg N/ha a treatment was only 22% for the 1.0×0.8m spacing and 23% for the 1.0×0.4m spacing. Thus, applying a high rate of N fertilizer could decrease the rate of yield decline for the following crops.

B. *Maize*

The maize yield data are presented in Table III. In the first year crops, planting cassava for forage production in a cassava + maize intercropping system did not significantly influence the yield of the intercropped maize. This is to be expected because maize was harvested before the pruning of cassava. In the second and third year, however, different phenomena were observed. In these years, planting cassava for forage production in a cassava + maize intercropping system significantly reduced the yield of the intercropped maize.

TABLE III. EFFECT OF NITROGEN RATE ON MAIZE YIELD PLANTED IN CASSAVA BASED INTERCROPPING FOR FORAGE PRODUCTION

Treatments		Grain yield (t/ha)		
Cassava plant spacing (m×m)	Nitrogen rate (kg/ha)	First year	Second year	Third year
1.0×0.8	135	3.68 a	2.58 b	2.05 cd
	180	3.97 a	3.15 ab	2.70 bc
	225	4.04 a	3.40 a	3.05 ab
	270	3.97 a	3.70 a	3.24 ab
1.0×0.8	135	2.97 b	2.15 c	1.90 d
	180	3.17 b	2.48 c	2.30 cd
	225	3.05 b	2.70 bc	3.05 ab
	270	3,43 ab	3.05 abc	2.50 cd
Control (1.0×0.8; no pruning)	300	3.63 a	3.48 a	3.60 a

***)** value means followed by the same letters in the same column are not significantly different (*P*>0.05)

The results in Table III also show that during the first year the yield of maize in the control treatment was 3.63t/ha; this is not significantly different from the yield of maize with forage production (given 135kg N/ha) at plant spacing of 1.0×0.8m (3.68t/ha), but was significantly higher than at the spacing of 1.0×0.4m (2.97t/ha). In the second and third year, the maize yield in the forage production system varied from 1.90t/ha (plant spacing of 1.0×0.4m, third year) to 2.58t/ha (plant spacing of 1.0×0.8m; second year), which are significantly lower compared to the maize yield in the control treatment.

It seems that in the first year, the limiting factor for maize was only soil nitrogen content, not the cropping system. This argument was supported by the result of the second and third year experiment in which maize yield decreased drastically. By planting cassava for forage production, in addition to removing cassava roots there was also the removal of cassava forage. Harvesting cassava forage would drastically increase the uptake of nitrogen from the soil, and therefore would influence the growth and yield of cassava and maize in subsequent crops. As discussed before, removing 3.14-4.18t/ha of dry cassava forage would remove an additional amount of nitrogen of about 120-160kg N/ha.

Furthermore the results in Table III show that in the year 1, 2, and 3, maize yields increased with increasing rates of nitrogen application. However, the extent of the increase was not the same. In the first year and at 1.0×0.8 m plant spacing, maize yields increased up to the application rate of 225kg N/ha; a further increase in application rate did not significantly increase maize yields. In years 2 and 3, on the other hand, maize yields increased steadily up to the highest rate of 270kg N/ha.

Again, these phenomena indicate that there was a decrease in soil nitrogen content due to cassava forage harvesting.

C. *Soil Quality*

After three consecutive years of this experiment, the soil organic matter content in the cassava + maize intercropping system was lower (1.67-1.7.8% OM) compared to the initial soil organic matter content (2.79%). Similarly, the soil-N content in all treatments decreased from the initial soil-N content of the corresponding soil (Table IV), at the rate of 30-50% from the initial N-content of 0.18%. Despite the increasing soil-N content following the application of N fertilizer (Table IV), the additional N input did not significantly increase the soil organic matter content in both plant spacing treatments (Table IV). The application of N fertilizer did increase the soil-N content; however, this was not followed by an increase in soil organic matter content. This was due to the removal of cassava biomass as forage, which resulted in little or no organic matter input to the soil.

TABLE IV. EFFECT OF NITROGEN APPLICATION RATE ON SOIL QUALITY INDICATOR AFTER 3 YEARS PLANTING IN CASSAVA + MAIZE INTERCROPPING FOR FORAGE PRODUCTION

Treatments		Soil quality indicator	
Cassava plant spacing (m×m)	Nitrogen rate (kg/ha)	Organic matter (%)	Nitrogen (%)
1.0×0.8	135	1.67 b	0.05 d
	180	1.85 b	0.07 c
	225	1.56 b	0.09 b
	270	1.49 b	0.08 bc
1.0×0.4	135	1.78 b	0.06 cd
	180	1.12 b	0.07 c
	225	1.45 b	0.09 b
	270	1.45 b	0.08 bc
Control (1.0×0.8; no pruning)	300	2.67 a	0.12 a

*) value means followed by the same letters in the same column are not significantly different ($P > 0.05$)
**) soil organic matter and nitrogen content before planting were 2.79% and 0.18% respectively

The results presented in Table IV give warning that we should be extra careful planting cassava for forage production, because this practice could drastically decrease soil quality, especially soil organic matter. Application of inorganic fertilizer could not avoid the decrease of soil quality. If we are intending to plant cassava for forage production, addition of organic materials is strongly recommended. The use of resistant organic resources, such as biochar would be more advantageous [11]-[13].

IV. CONCLUSION

The experimental results discussed here show that planting cassava for forage production in a cassava + maize intercropping system accelerated the decrease of soil quality. Increasing the application rate of nitrogen fertilizer to the cassava + maize intercropping system increased the yield of all harvested parts. Indeed, application of nitrogen fertilizer could minimize the decrease of soil nitrogen, but at the rates used in this experiment it could not avoid the decline of crop yield as well as the soil organic matter content. Furthermore, soil management, such as addition of organic materials together with N-fertilizers could be a potential solution to avoid the decline in crop yield and soil quality, as well as maintain a sustainable cassava production for forage system.

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Wani Hadi Utomo is professor at University of Brawijaya, Malang, Indonesia. He got his Agricultural engineer degree from University of Brawijaya, Malang, Indonesia in 1974 and his PhD from Adelaide University, Australia, in 1981.
His interest is Soil Management, especially Soil and Water and conservation. He works on cassava since 1982. Lately he works on the management of degraded land, especially the use of biochar to improve soil quality. He also works in the restoration of mining land with the use of phytoremediation technology.

Erwin Ismu Wisnubroto is lecturer at Tribhuwana Tunggadewi, Malang, Indonesia. He received his Bachelor of Science in Agriculture from the University of Brawijaya, Malang Indonesia in 2007.
He graduated from Massey University, Palmerston North – New Zealand after completing the Post Graduate Diploma course in soil science (2010), and M. Phil in soil science, majoring in soil carbon (2015). Research interest includes: agriculture management for soil carbon sequestration, soil and water conservation, and sustainability farming production.

Reinhardt Howeler was born in Indonesia but grew up in the Netherlands. After completing his undergraduate degree in Tropical Agriculture he immigrated to the US, where he continued his study, obtaining a PhD degree in soil chemistry from Cornell University.
He joined CIAT in Cali, Colombia in 1970, and the newly formed cassava program in 1972, conducting numerous greenhouse and field experiments to determine the nutritional requirements of the crop, and how to manage cassava without causing serious erosion. In 1986 he moved to the CIAT office in Bangkok, Thailand, where, during the following 23 years he worked closely with researchers, extension workers and farmers in practically all cassava growing countries in the region, to develop better soil and crop management practices, and enhance their adoption by using a Farmer Participatory Research (FPR) methodology.