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Increasing Productivity of Yam (*Dioscorea esculenta*) through Improved Cultural Management Practices

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Abstract

Yams (*Dioscorea*) are among the food sources in the country especially in times of food scarcity. *D. esculenta*, locally known as *tugui*, is one of two species, which are economically important in the Ilocos Region. *Tugui* thrives well in marginal areas and is considered as a cash crop by upland farmers. To date, no production technology has been developed for this crop; as such, productivity is relatively low at 2.6t ha^{-1}- 3.3t ha^{-1} in farmers' fields. Assessment of yam farmer's current production practices shows the need to fine-tune some of its components. The most critical of them are fertilizer and seed management. Hence, field experiments were conducted to improve the existing cultural management practices for increased yam production.

It was found that *tugui* can be successfully grown for three consecutive years without using fertilizer, as *tugui* farmers have been practicing ever since, with yields comparable with those applied with organic and inorganic fertilizers. Nevertheless, a declining trend in soil fertility of the unfertilized plots, implying the depletion of the soil's natural fertility, which might cause the drastic decline in yield after three consecutive cropping seasons. However, applying two tons of organic fertilizer per hectare was found to sustain high yield and maintain the residual fertility of the soil after continuous cropping. With this, the capacity of the soil to produce high yield is sustained; therefore, shifting cultivation, a common practice among *tugui* growers, is minimized. In addition, the use of bigger setts (40-89 g) was found to significantly produce more vigorous plants and higher crop stand, resulting to an increase in yield by 138% as compared to the farmers' practice of using small setts.

Keywords: *yam, marginal area, improving cultural management practices*

Introduction

Yam (*Dioscorea*) is an important food source especially in rural communities. Traditionally, yam is a minor rootcrop, a low priority commodity. These crops thrive well in marginal areas where the more important crops cannot be successfully grown. Yam is a very important crop for food security because of its excellent storage properties; it can be stored four to six months without refrigeration and it provides an important food safety net between growing seasons. *Dioscorea esculenta*, grown in the Indian subcontinent, in southern Vietnam, in the South Pacific islands, and in the Philippines is one of the most nutritious yams (http://www.croptrust.org/main). Recent research studies have shown that *tugui* can also be processed and cooked into various food

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products. The acceptability of processed yam as a functional ingredient in food products was evaluated and found to be an excellent substitute to modified starches and a functional ingredient for low pH processed food like sauce and salad dressing (Amani *et al*, 2004).

Traditionally, yam is grown with minimal or no intervention at all and thrives well in marginal areas. However, this growing condition explains the very low yield obtained in farmers' field, which is only around 2.6t ha^{-1} - 3.3t ha^{-1} (BAS, 2002). Hence, one way to increase yam production is to improve its existing production management. In Papua New Guinea, Ernest and O'Sullivan (2003) studied the effect of improved fallow and live-staking of yam using *Gliricidia sepium*. Results from four trial sites showed no difference in yield attributable to staking system, while NPK fertilizer increased yield by 50% (from 18.6 to 27.9t/ha) in two Bogia District sites, but not in two Markham Valley sites (http://www.cropscience.org.au). Moreover, in Diby's study in Ivory Coast, the leaf area index (LAI), tuber diameter and final yield of two yam species were influenced by fertilizer application and soil characteristics. The values for these parameters were significantly increased in the most fertile soil (forest site); however, the soil effect was more marked for *D. alata*. Fertilizer application enhanced the yield in the Savannah site, whereas slight or even negative fertilizer responses were recorded in the forest site (http://www.cropscience.org.au/ics2004). Elfick (2008) recommends that yams planted in soil, which has just been cleared from bush does not usually need any fertilizers. If the soil has had yams or other crops growing in it before, it is advisable to apply it with some fertilizers (http://www.uq.edu.au/School_Science_Lessons).

The production statistics of yam, especially *tugui* (*D. esculenta*) points to Ilocos region as the top grower. In fact, half of the yam produced in the country comes from the Ilocos. Majority of the upland farmers in Ilocos Norte consider *tugui* as a cash crop, being one of the only few crops that can be successfully grown in sloping and marginal areas. However, production is limited to only about 3.3t $ha\text{-}^{1}$. Based on the feedback of farmers, the absence of a recommended technology for yam largely contributes to its low yield.

Assessment on the existing farmers' cultural management practices prompts the need to fine-tune some of its components, particularly on nutrient and seed management. In Ilocos Region, yam farmers do not apply fertilizer on their plants, that is why they need to look for a new area to plant their crop after at least three years of continuous cropping in the same area due to the possible drastic decline in yield. This is the reason why uplanders cannot do away with shifting cultivation or commonly known as "*kaingin*" system, which in turn has a hazardous effect to the environment. Another contributory factor to the low yield is the use of planting materials or setts, averaging about 20-30g. As observed, farmers sell their quality produce while they set aside small and non-marketable ones for household consumption and some are set aside as planting materials. In selecting seed stock, it is a general rule that the premium produce should be chosen as planting materials to ensure quality. In line with that, several of field experiments have been conducted to develop or improve existing management practices that could be integrated as package of technology (POT) components for yam.

Methodology

Experiments that fine-tune yam farmers' cultural management practices were done from 2006 to 2009 in order to develop a technology that could increase the productivity of this crop. In three years, field experiments were conducted to improve the existing management practices, which could increase yam production via fertilizer application and seed management. Except for the specified treatments, management practices employed in conducting the field experiments were based on the Standardized Techniques for Rootcrops Evaluation developed by the Rootcrops Varietal Improvement Group of the National Seed Industry Council. The detailed methodology for each experiment is presented next.

Response of tugui to fertilizer application. Traditionally, farmers never applied fertilizer to their *tugui* crops. However, they claimed a drastic decline in yield after two to three consecutive years of planting in the same area. To draw a scientific basis of this observation, an experiment, which assumed that the drastic decline in yield is due to the depletion of the natural soil fertility after three consecutive years of cropping without using any fertilizers was done. The same area was used for each treatment in three cropping seasons. Soil samples before and after each cropping were taken for analyzed.

In the experiment, three fertilizer treatments were evaluated: T_1 – Inorganic (30-30-30 kg N, P_2O_5, K_2O/ha); T_2 – Organic (2 tons/ha); and T_3 – No fertilizer application. The experiment was laid-out in Randomized Complete Block Design (RCBD) with three replications. The experimental unit was a 15 m^2 plot, with three rows each, spaced at 1m apart while each experimental unit was spaced 2m apart; hence, there was a total of 30 hills per plot. The fertilizer treatments were basally applied. Meanwhile, the setts were planted at 0.50m in between. Hilling-up was done two months after planting (MAP) and stakes were provided for each hill, which served as anchor for the vines. Weeding was done whenever necessary. The plants were harvested at 10 MAP.

Effect of the sett size on yam yield. This experiment assumed that one factor contributing to the low yield of farmers is the use of small setts. Hence, the experiment used different seed sizes as treatments: big (>90g), medium (40-89g), and small (<40g). The study was laid-out in RCBD with three replications. The experimental unit was a 15m^2 plot with three rows, each spaced at 1m apart, with a total of 30 hills per plot. Fertilizer was basally applied at a rate of 30-30-30kg N, P_2O_5, and K_2O ha^{-1}. Moreover, the setts were planted at 0.50m apart. Hilling-up was done at 2 MAP and stakes were provided for each hill to serve as anchor for the vines. Weeding was done whenever necessary. Eventually, the plants were harvested at 10 MAP.

Results and Discussion

Response of *Tugui* to Fertilizer Application

Generally, it was found that there were no significant differences among treatments across all parameters observed. Percentage of hills harvested was high in all cropping seasons (Table 1). Notably, yield during the first year of the experiment was lowest on plots applied with inorganic fertilizer although differences were very nil and were not significantly different among treatments. Highest yield (t ha^{-1}) was obtained in the second year with an average of 15-17t ha^{-1} wherein unfertilized plots produced the highest yield (17.44t ha^{-1}). In the third year however, the decline in yield was very apparent particularly on plots applied with organic fertilizer and those that were not applied with fertilizers (13.58t ha^{-1} and 13.63t ha^{-1}, respectively).

The decrease in yield on plots applied with organic fertilizer, which was a little bit lower than the plots without fertilizer, was expected because the conversion period in organic farming is about 3-5 years. This means that the effect of the organic fertilizer, which was applied could hardly be manifested yet in the crop's performance in the first cropping years. That is entirely different from the 'boom and bust' pattern observed when using inorganic fertilizer.

Further, the average number of tubers per hill was noted and findings indicate that more tubers were produced in the second year regardless of the treatments. It was likewise observed that plots applied with inorganic fertilizer produced the most number of tubers during the third year.

Data on average tuber weight show that bigger tubers were produced in the second year of trial. Interestingly, data gathered further show that plots without fertilizer application produced the biggest tubers in the first two years of the experiment. In the

Table 1. Percent hills harvested and computed yield (t ha^{-1}) of *tugui* as affected by organic and inorganic fertilizer application, MMSU, Batac, I. Norte.

TREATMENT	HILLS HARVESTED (%)			COMPUTED YIELD (t ha^{-1})		
	Y1	Y2	Y3	Y1	Y2	Y3
	ns	ns	ns	ns	ns	ns
Inorganic	82.22	98.88	93.33	10.74	15.67	16.01
Organic	91.11	93.33	85.55	11.86	16.86	13.58
No Fertilizer	94.44	93.33	93.33	11.80	17.44	13.63

ns – not significant

first year, the said treatment produced tubers with an average weight of 74.31g as compared with those applied with fertilizer, which had an average weight of less than 60g. In the second year, plots without fertilizer produced tubers with an average weight of 77.7g while those applied with inorganic and organic fertilizer had an average weight of 70.39g and 66.34g, respectively. In the third year however, plants without fertilizer produced the smallest tubers (50.18g) as compared with those applied with inorganic (57.21g) and organic fertilizers (56.73g).

The highest percentage of marketable tubers in terms of number and weight was the direct result of the bigger tubers produced in the second year of trial (Table 3). That result follows the general trend that unfertilized plants, which registered the highest percent marketable tubers in the last two years, eventually had the lowest in the third year.

Congruent to farmers' claim, results imply that *tugui* can be successfully grown in newly-cultivated areas without applying any fertilizers as evidenced by their higher though comparable yield with the fertilized ones. Moreover, unfertilized plants were able to produce high yield, which was comparable with the fertilized plants (either

Table 2. Average number of tubers per hill and average tuber weight (g) of *tugui* as affected by organic and inorganic fertilizer application, MMSU, Batac, Ilocos Norte.

TREATMENT	AVE. NUMBER OF TUBER/HILL			AVE. TUBER WEIGHT (g)		
	Y1	Y2	Y3	Y1	Y2	Y3
	ns	ns	ns	ns	ns	ns
Inorganic	8.94	10.27	16.53	59.89	70.39	57.21
Organic	10.51	11.60	15.87	56.41	66.34	56.73
No Fertilizer	8.29	11.53	15.13	74.31	77.70	50.18

ns – not significant

Table 3. Percent marketable tubers (by number and weight) of *tugui* as affected by organic and inorganic fertilizer application, MMSU, Batac, Ilocos Norte.

TREATMENT	PERCENT MARKETABLE (NO)			PERCENT MARKETABLE (WT)		
	Y1	Y2	Y3	Y1	Y2	Y3
	ns	ns	ns	ns	ns	ns
Inorganic	26.07	39.74	26.94	48.56	66.57	51.78
Organic	27.49	35.94	26.08	51.51	66.55	49.03
No Fertilizer	34.13	45.23	22.98	52.35	70.92	48.91

ns – not significant

organic or inorganic) for three consecutive years. This is attributed to the natural soil fertility, which provided enough nutrients for the plants within the experimental period. This result concurs with Elfick's observation, which prompted him to recommend that yams planted in soil, which has just been cleared do not usually need any fertilizers. However, if the soil has been used to grow yams or other crops earlier, fertilizer application is recommended (http://www.uq.edu.au/ School_Science_Lessons).

After the third year of the experiment, natural soil fertility was depleted (Table 4). Generally, highest reduction in soil nutrient content was observed on plots applied with inorganic fertilizer and those not applied with fertilizers. In terms of organic matter reduction, the highest was recorded in unfertilized plots. However, the difference in percent reduction with treatments applied with inorganic fertilizer was very nil. Similar trend was observed in terms of nitrogen reduction. Nevertheless, phosphorus content of plots applied with organic fertilizer increased while that of the plots under the other two treatments decreased by 35%. Meanwhile, highest percent reduction in potassium was observed in unfertilized plots. Although plots applied with inorganic and those not applied with fertilizers had almost the same fertility status after three years, a relatively high yield was still obtained by the former. This means that the plants were able to convert the applied supplemental fertilizer into economic returns.

Further, soil analysis results show that plots applied with organic fertilizer had the highest residual soil fertility after three years. This implies the capacity of the soil to sustain yield, which was comparable with those applied with inorganic fertilizer for the succeeding years. Although the yields obtained in unfertilized plots were comparable, their fertility declined. Such trend may cause a drastic reduction in yield during the succeeding years, most especially if supplemental fertilizer is not applied.

Table 4. Soil fertility analysis before and after the conduct of the fertilizer experiment on *tugui*, MMSU, Batac, Ilocos Norte.

TREAT-MENT	OM		N		P		K	
	(%)	% reduction	(%)	% reduction	(ppm)	% reduction	(ppm)	% reduction
Before the Experiment	1.89		0.0945		31.95		1054.13	
After 3 Years								
Inorganic	1.216	35.66	0.0608	35.66	20.77	34.99	490.11	53.50
Organic	1.516	19.78	0.0758	19.78	38.37	-20.09	493.35	53.19
No Fertilizer	1.203	36.34	0.0601	36.40	20.58	35.58	408.30	61.26

Additionally, soil analysis results show that plots applied with organic fertilizer had the highest residual soil fertility results after three years. This implies the capacity of the soil to sustain yield, which was comparable with those applied with inorganic fertilizer for the succeeding years. Although the yields obtained in unfertilized plots were comparable, their fertility declined. Such trend may cause a drastic decline in yield during the succeeding years, most especially if supplemental fertilizer is not applied.

Effects of Sett Sizes on Yam Yield

Yam farmers' practice using smaller tubers or setts caused their low production. Result of the experiment shows comparable treatment effect in most of the observed parameters. As recorded at 2 MAP, the highest percent emergence, was obtained on medium-sized setts (88.89%). However, this was comparable with the big setts having an average of 84.44% (Table 5). Meanwhile, small setts significantly had the lowest emergence with an average of 61.11%.

In addition, percent hills harvested was comparable in all treatments. In fact, a decline in plant survival was evident in all treatments, which could be attributed to the heavy sustained rainfall during the growth stages of the crop. In terms of vigor, big and medium setts significantly produced more vigorous plants while small setts produced less vigorous ones. This could be due to the fact that bigger tubers have more stored food to sustain the growing seedlings while their roots are not yet fully developed. Hence, seedlings produced from bigger tubers have an advantage over those from smaller ones at the early growth stages.

As shown in Table 6, treatment effects on yield components were not significant in terms of the average number of tubers per hill, average weight of tubers, and

Table 5. Percent emergence, percent hills harvested, and plant vigor of tugui as affected by sett size, MMSU, CY 2008-2009.

TREATMENT	EMERGENCE (%)	HILLS HARVESTED (%)	PLANT VIGOR[1]
	*	ns	*
BIG	84.44[a]	81.11	8.30[a]
MEDIUM	88.89[a]	77.77	7.70[a]
SMALL	61.11[b]	52.21	5.70[b]
CV (%)	10.96	22.60	9.25

Means followed by the same letter are not significantly different at 1% level by DMRT.
* - significant at 5% level
[1]Vigor: 9 – very vigorous to 1 –very poor vigor
ns - not significant

average yield per hill. Nevertheless, numerical values show that bigger setts produced plants, which were more superior than those coming from the smaller ones. The average number of tubers per hill ranged from 6.87-8.51, with medium setts having the highest. On the other hand, average weight of tubers ranged from 47.60g to 62.20g while average yield per hill was 321.30g to 502.30g. The bigger setts produced heavier tubers and the highest yield per hill. This trend was followed by the medium ones.

Inspite of the comparable treatment effects on yield components, significant difference was observed on computed yield per hectare (Table 7). Big and medium setts significantly produced the highest yield with an average of 8.00t ha^{-1} and 7.69t ha^{-1}, respectively. Lowest yield was obtained on small setts with only 3.23t ha^{-1}, which was interestingly comparable with yields obtained by the farmers. No significant difference was observed on percent marketable tubers although small setts numerically produced the least marketable tubers.

Table 6. Average number of tuber per hill, average weight of tubers, and average yield per hill of *tugui* as affected by sett size, MMSU, CY 2008-2009.

TREATMENT	AVE. NO. OF TUBER PER HILL	AVE. WEIGHT OF TUBERS (g)	AVE. YIELD PER HILL (g)
	ns	ns	ns
BIG	8.04	62.20	502.30
MEDIUM	8.51	59.62	497.30
SMALL	6.87	47.60	321.30
CV (%)	24.56	15.09	21.96

ns - not significant
Means followed by the same letter are not significantly different at 1% level by DMRT.

Table 7. Computed yield, and percent marketable tubers (by number and weight) of *tugui* as affected by the size of sett, MMSU, CY 2008-2009.

TREATMENT	COMPUTED YIELD (t ha^{-1})	PERCENT MARKETABLE TUBER BY NUMBER	PERCENT MARKETABLE TUBER BY WEIGHT
	*	ns	ns
MEDIUM	7.69^a	37.36	63.53
SMALL	3.23^b	24.78	50.75
CV (%)	26.36	19.51	14.08

* - significant at 5% level   ns - not significant
Means followed by the same letter are not significantly different at 1% level by DMRT.

Conclusions and Recommendations

Tugui can be grown without the use of inorganic input; hence, its hazardous effects to human and animal life and the environment are limited. Although applying inorganic fertilizers sustains high yield, it is not significantly different from those applied with organic fertilizer and those without fertilizer. On the other hand, soil fertility analysis shows that applying organic fertilizer sustains soil fertility, which prompts farmers to plant the crop in the same area without any fear of drastic yield decline. With this, shifting cultivation is avoided and its negative effect to ecological balance is abated. In addition, the use of medium setts produced plants with better growth and significantly increased yield by 138%, which is equivalent to an ROI of 1.69.

Additionally, *tugui* production offers a source of additional income to farmers. Although the computed net income is relatively low considering that it matures in at least 10 months, it should be noted that this crop thrives well in areas where more important crops can hardly be grown productively. Hence, planting yam in idle and marginal areas would make them productive and would eventually offer an opportunity to farmers particularly those in the uplands, to augment their income from yam production.

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