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Full Length Research

Productivity and nutrient use efficiency of yam bean (*Pachyrhizus erosus* L. Urban) genotypes in Ilocos Norte, Philippines

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A field experiment was conducted in three sites of Ilocos Norte, Philippines from March 2008 to March 2009: to evaluate the growth and yield performance of yam bean genotypes grown at different sites; determine the nutrient-use efficiency of yam bean genotypes grown at varying fertilizer treatments; and, compute for the cost and return analysis of the different yam bean genotypes grown at varying fertilizer treatments and sites in Ilocos Norte.
The experiment was laid out in split-plot design with fertilizer treatments (control, organic, 50% organic fertilizer + 50% inorganic fertilizer) as the main-plot factors and genotypes (G1, G2, G3, G4 and G5) as the sub-plot. Results were tested and compared across three sites.
Generally, fertilizer significantly affected yield and yield contributing characters in all sites but not all with genotypes.
In site 1, fertilizer significantly affected days to germinate, flower and mature as well as root characteristics, Crop Growth Rate, Dry Matter Production, Harvest Index, yield and Potassium uptake, PFPN and AEN while the rest were not significantly affected. The application of 50% OF + 50% IF with G3 was found out to be best in this site with
In site 2, fertilizer significantly affected days to germinate, flower, and mature, shoot fresh and dry weights, yield, N uptake and PFPN. The use of 50% OF + 50% IF with G3 and G4 was also found to be beneficial for it results to best with regards to yield and yield characters as well as nutrient efficiencies.
For Site 3, as was observed, OF application to the plants resulted to best plant performance and returns, and the genotype best for the area was G4 or G1.
To improve yield and other plant characters as well as enhance soil fertility conditions, the use of organic fertilizer can be done since this is the cheapest, locally available, and gives high returns.

Keywords: genotypes, productivity, yambean, organic fertilizer (OF), inorganic fertilizer (IF)

INTRODUCTION

Yam bean is one of the Neotropical legume genera with edible tuberous roots. It is extensively cultivated, both as a garden crop, and on a large scale for export.

In the Philippines, this crop is popularly grown particularly in Luzon areas specifically in northeastern areas like Ilocos Norte, produces high root yields of 25-40 t ha^{-1} to as high as 60 t ha^{-1}, and seed or grain yield of 4-5 t ha^{-1} (BAS, 2005). Currently, the area planted is not so wide, 24.30 ha (BAS POC Ilocos Norte, 2009) although it is periodically increasing due to attention being given because of its potential as source of additional income especially in its processed forms.

The Bureau of Agricultural Statistics Provincial Office (BASPO) of Ilocos Norte noted that there are different genotypes being grown with variable sizes and shapes at different sites in Ilocos Norte. Specifically, there are five genotypes observed being grown and sold in the local market, and in other provinces and regions that have not been identified and characterized for maximum yields and adaptability under varying growing conditions.

Yam bean root contains 32% soluble sugars and 15% starch as storage carbohydrates on dry basis (Paul and Chen, 1988). The functional properties of yam bean starch, allows it to be used as potential source of starch (Melo et al., 2003

The seeds are characterized by high oil (20-28%) and protein (23-34%) contents. Seed oil contains high concentrations of palmitic (25-30% of the total fatty acids), oleic (21-29%), and linoleic acids (35-40%) (Gruneberg et al., 1999).

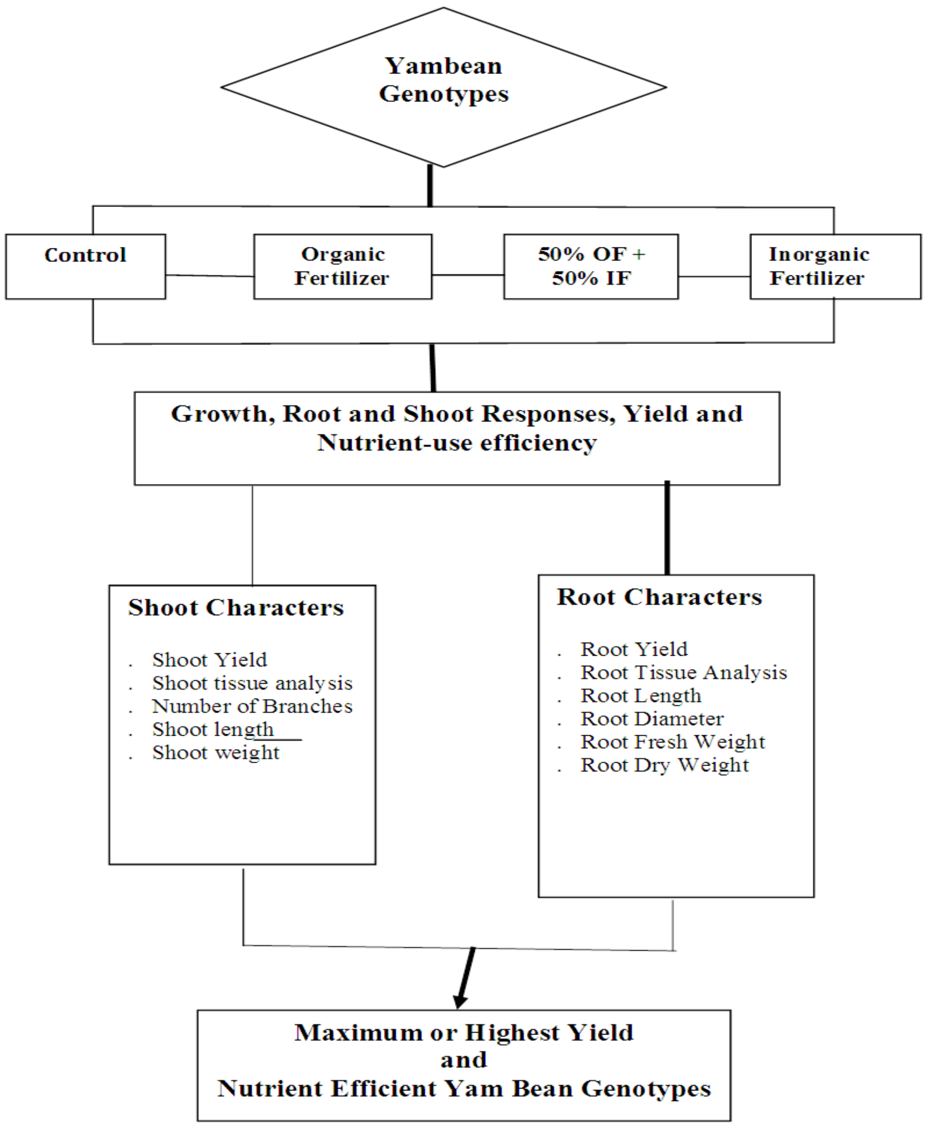
The mature seeds contain up to 26% protein and 30% vegetable oil – a composition comparable to ground nut and cotton seed oils. However, the mature seeds contain up to 0.5% rotenone (an isoflavonoid), an insecticidal compound that makes them inedible but this secondary metabolite can prevent harmful insects in vegetable fields. (Villar and Valio, 1994).

Yam bean genotypes generally survive in all types of soil characteristics, but respond well to the addition of fertilizer materials. In addition, the crop shows favorable response to added nutrient inputs (Sorensen, 1990). In Ilocos Norte, yam bean farmers usually apply inorganic fertilizer to their yam bean plants and it was observed based on record that the yield increased to 47.67 mt ha^{-1} (Table 1) as compared to yield during the last 5 years which was 15-20 mt ha^{-1} (DA PAO, 2009).

With the increasing demand due to the benefits from the crop, there is a need to clearly identify and evaluate these existing genotypes as to where they could fit in for optimum production.

This study was conducted to evaluate the growth and yield performance of yam bean genotypes grown at different sites; determine the nutrient-use efficiency at varying fertilizer treatments; and, compute for the cost and return analysis of the different yam bean genotypes grown at varying fertilizer treatments and sites in Ilocos Norte.

Conceptual Framework of the Study



MATERIALS AND METHODS

Prior to the conduct of the study, a survey was done on the areas where yam bean is commonly grown. The yam bean production in Ilocos Norte (BAS POC, 2009) as shown in Table 1 was considered.

Table 1: Volume of production, area and yield of yam bean in Ilocos Norte (January-June, 2008-2009)

PRODUCTION (mt)		AREA (ha)		YIELD (mt ha^{-1})	
2008	2009	2008	2009	2008	2009
185.27	186.40	24.20	24.30	47.66	47.67

Source:BAS POC Ilocos Norte, 2009

Experimental Variables and Design

The experimental variables were: three (3) sites, five (5) yam bean genotypes and four (4) fertilizer treatments. The three locations represented the three dominant soil series of yam bean growing areas in Ilocos Norte, such as: S_1 – Cabuloan, Sarrat (Umingan Series); S_2 – MMSU, Dingras (San Manuel Series); and, S_3 – San Lorenzo, Bangui (San Fernando Series).

The experiment was laid out in a split-plot design in each site with fertilizer treatments (F)as the mainplot and yam bean genotypes (G) in the subplot. The treatment details were:

Mainplot: Fertilizer treatments

F1 – control (0 fertilizer)
F2 – Dried chicken manure (DCM)
F3 – Dried chicken manure (50%) + Inorganic Fertilizer (50%)
F4 – Recommended Fertilizer (35-60-40 kg NPK ha^{-1})

Subplot: Genotypes (G)

1 – G_1 (119 days growth duration)
2 – G_2 (124 days growth duration)
3 – G_3 (98 days growth duration)
4 – G_4 (120 days growth duration)
5 – G_5 (124 days growth duration)

The four fertilizer treatments were used to evaluate the indigenous nutrient supply of the different soils grown to yam bean and determine the responses of yam bean genotypes to varying levels and sources of fertilizers. The five yam bean genotypes were selected based on their availability and initial performance in the area. Initially, these were characterized using available descriptors' list as shown in Table 2.

Table 2: Some characteristics of yam bean genotypes used in the experiment.

ENTRY	DESCRIPTION
G_1	Green-stalked, brown-colored roots with dark-brown surface color. Medium-sized, monotuberous, semi-round, fairly lobed roots, dentate leaves, flowers light lavender borne in racemes, medium maturing.
G_2	Green-stalked, light-brown and smooth, big root size line without any lobe, flowers are borne alternately with lavender to white in color, big trifoliate leaves borne in just a short vine, late maturing roots.
G_3	Red-stalked, light brown-colored roots, little bit bigger than G_2; lobed roots with dentate leaves, flowers light lavender in color; early maturing roots.
G_4	Dark-green stalk; roots small, a little bit pointed end with strigose hairs; deeply lobed, dark-green leaves; long vines; flowers borne in clusters, deep lavender; medium to late maturing roots.
G_5	Light-green stalk; medium-sized light-brown and smooth, round, monotuberous roots; light lavender flowers borne in racemes.

G: Genotype

Table 3: Energy equivalents of labor, seed and root for yam bean production

INPUT/OUTPUT	ENERGY EQUIVALENT (Mcal/unit)	REFERENCES
Labor (hr)	0.55*	*Pimentel (1980) and Duff (1978)
Seed (kg)[1]	1.70**	** derived from Pimentel, D. 1980 (ed.)
Root (kg)[2]	1.14**	Handbook of Energy Utilization in Agriculture

[1]Energy coefficient of yam bean seeds (Mcal/kg)= Total energy input Mcal/kg ha^{-1}
/Total energy output (yam bean yield) (kg ha^{-1})=5475020/3212928=1.7 Mcal
[2]Energy coefficient of yam bean roots (Mcal/kg)=Total energy input Mcal/kg ha^{-1}
/Total energy output (yam bean yield) (kg $ha^{applied}$)=33789543/29715144=1.14 Mcal

Table 4: Energy equivalents of fertilizer, pesticides, machinery and diesel of yam bean production.

INPUT	ENERGY EQUIVALENT (Mcal/unit)	REFERENCES
Nitrogen	14.3	Locheritz, 1980 in Pimentel's Handbook
Phosphorous	1.6	
Potassium	1.6	
Pesticides (L)	7.61	
Machinery (kg)	18	Summarized from the different sources in Pimentel, D. 1980 (ed) Handbook of Energy Utilization in Agriculture by Mendoza (2008)
Diesel (l)	11.88	

Energy input of machinery and direct diesel energy use of yam bean production are 180 Mcal/ha and 172.10 (L ha^{-1}, respectively (BASILIO, 2000).

Table 5: Physico-chemical properties of the soils from the three sites before the experiment in Ilocos Norte, Philippines. 2008-2009.

Soil Property	Site 1 (Sarrat, Ilocos Norte)	Site 2 (Dingras, Ilocos Norte)	Site 3 (Bangui Ilocos Norte)
pH	6.30	6.23	6.41
Organic matter (%)	1.34	0.90	0.72
Nitrogen, N (%)	0.067	0.045	0.036
Phosphorous,P (ppm)	36.08	17.85	12.54
Potassium, K (ppm)	175.51	135.34	148.73
Texture	Light	Light	Light
Particle size (%)			
sand	13.4	20.4	28.2
silt	35.8	58.0	35.6
clay	50.8	21.6	36.2

Source: Soil survey of Ilocos Norte, Philippines (Mangloñgat et al., 1980)

RESULTS AND DISCUSSION

Soil and Climatic Characteristics of the Sites

Soil Characteristics

Site 1 (Sarrat, Ilocos Norte). The site (Barangay Cabuloan) is 7 km east of Laoag City. It is bounded in the east by the town of Piddig, in the south by San Nicolas, west by Laoag City and north by Vintar. Aside, it is bounded in the north by a mountain traversing from east to west dividing Sarrat from the town of Vintar and south by Padsan river. The soil type used for the study was identified as *Umingan clay loam* with particle size distribution of 13.4% sand; 35.8% silt; and 50.8% clay. Based from the pre-planting soil analysis results conducted by the Bureau of Soils Laboratory-Ilocos Norte, the soil physico-chemical properties of the experimental sites are as follows: pH of 6.30; 1.34% organic matter (OM) content; 0.67% (N); 36.08 ppm (P); and 175.51 ppm K). The soil in the experimental site is light textured and generally well-drained soil (Table 5).

Site 2 (Dingras, Ilocos Norte). Dingras is located $18^0$6'33N latitude and $120^0$41'34E longitude. It is 20 km from Laoag City. The study site (Barangay Madamba) is bounded by the towns of Piddig and Solsona in the north; by Nueva Era in the east; in the south by Marcos; and by Sarrat in the west. *San Manuel silt loam* was identified as the soil type of this site with particle size distribution of 20.4% sand; 58% silt; and 21.6% clay (Table 5).

Site 3 (Bangui, Ilocos Norte). The site is located in the far northern end of the province; bounded in the north by South China Sea; east by the towns of Pagudpud and Dumalneg; west by the town of Burgos; and south by the towns of Vintar. It lies between latitudes $18^0$25' and $18^0$33' N and longitudes $120^0$41' and $120^0$50' E. It is 64 km north of Laoag City. San Lorenzo (the study area) is the barangay at the heart of the town. Bangui consists of mountainous lands which occupy >50% of the total land area. The agricultural lands are predominantly planted to seasonal annual crops such as rice, corn, garlic, lowland vegetables and some legumes as cowpea, mungbean and yam bean. The soil type of this site was identified as *San Fernando clay* with particle size distribution of 28.2% sand; 35.6% silt and 36.2% clay (Table 5).

Table 5: Physico-chemical properties of the soils from the three sites before the experiment in Ilocos Norte, Philippines. 2008-2009.

Soil Property	Site 1 (Sarrat, Ilocos Norte)	Site 2 (Dingras, Ilocos Norte)	Site 3 (Bangui Ilocos Norte)
pH	6.30	6.23	6.41
Organic matter (%)	1.34	0.90	0.72
Nitrogen, N (%)	0.067	0.045	0.036
Phosphorous,P (ppm)	36.08	17.85	12.54
Potassium, K (ppm)	175.51	135.34	148.73
Texture	Light	Light	Light
Particle size (%)			
sand	13.4	20.4	28.2
silt	35.8	58.0	35.6
clay	50.8	21.6	36.2

Source: Soil survey of Ilocos Norte, Philippines (Mangloñgat et al., 1980)

Climatic Characteristics

Generally, Ilocos Norte has a Type 1 climate based on the Corona Classification. Type 1 characterized by two pronounced seasons: dry and wet seasons. However, climatic variables (rainfall, temperature and windspeed) vary across the province (PAGASA, 1998). Data on monthly minimum, maximum and mean temperatures (^{0}C), rainfall (mm), wind speed (ms^{-1}), sunshine (mn^{-1}) in the experimental area during the cropping season (field experimental period) are shown in Table 6.

Site 1 (Sarrat, Ilocos Norte) . The average minimum and maximum temperatures ranged 14.3-23.4 ^{0}C and 33.2-38.0 ^{0}C, respectively. Highest rainfall was recorded in July 2008 (1505 mm) and no precipitation was recorded in December 2009. Wind speed ranged 2-3 ms^{-1} and recorded sunshine ranged 422-647 mn^{-1}. (PAGASA- Laoag City, 2009). There is a slight modification of the climate in this site since Sarrat is bounded by a mountain traversing from east to west.

*Site 2 (Dingras, Ilocos Norte)***.** Prevailing climatic factors are similar to Site 1, since Site 2 is adjacent to Site 1. However, the absence of mountain (features of topography) around the area makes it better for growing crops since the weather is fair as in Site 1 with two distinct dry and wet seasons.

For Sites 1 and 2, the total amount of rainfall received during the cropping season was 2,997.9 mm with monthly average minimum and maximum temperatures of 20.36 and 35.24 ^{0}C, respectively. The average prevailing wind in Sites 1 and 2 is 3.23 m s $^{-1}$

Site 3 (Bangui, Ilocos Norte). The average monthly minimum, maximum and mean temperatures ranged 24.6-28.6^{0}C and 26.2 to 29.9^{0}C, respectively. The highest rainfall was recorded in December with 1879 mm. Prevailing wind speed recorded ranged 5.79 to 12.35 ms^{-1} with recorded average of 8.01 m s $^{-1}$. The total rainfall received during the cropping period was 3,230.78 mm, with average monthly minimum and maximum temperatures of 26.44 and 28.03 ^{0}C respectively (NWPDC-BBWPP, 2009).

While yam bean favorably grow and have high yields at optimum temperatures of 24^{0}C and a well-drained soil (Siemonsma and Piluek, 1993), the climatic factors during the cropping season for the experimental Sites 1 and 2 were within optimum temperature range but within upper limit. On the other hand, the minimum temperature in Site 3 was within the upper limit. In addition, the soil in Site 3 contains high proportion of sand (28.2%) and windy condition with windspeed of 8.01 ms^{-1}. This also contributed to the quick drying of the soil in this site, thus may affect the growth and development of the plants.

Days to Germination, Flowering and Maturity of Yam Bean Genotypes

Site 1 (Sarrat, Ilocos Norte). Days to germination in yam bean plants was significantly affected by fertilizer treatment in Site 1 (Table 7). Days to germination in this Site was observed at 4-6 days. Seeds applied with organic fertilizer germinated earlier (4 DAP), followed by the control plants (5 DAP) and the latest to germinate was by those plants applied with inorganic fertilizer. Genotype did not significantly affect days to germination of the yam bean plants. However, Genotypes 1, 2 and 4 germinated 5 DAP while Genotype 3 and Genotype 5 germinated at 6 DAP.

Table 6: Climatic data during the experimental period from March 2008 to March 2009. Sarrat, Dingras and Bangui, Ilocos Norte

Year/Month	Temperature (^0C)		Rainfall (mm)	Prevailing Wind Speed (ms^{-1})	Sunshine (mn^{-1})
	Minimum	Maximum			
SITE 1 and 2*					
2008 MAR	16.4	35.5	0	2	584.8
APRIL	22.1	36.3	0.1	3	646.8
MAY	23.2	35.6	65.8	3	549.4
JUNE	23.3	38.0	36.2	3	535.2
JULY	22.9	34.2	1505.1	3	363.2
AUG	22.2	34.8	805.6	3	347.7
SEPT	23.4	35.2	478.1	3	450.9
OCT	22.3	35.6	38.5	2	481.6
NOV	20.0	34.4	68.4	3	422.2
DEC.	16.0	34.2	0	3	500.6
2009 JAN	14.3	33.6	Trace	3	464.8
FEB	17.5	35.0	Trace	2	510.0
MAR	21.1	35.7	0.1	3	602.1
SITE 3**					
2008 MAR	27.9	28.05	0	6.89	No record
APRIL	26.22	27.46	Trace	7.56	
MAY	26.54	28.78	0.1	10.02	
JUNE	28.59	29.9	0	5.79	
JULY	24.78	26.67	0	7.01	
AUG	25.01	26.89	5.2	7.89	
SEPT	27.56	28.76	26.4	8.12	
OCT	27.20	29.76	189.56	7.24	
NOV	25.66	26.90	876.12	8.51	
DEC	25.94	28.18	1879.4	8.41	
2009 JAN	24.58	26.17	234	12.35	
FEB	26.01	27.52	20	7.21	
MAR	27.79	29.38	Trace	7.17	

*** Source:** PAGASA, Laoag International Airport, Ilocos Norte, 2009
****Source:** North Wind Power Development Corporation Bangui Bay Wind Power Project, 2009

Days to flowering was not significantly affected by fertilizer treatments (Table 7). However, applied with inorganic fertilizer as well as control plants flowered earlier than the other fertilizer treatments. Days to flowering differed with genotypes. Among the genotypes, Genotype 4 flowered the latest (82 DAP) as compared with the other genotypes that flowered 78 (Genotypes 2 and 3) and 79 (Genotypes 1 and 5) DAP.

Fertilizer treatments significantly affected days to maturity. Plants matured the earliest in control treatments, while plants applied with organic fertilizer matured the latest (97 DAP). Among the genotypes, Genotype 3 was the earliest to mature (92 DAP), while the latest to mature was Genotype 4 (99 DAP).

In Site 1, OF application was found out to shorten germination, flowering and maturity. The addition of OF had probably contributed to the improvement of the soil since it is high in clay (Table 5). The porosity has been improved and thus contributed to proper drainage in the soil, in addition to its OM content as source of additional nutrients for proper growth of the plants. For the genotype that flowered the earliest across fertilizer treatments, this could be a genotype characteristics being an early maturing type (98 DAP).

Site 2 (Dingras, Ilocos Norte). Fertilizer treatments significantly affected days to germination of the yam bean plants (Table 7). The plants germinated 4-5 days after planting in plants applied with 50%OF + 50%IF, the earliest to germinate. With regards to genotypes, days to germination was not significantly affected although Genotype 4 and Genotype 5 germinated the earliest (4 DAP), which could be a genotype characteristics.

Flowering was significantly affected by both fertilizer treatments and genotypes. 50%OF + 50%IF application resulted to earliest flowering of the plants with 76 DAP, while the rest of the treatments flowered at the same time (80 DAP). Among the genotypes, Genotype 3 flowered the earliest with 75 DAP while Genotype 5 was the latest to flower (82 DAP)

The days to maturity was significantly affected by both fertilizer ad genotypes. Control plants matured the earliest while those with OF matured the latest with 102 DAP. Among the genotypes, Genotype 3 matured the earliest with 97 DAP and the latest was Genotype 4.

In Site 2, the soil and climatic characteristics favored the performance of the genotypes. That the particle size distribution of sand, silt and clay (20.4, 58 and 21.6% respectively) is just balanced. Such that the use of 50% OF + 50% IF is the best for this type of site with sufficient amount of soil OM that favored the activity of microorganisms and formation of soil aggregates which improved the soil structure favorable for crop growth and development.

Site 3 (Bangui, Ilocos Norte). Days to germination was not significantly affected by fertilizer. The yam bean plants germinated longer (by 3-4 days) as compared to Sites 1 and 2. Genotypes on the other hand significantly affected days to germination. Genotype 1 was the earliest to germinate (8 DAP) while Genotype 2 the latest with 10 DAP.

Fertilizer treatments did not affect days to flowering of yam bean plants in Site 3. Control plants flowered the earliest (82 DAP), while it differed with genotype wherein Genotype 1 flowered the earliest in this site.

Days to maturity was not significantly affected by fertilizer treatments, but significantly differed in test genotypes, wherein Genotype 1 was the earliest to mature in this site. In this site, it was found out prior to planting that the area is slightly different from the two sites. Pre-planting soil analysis indicated that the area is low in OM (0.71%) and has high proportion of sand (28.2%) as compared to the other sites (Table 5). These factors in addition to strong winds visiting the area contributed to condition wherein the area could easily dry up at the different stages of crop growth and development.

The application of 50% organic fertilizer (OF) + 50% inorganic fertilizer with organic fertilizer (OF) in Site 3. The combination of OF and IF hastened germination and flowering, OF application alone prolonged the days to maturity.

Table 7: Days to germination, flowering and maturity of yam bean genotypes grown with different fertilizer treatments at three sites in Ilocos Norte. 2008-2009 Cropping Season

GENOTYPE	Days to Germination														
	Site 1 (Sarrat, Ilocos Norte)					Site 2 (Dingras, Ilocos Norte)					Site 3 (Bangui, Ilocos Norte)				
	C	OF	50% OF + 50%IF	IF	Mean	C	OF	50%OF + 50%IF	IF	Mean	C	OF	50%OF + 50%IF	IF	Mean
1	5	5	6	5	5	6	6	4	7	6 a	8	8	8	9	8 c
2	5	3	6	6	5	5	6	4	5	5 ab	9	10	10	10	10 a
3	4	6	7	6	6	4	7	4	6	5 ab	8	10	9	9	9 b
4	4	4	5	5	5	5	3	4	5	4 b	10	8	10	10	9 b
5	6	4	7	7	6	5	5	4	3	4 b	9	9	9	10	9 b
MEAN	5 bc	4 c	6 a	6 ab		5 a	5 a	4 b	5 a		9	9	9	9	
	F: Pr >F=0.0018 ; LSD= 0.96					F: Pr > F = 0.0277 ; LSD = 1.0					F: Pr > F= 0.3151 ; LSD = 0.82				
	G: Pr > F= 0.0617; LSD=1.07					G: Pr > F= 0.1057 ; LSD = 1.24					G: Pr > F= 0.0322 ; LSD=0.92				
	F X G: Pr > F =0.4445					F X G: Pr > F = 0.3190					F X G: Pr > F = 0.4774				
Days to Flowering															
1	79	82	75	78	79 ab	84	84	80	80	82 a	78	83	84	80	81 b
2	77	80	82	73	78 b	80	80	77	82	80 ab	84	84	84	83	84 a
3	73	78	83	77	78 b	76	77	74	74	75 c	84	84	84	83	84 a
4	83	81	84	82	82 a	82	82	80	81	81 a	82	84	84	84	84 a
5	77	82	77	82	79 ab	80	77	71	82	77 c	84	85	84	84	84 a
Mean	78	80	80	78		80 a	80 a	76 b	80 a		82 b	84 a	84 a	83 ab	
	F: Pr > F= 0.2273 ; LSD =1.85					F: Pr > F= 0.0124 ; LSD = 2.65					F: Pr > F = 0.0732 ; LSD =1.57				
	G: Pr > F = 0.0607; LSD = 3.45					G: Pr > F= 0.0033 ; LSD = 2.96					G: Pr > F = 0.0067 ; LSD = 1.75				
	F x G: Pr > F =0.0629					F X G: Pr > F = 0.4163					F X G: Pr > F = 0.6541				
Days to Maturity															
1	95	98	97	97	97 b	100	103	102	102	102 ab	119	119	119	120	119 b
2	94	97	95	94	95 bc	99	102	100	99	100 bc	121	121	121	121	121 a
3	92	93	92	93	92 d	97	98	97	98	97 d	119	121	120	120	120 ab
4	97	103	97	98	99 a	102	108	102	103	104 a	121	119	122	122	121 a
5	92	95	95	93	94 cd	97	100	101	98	99 cd	120	120	121	121	121 ab
Mean	94 b	97 a	95 b	95 b		99 bc	102 a	100 b	100 b		120	120	121	121	
	F: Pr > F = 0.0114 ; LSD = 1.85					F: Pr > F = 0.0170 ; LSD = 1.93					F: Pr > F = 0.3179 ; LSD = 1.15				
	G: Pr > F = 0.0001 ; LSD = 2.07					G: Pr > F = 0.0481 ; LSD = 2.16					G: Pr > F= 0.0481 ; LSD = 1.28				
	F X G: Pr > F = 0.7767					F X G: Pr > F = 0.7221					F X G: Pr > F = 0.5001				

Within a column (G means) and/or within a row (F means), means followed by different letters are significantly different at 5% level of significance by LSD.

Root Characteristics of Yam Bean Genotypes

The parameters used in evaluating root characteristics were root length, root diameter, root fresh weight and root dry weight. These were taken at harvest time from 10 randomly selected plant genotypes from each treatment plot to determine the effect of different fertilizer treatments the different genotypes in each site. Results are shown in Table 8.

Site 1 (Sarrat, Ilocos Norte). Root length and root diameter were affected by fertilizer treatments but not for root fresh weight and root dry weight (Table 8). Root characteristics did not differ in genotypes as well as on the interaction between fertilizer and genotype.

In this site, plants applied with organic fertilizer had the longest root length (19.54 cm) and biggest root diameter (95.14 cm). This was followed by the plants applied with 50% OF + 50% IF (19.17 cm and 94.44 cm, respectively), while the smallest were those plants with inorganic fertilizer with 17.86 and 86.75 cm, respectively. However, for root fresh and dry weight, plants applied with 50% OF + 50% IF had the heaviest (133.71 and 10.49 g, respectively), while the lowest was observed from plants applied with inorganic fertilizer with 115.05 and 8.87 g, respectively. Among the genotypes, genotype 1 had relatively the best root growth characteristics.

The results show that bigger and longer roots cannot be directly equated to heavier root weights. Organic matter contributed to the increase in size but not on weight. Instead a combination of 50% OF + 50% IF produced the heaviest root weights.

The characteristics of the soil in this site could have contributed to the root development. This site is high in clay proportion, that addition of OF alone probably had helped in the improvement of its aggregates that could have contributed to higher infiltration. Moreover, it has relatively high (1.34%) OM content such that there is an increase in microbial activity for N-fixation by the plant being a legume resulting to high N content which is important in cell elongation and growth, thus with longer length and diameter. While soil K is high in this site. Thus may have contributed to heavier root weight (fresh and dry) resulted, and thus the plants responded to additional OF and OF-IF combinations.

Site 2 (Dingras, Ilocos Norte. The different root parameters were not significantly affected by fertilizer treatments or genotypes as well as the interaction of fertilizer treatment and genotype in this site. The same trend was observed with respect to fertilizer treatment as in Site 1. The use of organic fertilizer alone produced the longest roots, bigger in diameter, while an application of 50% OF + 50% IF resulted to heavier root weights (fresh =178.51 g, dry = 14.28 g). This was followed by plants applied with inorganic fertilizer with 174.59 g and 12.92 g, respectively. Among the genotypes, genotype 3 had the best with longest and heaviest roots, i. e., in terms of length and diameter, respectively with 22.99 cm and 107.25 cm, and root fresh weight and root dry weights with 171.38 and 13.71 g, respectively. The lowest values of root fresh weight and root dry weight were obtained in the unfertilized plot with 158.06 and 12.64 g, respectively.

Generally, similar trend of results were observed in this site compared with Site 1. Considering the soil characteristics, the proportion of particle size however, Site 2 has lower clay content but with higher silt content which is favorable for growth of yam bean, particularly on the root development. It has available moisture with proper air circulation and drainage, and with addition of organic fertilizer, or in combination with inorganic fertilizer, can maintain the favorable characteristics of the soil to support a good crop growth. The most adapted genotype in this site is Genotype 3.

Site 3 (Bangui, Ilocos Norte). In this site, no significant effects of fertilizer treatments on all root parameters was observed, while genotypes significantly affected root length (Table 8). No interaction effect between fertilizer treatment and genotype was observed either on root parameters was noted. The application of organic fertilizer in this site resulted to biggest root diameter as well as heaviest root fresh and dry weights with 97.43 cm; 119.75 and 9.55 g, respectively. The lowest root weight values were obtained from plants applied with 50%OF + 50% IF, with 20.32 cm root length, 95.01 cm root diameter; 104. 65 g root fresh weight; and 8.37 g root dry weight, respectively. Among the genotypes, Genotype 4 had the biggest root diameter and heaviest root, while Genotype 2 had the longest root in this site.

This site has slightly different soil characteristics with Sites 1 and 2. It has low OM and high proportion of sand thus prone to water deficit and uneven rainfall distribution in the area contributed to conditions wherein the area easily dries up and plants could have been exposed to longer moisture deficits during their growth and development. The application of organic fertilizer in this site was favorable as shown by adaptive root growth. The favorable effect of OF can be attributed to the improvement of soil texture for proper moisture retention, as well on better microbial population that increased soil clumping and forming of soil aggregates which improves soil structure favorable for root growth.

Among the genotypes, Genotype 4 appeared to have adaptive capacity (in terms of root growth parameters).

Shoot Characteristics of Yam Bean Genotypes

Shoot characteristics of yam bean genotypes were evaluated using the parameters: number of branches, shoot fresh weight and shoot dry weight. These were taken from 10 randomly selected sample plants from each of the treatments from each site. Number of branches were counted at harvesting time together with the shoot fresh and dry weights.

Site 1(Sarrat, Ilocos Norte). Table 7 shows the number of branches, shoot fresh and dry weights in yam bean genotypes as affected by fertilizer treatments in three test sites. The number of branches was significantly affected by fertilizer treatments, but not on the shoot fresh and dry weights. The application of inorganic fertilizer (100% IF) produced the highest number of branches (2 branches), but is comparable with the other treatments (1 branch). For the shoot fresh and dry weights, an application of organic fertilizer alone resulted to heaviest weights with 19.68 and 3.74 kg, respectively, compared with the other fertilizer treatments i. e. 50%OF + 50% IF had 18.49 and 3.51 kg, respectively, and the lowest control (unfertilized plants) with 16.58 and 2.95 kg.

The use of organic fertilizer resulted to relatively (ns) higher shoot weights both fresh and dry, which be attributed to the property of this fertilizer material that it does not only improve the quality of the soil but also on the crop through better soil aggregation and moisture retention. For the genotypes, Genotype1 had good branching characteristics (2 branches vs. 1 branch for other genotypes), while Genotype 3 had relatively better production of shoot biomass than the other genotypes.

Table 8: Root characteristics of yam bean genotypes grown with different fertilizer treatments at three sites in IlocosNorte. 2008-2009 CS

GENOTYPE	**Root Length (cm)**														
	Site 1 (Sarrat, Ilocos Norte)					**Site 2 (Dingras, Ilocos Norte)**					**Site 3 (Bangui, Ilocos Norte)**				
	C	**OF**	**50% OF + 50%IF**	**IF**	**Mean**	**C**	**OF**	**50%OF + 50%IF**	**IF**	**Mean**	**C**	**OF**	**50%OF + 50%IF**	**IF**	**Mean**
1	16.78	20.57	21.11	18.08	19.14	22.28	22.98	22.77	23.97	23.00	22.53	22.67	20.67	21.90	21.94
2	18.22	18.88	19.83	17.93	18.72	22.03	23.45	23.97	22.35	22.95	24.25	20.68	21.21	21.98	22.03
3	17.92	20.23	18.73	18.02	18.73	23.23	23.27	22.92	22.53	22.99	20.62	20.95	20.30	19.15	20.25
4	17.95	19.36	18.30	18.43	18.51	23.37	23.25	21.68	22.38	22.67	22.33	22.62	20.17	21.78	21.73
5	20.37	18.65	17.87	16.83	18.43	22.67	21.20	21.28	23.08	22.06	22.08	20.68	19.28	20.27	20.08
Mean	18.25 bc	19.54 a	19.17 ab	17.86 c		22.72	22.83	22.52	22.86		21.96 a	21.52 ab	20.32 b	21.02 ab	
	F: Pr > F = 0.0229 ; LSD = 1.18					F: Pr > F = 0.9224 ; LSD = 1.10					F: Pr > F = 0.0569 ; LSD = 1.22				
	G: Pr > F = 0.8374 ; LSD = 1.32					G: Pr > F = 0.4905 ; LSD = 1.23					G: Pr > F= 0.0083 ; LSD = 1.36				
	F X G: Pr > F = 0.1227					F X G: Pr > F = 0.4899					F X G: Pr > F = 0.6111				
Root Diameter (cm)															
1	86.49	105.42	102.05	86.00	94.99	98.00	109.33	106.67	107.33	105.33	94.00	100.33	94.33	103.00	97.92
2	90.84	90.90	97.00	88.73	91.87	109.33	102.33	105.00	106.67	105.83	97.57	96.00	93.33	94.33	95.31
3	89.67	90.93	95.63	85.33	90.39	105.33	107.00	99.67	102.67	103.67	93.67	92.80	97.67	93.00	94.28
4	88.93	97.03	85.89	92.00	90.96	101.33	110.00	107.33	110.33	107.25	100.67	103.67	103.00	94.00	100.33
5	101.82	91.41	91.60	81.67	91.63	102.33	100.67	98.50	110.40	102.98	95.00	94.33	92.00	90.70	93.00
Mean	91.55 ab	95.14 a	94.44 a	86.75 b		103.27	105.87	103.43	107.48		96.18	97.43	96.07	95.01	
	F: Pr > F = 0.0422 ; LSD = 6.28					F: Pr > F = 0.1583 ; LSD = 4.3					F: Pr > F = 0.9198 ; LSD = 7.04				
	G: Pr > F = 0.7094 ; LSD = 7.02					G: Pr > F = 0.3953 ; LSD = 4.81					G: Pr > F = 0.3467 ; LSD = 7.86				
	F X G: Pr > F = 0.1403					F X G: Pr > F = 0.01675					F X G: Pr > F = 0.9551				
Root Weight (g)															
1	96.13	141.17	176.70	125.00	134.75	135.07	163.03	167.43	175.47	160.25	114.60	117.30	89.63	109.63	107.79
2	110.57	135.58	136.80	121.57	126.13	179.70	152.67	180.10	171.10	170.89	135.13	106.83	98.63	110.20	112.70
3	123.13	122.90	133.20	107.90	121.78	167.50	168.60	188.40	161.03	171.38	109.57	121.83	114.23	103.07	112.18
4	110.43	123.20	117.93	128.80	120.09	152.87	174.10	178.37	178.57	170.98	116.70	136.00	114.30	97.60	116.15
5	177.13	138.90	103.93	92.00	127.99	155.17	149.10	178.27	186.77	167.33	104.40	116.80	118.00	102.73	110.48
Mean	123.48	132.35	133.71	115.05		158.06 b	161.50 ab	178.51 a	174.59 ab		116.08	119.75	106.96	104.65	
	F: Pr > F = 0.4294 ; LSD = 25.68					F: Pr > F = 0.1159 ; LSD = 19.60					F: Pr > F = 0.2600 ; LSD = 17.55				
	G: Pr > F = 0.8524 ; LSD = 28.72					G: Pr > F = 0.8171 ; LSD = 21.88					G: Pr > F = 0.9349 ; LSD = 19.62				
	F X G: Pr > F = 0.1407					F X G: Pr > F = 0.7861					F X G: Pr > F = 0.7417				

Within a column (G means) and/or within a row (F means), means followed by different letters are significantly different at 5% level of significance by LSD.

Site 2 (Dingras, Ilocos Norte). Fertilizer treatment did not significantly affect the number of branches, while significant effects were observed in shoot fresh and dry weights (Table 9). Heaviest shoot fresh (19.09 kg) and dry (3.63 kg) weights were obtained from plants applied with inorganic fertilizer compared with plants applied with organic fertilizer (16.48 and 3.13 g, respectively).

No significant effects were observed in number of branches, shoot fresh and dry weights among genotypes and interaction. It is interesting to note however, that Genotype 2 produced heaviest shoot weight.

Site 3 (Bangui, Ilocos Norte). No significant differences were observed due to fertilizer treatment, genotypes evaluated or interactions. In this site, fertilizer treatment did not affect the number of branches. The use of 50% OF + 50% IF produced relatively (ns) highest shoot fresh and dry weights (9.33 and 1.77 kg), followed by the control plants and lowest were those applied with inorganic fertilizer with 8.89 and 1.69 kg respectively.

The application of 50% OF + 50% IF had improved the shoot weight. The immediate releasing nature of inorganic fertilizer and the beneficial effects of organic fertilizer via improvement of soil texture and nutrient and water retention capacity of the soil (through root growth) may have contributed to good shoot biomass accumulation.

In terms of shoot parameters, Genotype 1 (in terms of shoot branching) and Genotype 3 (in terms of shoot weight) had good performance in this site.

The growth and development of the yam bean plants was observed to be highest in Site 2, followed by Site 1, while the lowest was in Site 3. The use of inorganic fertilizer contributed to high number of branches which is consistent across sites. This can be attributed to the immediate availability of absorbed nutrients, particularly during the branch formation stage. With respect to shoot biomass formation, (or root weight), the use of 50% OF + 50% IF improved shoot biomass accumulation. Among the genotype, Genotype 3 had good shoot characteristics in Site 1. Genotype 2 for Site 2, and Genotype 1 for Site 3.

Growth, Dry Matter Production and Harvest Index of Yam Bean Genotypes

The parameters used for evaluating the growth, dry matter production and harvest index of the different yam bean genotypes are crop growth rate (CGR), dry matter production (DMP) and harvest index (HI). CGR is the gain in weight of the plant community per unit of area of cropped land per unit time expressed in g $m^{-2}day^{-1}$. It is closely related to interception of solar radiation, or it is the gain in plant dry weights per unit land area per unit time. This was computed using 5 sample plants that were randomly selected from each plot per treatment. Dry matter production on the other hand is the plant dry weight at harvest projected to a hectare-basis, expressed in kg ha^{-1}. Harvest index is the ratio of economic yield to biological yield. Biological yield represents the total dry matter accumulation, while economic yield refers to the weight of those plant organs that constitute the product of economic and agricultural value, in this case, the root weight.

Table 9: Shoot characteristics of yam bean genotypes grown with different fertilizer treatments at three sites in Ilocos Norte. 2008-2009 CS

GENOTYPE	Number of Branches														
	Site 1 (Sarrat, Ilocos Norte)					Site 2 (Dingras, Ilocos Norte)					Site 3 (Bangui, Ilocos Norte)				
	C	OF	50% OF + 50%IF	IF	Mean	C	OF	50%OF + 50%IF	IF	Mean	C	OF	50%OF + 50%IF	IF	Mean
1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2
2	1	1	1	2	1	2	2	2	2	2	2	2	1	1	1
3	1	1	1	2	1	2	2	2	2	2	2	1	2	2	2
4	1	1	1	2	1	1	2	2	2	2	2	2	2	2	2
5	1	1	1	1	1	2	1	2	2	2	2	1	2	2	2
Mean	1a	1a	1a	2b		2	2	2	2		2	2	2	2	
	F: Pr > F =0.0327; LSD = 0.27					F: Pr > F = 0.1099 ; LSD = 0.24					F: Pr > F = 0.4879 ; LSD = 0.30				
	G: Pr > F = 0.2985 ; LSD = 0.30					G: Pr > F = 0..4486 ; LSD = 0.26					G: Pr > F = 0.0595 ; LSD = 0.33				
	F X G: Pr > F = 0.5863					F X G: Pr > F = 0.1662					F X G: Pr > F = 0.4746				
Shoot Fresh Weight (g)															
1	13.97	20.53	20.73	19.37	18.65	13.87	17.70	15.03	21.27	16.97 ab	9.87	9.70	6.87	8.93	8.84
2	14.63	19.78	20.20	18.08	18.18	18.07	16.23	18.17	20.30	18.19 a	7.80	5.93	10.60	6.87	7.80
3	17.37	20.17	19.62	19.33	19.12	17.00	17.24	15.60	19.37	17.31 ab	9.07	7.40	11.50	6.90	8.72
4	15.63	18.67	14.27	19.57	17.03	11.50	15.53	13.67	19.07	14.94 b	8.80	8.67	6.07	8.53	8.02
5	21.30	19.27	17.65	13.77	18.00	14.57	15.62	13.43	15.46	14.77 b	8.93	7.23	11.60	6.00	8.44
Mean	16.58	19.68	18.49	18.02		15. 00 b	16.48 ab	15.18 b	19.09 a		8.89 ab	7.79 ab	9.33 a	7.45 b	
	F: Pr > F = 0.3278 ; LSD = 3.38					F: Pr >F = 0.0124 ; LSD = 2.64					F: Pr > F =0.1242 ; LSD = 1.79				
	G: Pr > F = 0.8382 ; LSD = 3.78					G: Pr > F = 0.0947 ; LSD = 2.95					G: Pr > F= 0.7963 ; LSD = 1.99				
	F X G: Pr > F = 0.5140					F X G: Pr > F = 0.8561					F X G: Pr > F= 0.0898				
Shoot Dry Weight (g)															
1	2.32	3.90	3.94	3.68	3.46	2.64	3.36	2.85	4.04	3.22 ab	1.87	1.84	1.31	1.70	1.68
2	2.44	3.76	3.84	3.44	3.37	3.43	3.08	3.45	3.86	3.46 a	1.48	1.13	2.01	1.30	1.48
3	2.97	3.83	3.73	3.67	3.55	3.23	3.28	2.96	3.68	3.29 ab	1.72	1.41	2.18	1.31	1.66
4	2.97	3.54	2.71	3.72	3.24	2.19	2.95	2.60	3.62	2.84 b	1.67	1.65	1.15	1.62	1.52
5	4.05	3.66	3.53	2.62	3.42	2.77	2.97	2.55	2.94	2.81 b	1.70	1.38	2.21	1.14	1.61
Mean	2.95 b	3.74 a	3.51 ab	3.43 ab		2.85 b	3.13 ab	2.88 b	3.63 a		1.69 ab	1.48 ab	1.77 a	1.41 b	
	F: Pr > F = 0.1054 ; LSD = 0.27					F: Pr > F = 0.0124 ; LSD = 0.24					F: Pr > F = 0.1234 ; LSD = 0.30				
	G: Pr > F = 0.9255 ; LSD = 0.30					G: Pr > F = 0.959 ; LSD = 0.26					G: Pr > F = 0.7982 ; LSD = 0.33				
	F X G: Pr > F = 0.3246					F X G: Pr > F = 0.8558					F X G: Pr > F = 0.0911				

Crop Growth Rate

Site 1 (Sarrat, Ilocos Norte). Tables 10 and 11 show that CGR was significantly affected by fertilizer treatment at 45 and 90 DAP, while no significant effect due to fertilizer treatment was observed at 30 and 60 DAP. On the other hand, CGR did not vary with genotypes, as well as the interaction effects of fertilizer treatments x genotype was observed.

The CGR was observed to be highest in plants applied with 50% OF + 50% IF at 30, 45, and 60 DAP with 8.50, 40.18 and 66.91 g m^{-2} d^{-1}, respectively. At 90 DAP however, plants under control plots appeared to have the highest in CGR (80.54g m^{-2} d^{-1}). Among genotypes, Genotype 5 had the highest CGR at 30 (7.70 g m^{-2} d^{-1}); Genotype 3 at 45 (41.30 g m^{-2} d^{-1}); Genotype 1 at 60 (65.56 g m^{-2} d^{-1}) and Genotype 5 at 90 DAP (82.30 g m^{-2} d^{-1}). Genotype 5 appears to be the most responsive to fertilizer treatments starting from 30 - 90 DAP in this site.

The above results suggest that at early stage, plants responded to fertilizer treatment, while at later stages, fertilizer appears to be not needed since the soil already contains sufficient amount of nutrients at early growth stages that will support the nutrient needs for the later growth stages.

Site 2 (Dingras, Ilocos Norte). The same trend as in Site 1 was observed in this site. The CGR was significantly affected by fertilizer at 45 and 90 DAP but not at 30 and 60 DAP. Also, no significant effects were observed on CGR due to genotypes and their interaction with fertilizer treatments.

With regards to fertilizer treatments, the application of 50% OF + 50% IF resulted to highest CGR in all the growth stages with 3.79; 33.98 g m^{-2} d^{-1}. Among genotypes, Genotype 4 had the highest CGR at 30 DAP (4.25 g m^{-2} d^{-1}); Genotype 3 at 45 DAP (37.12 g m^{-2} d^{-1}); Genotype 5 at 60 DAP (51.31 g m^{-2} d^{-1}) and Genotype 1 at 90 DAP (127.18 g m^{-2} d^{-1}). This means that Genotype 4 was the most responsive to fertilizer at early stages of growth having relatively the highest CGR. genotypes. This proves that different genotypes possess genetically variable properties with variable growth performance specific to site.

Table 10: Crop growth rate of yam bean genotypes at 30 and 45 DAP grown with different fertilizer treatments at three sites in IlocosNorte. 2008-2009 Cropping Season

Within a column (G means) and/or within a row (F means), means followed by different letters are significantly different at 5% level of significance by LSD.

GENOTYPE	**Crop Growth Rate at 30 DAP**														
	Site 1 (Sarrat, Ilocos Norte)					**Site 2 (Dingras, Ilocos Norte)**					**Site 3 (Bangui, Ilocos Norte)**				
	C	**OF**	**50% OF + 50%IF**	**IF**	**Mean**	**C**	**OF**	**50%OF + 50%IF**	**IF**	**Mean**	**C**	**OF**	**50%OF + 50%IF**	**IF**	**Mean**
1	6.28	9.34	8.44	7.44	7.87	2.77	2.74	2.58	3.22	2.83 b	3.06	3.43	3.60	3.05	3.29
2	7.89	7.25	8.15	8.11	7.84	3.38	3.80	4.54	4.12	3.96 a	3.22	3.87	3.00	3.86	3.49
3	8.87	7.79	8.05	6.05	7.70	4.35	3.25	4.35	2.45	3.60 ab	3.06	3.00	4.02	3.27	3.34
4	10.24	6.44	8.47	9.31	8.61	4.06	4.44	3.77	4.74	4.25 a	3.97	3.81	4.38	4.03	3.80
5	7.57	9.24	9.4	9.57	8.95	2.71	4.09	3.71	3.64	3.53 ab	3.54	3.11	4.02	3.81	3.62
Mean	8.17	8.01	8.50	8.10		3.45	3.66	3.79	3.63		3.37	3.45	3.61	3.60	
	F: Pr > F = 0.9595 ; LSD = 1.95					**F: Pr > F= 0.8919 ; LSD = 0.88**					**F: Pr > F = 0.8786 ; LSD = 0.72**				
	G: Pr > F = 0.7162 ; LSD = 2.19					**G: Pr > F = 0.0627 ; LSD = 0.98**					**G: Pr > F= 0.6917 ; LSD = 0.80**				
	F X G: Pr > F = 0.7257					**F X G: Pr >F = 0.5888**					**F X G: Pr > F = 0.8777=ns**				
Crop Growth Rate at 45 DAP															
1	42.66	37.35	32.48	35.97	37.12 ab	29.08	24.80	39.12	39.93	33.23 ab	17.07	16.05	12.02	17.87	15.75
2	38.32	38.64	41.47	35.65	38.52 a	28.18	38.53	29.24	23.88	29.95 b	11.27	13.52	16.96	15.46	14.30
3	38.17	32.95	49.43	44.66	41.30 a	36.64	38.90	33.49	37.45	37.12 a	17.87	14.87	13.53	15.56	15.46
4	39.98	31.72	47.43	23.39	35.63 ab	33.58	25.16	33.44	31.27	30.97 ab	15.35	15.35	15.46	12.08	14.56
5	26.08	30.54	30.12	31.40	29.54 b	27.76	33.60	34.62	32.73	32.18 ab	16.91	18.62	10.14	25.65	17.83
Mean	37.04	34.24	40.18	34.21		31.45	32.20	33.98	33.13		15.69 ab	15.68 ab	13.62 b	17.32 a	
	F: Pr > F = 0.3580 ; LSD = 7.75					**F: Pr > F = 0.8882 ; LSD = 5.84**					**F: Pr > F = 0.2303 ; LSD = 3.55**				
	G: Pr > F = 0.1011 ; LSD = 8.66					**G: Pr > F = 0.2288 ; LSD = 6.53**					**G: Pr > F = 0.4099 ; LSD = 3.97**				
	F X G: Pr > F = 0.4482					**F X G: Pr > F = 0.1495**					**F X G: Pr > F = 0.1495**				

Table 11. Crop growth rate of yam bean genotypes at 60 and 90 DAP grown with different fertilizer treatments at three sites in Ilocos Norte. 2008-2009 Cropping Season

GENOTYPE	**Crop Growth Rate at 60 DAP**														
	Site 1 (Sarrat, Ilocos Norte)					**Site 2 (Dingras, Ilocos Norte)**					**Site 3 (Bangui, Ilocos Norte)**				
	C	**OF**	**50% OF + 50%IF**	**IF**	**Mean**	**C**	**OF**	**50%OF + 50%IF**	**IF**	**Mean**	**C**	**OF**	**50%OF + 50%IF**	**IF**	**Mean**
1	78.03	54.53	63.83	65.84	65.56	42.25	53.56	38.96	62.68	49.36	26.83	18.10	23.47	19.96	22.09
2	53.88	64.72	62.75	62.08	60.86	53.56	53.38	45.25	42.97	48.79	22.00	18.68	19.36	23.18	20.81
3	72.46	65.76	66.44	51.99	64.16	49.91	56.52	33.92	48.79	47.29	17.39	23.44	18.35	30.02	22.30
4	71.73	44.97	61.89	46.51	56.27	31.41	46.08	55.46	40.76	43.43	14.10	16.03	14.81	19.97	16.23
5	46.69	56.10	79.65	59.89	60.58	49.41	48.80	56.89	50.15	51.31	21.90	20.46	19.64	23.54	21.39
Mean	64.56	57.22	66.91	57.26		45.31	51.67	46.10	49.07		20.44	19.34	19.13	23.33	
	F:Pr > f = 0.3530 ; LSD = 13.56					**F: Pr > f = 0.5917 ; LSD =10.45**					**F: Pr > f = 0.6214 ; LSD = 7.22ns**				
	G: Pr > f = 0.7576 ; LSD = 15.17					**G: Pr > f = 0.7142 ; LSD = 11.68**					**G: Pr > f = 0.5382 ; LSD = 8.07**				
	F X G: Pr > f = 0.5089					**F X G: Pr > f = 0.3343**					**F X G: Pr > f = 0.9713**				
Crop Growth Rate at 90 DAP															
1	83.72	81.79	68.63	71.57	76.43 ab	155.56	131.44	116.50	105.23	127.18 a	67.30	33.27	36.11	56.22	48.22
2	68.84	69.55	91.94	67.58	74.48 ab	114.63	113.94	71.20	101.71	100.37 c	67.30	52.55	45.81	29.37	48.76
3	89.07	69.60	67.69	68.48	73.71 ab	105.49	114.48	126.42	90.13	109.13 abc	76.89	33.19	39.99	53.56	50.91
4	65.64	54.97	68.63	64.23	63.37 b	65.60	87.93	128.72	125.30	101.89 bc	64.29	72.60	47.34	72.84	64.27
5	95.44	94.52	96.28	82.30	92.14 a	102.68	124.72	153.92	112.20	123.38 ab	66.07	54.98	54.10	63.20	59.88
Mean	80.54	74.09	78.63	70.83		108.79	114.50	119.35	106.92		68.37 a	49.32 b	44.67 b	55.04 ab	
	F: Pr > F = 0.7455 ; LSD = 19.72					**F: Pr > F = 0.5787 ; LSD = 19.94**					**F: Pr > F = 0.0603 ; LSD = 0.017.90**				
	G: Pr > F = 0.1483 ; LSD = 22.05					**G: Pr > F = 0.0600 ; LSD = 22.29**					**G: Pr > F = 0.3880 ; LSD = 22.02**				
	F X G: Pr > F = 0.9854					**F X G: Pr > F = 0.0197**					**F X G:** Pr > F **= 0.7437**				

Within a column (G means) and/or within a row (F means), means followed by different letters are significantly different at 5% level of significance by LSD.

Table 12. Dry matter production (DMP) of yam bean genotypes grown with different fertilizer treatments at three sites in Ilocos Norte.

GENOTYPE	DMP at 15 DAP														
	Site 1 (Sarrat, Ilocos Norte)					Site 2 (Dingras, Ilocos Norte)					Site 3 (Bangui, Ilocos Norte)				
	C	OF	50% OF + 50%IF	IF	Mean	C	OF	50%OF + 50%IF	IF	Mean	C	OF	50%OF + 50%IF	IF	Mean
1	16.67	16.67	17.67	15.33	16.58 a	28.00	26.67	30.00	23.33	27.00	6.67	7.80	11.10	10.03	8.90 b
2	16.67	10.00	11.33	12.00	12.50 bc	26.67	22.33	24.67	25.67	24.83	16.67	10.00	8.90	10.00	11.39 a
3	9.67	17.67	16.67	15.33	14.83 ab	20.00	24.67	26.67	24.67	24.00	10.00	12.20	10.00	7.80	10.00 ab
4	12.33	13.33	18.00	15.67	14.83 ab	24.67	29.00	27.67	24.33	26.42	12.33	12.20	10.00	10.00	11.11 ab
5	10.00	17.67	6.33	10.00	11.00 c	25.33	24.33	23.33	22.33	23.83	10.00	14.43	10.00	8.90	10.83 ab
Mean	13.07	15.07	14.00	13.67		24.93	25.40	26.47	24.07		11.11	11.33	10.00	9.35	
	F: Pr > F = 0.5883 ; LSD = 2.99					**F: Pr > F = 0.4718 ; LSD = 3.11**					**F: Pr > F = 0.2279 ; LD = 2.19**				
	G: Pr > F = 0.0162 ; LSD = 3.35					**G: Pr > F = 0.2548 ; LSD = 3.47**					**G: pr > F = 0.2518 ; LSD = 2.44**				
	F X G: Pr > F = 0.0367					**F X G: Pr > F = 0.5468**					**F X G: Pr > F = 0.0560**				
DMP at 30 DAP															
1	81.67	113.33	120.00	95.00	102.50	56.67	55.00	56.57	56.67	56.25 b	38.33	43.33	48.33	41.67	42.92
2	98.33	85.00	83.33	118.33	96.25	61.67	61.67	71.67	68.33	65.83 ab	50.00	50.00	40.00	50.00	47.50
3	101.67	98.33	95.00	96.67	97.92	65.00	58.33	71.67	50.00	61.25 ab	41.67	43.33	52.67	41.67	44.58
4	118.33	80.00	116.67	123.33	109.58	66.67	75.00	66.67	73.33	70.42 a	53.33	51.67	45.00	51.67	50.42
5	88.33	113.33	103.30	78.33	95.83	53.33	66.67	61.67	60.00	60.42 ab	46.67	46.67	51.67	48.33	48.33
Mean	97.67	98.00	103.67	102.33		60.67	63.33	65.67	61.67		46.00	47.00	47.33	46.67	
	F: Pr > F = 0.9359 ; LSD = 23.45					**F: Pr > F = 0.7103 ; LSD = 9.26**					**F: Pr > F = 0.9809 ; LSD = 6.76**				
	G: Pr > F = 0.8061 ; LSD = 26.21					**G: Pr > F = 0.0258 ; LSD = 10.45**					**G: Pr > F = 0.2895 ; LSD = 7.56**				
	F X G: Pr > F = 0.5738					**F X G: Pr > F = 0.0813**					**F X G: Pr > F = 0.6917**				
DMP at 45 DAP															
1	300.00	263.33	230.00	253.33	261.67 ab	210.00	180.00	280.00	283.33	238.33 ab	120.00	113.33	86.67	126.67	111.67
2	270.00	270.00	290.00	250.00	270.00 a	203.33	273.33	210.00	173.33	215.00 b	83.33	96.67	120.00	110.00	102.50
3	266.67	233.33	346.67	313.33	290.00 a	273.33	276.67	240.00	266.67	264.17 a	126.67	106.67	96.67	110.00	110.00
4	280.00	233.33	333.33	166.67	250.83 ab	240.00	183.33	240.00	226.67	222.50 ab	110.00	110.00	110.00	86.67	104.17
5	183.33	216.67	210.00	220.00	207.50 b	200.00	240.00	246.67	233.33	230.00 ab	120.00	133.33	73.33	180.00	126.67
Mean	260.00	241.33	282.00	240.67		225.33	230.67	243.33	236.67		112.00	112.00	97.33 b	122.67	

											ab	ab		a	
	F: Pr > F = 0.3627 ; LSD = 53.55					**F: Pr > F = 0.8179 ; LSD = 10.12**					**F: Pr > F = 0.2410 ; LSD = 24.72**				
	G: Pr > F = 0.0938 ; LSD = 53.87					**G: Pr > F= 0.2306 ; LSD = 44.86**					**G: Pr > F = 0.4252 ; LSD = 27.64**				
	F X G: Pr > F = 0.4422					**F X G: Pr > F = 0.2033**					**F X G: Pr > F = 0.1681**				

2008-2009 Cropping Season

Table 13. Dry matter production (DMP) of yam bean genotypes at 60 and 90 DAP grown with different fertilizer treatments at three site in Ilocos Norte. 2008-2009 Cropping Season

Within a column (G means) and/or within a row (F means), means followed by different letters are significantly different at 5% level of significance by LSD.

GENOTYPE	**DMP at 60 DAP**														
	Site 1 (Sarrat, Ilocos Norte)					**Site 2 (Dingras, Ilocos Norte)**					**Site 3 (Bangui, Ilocos Norte)**				
	C	**OF**	**50% OF + 50%IF**	**IF**	**Mean**	**C**	**OF**	**50%OF + 50%IF**	**IF**	**Mean**	**C**	**OF**	**50%OF + 50%IF**	**IF**	**Mean**
1	813.33	570.00	666.67	686.67	684.17	446.67	563.33	413.33	656.67	520.00	280.00	190.00	246.67	210.00	231.67
2	563.33	673.33	653.33	646.67	634.17	563.33	560.00	476.67	453.33	513.33	233.33	196.67	203.33	243.33	219.17
3	753.33	686.67	693.33	543.33	669.17	523.33	593.33	360.00	513.33	497.50	183.33	246.67	193.33	313.33	234.17
4	746.67	470.00	646.67	486.67	587.50	333.33	486.67	583.33	430.00	458.33	150.00	170.00	156.67	210.00	171.67
5	486.67	586.67	826.67	623.33	630.83	520.00	513.33	596.67	526.67	539.17	230.00	216.67	206.67	246.67	225.00
Mean	672.67	597.33	697.33	597.33		477.33	543.33	486.00	516.00		215.33	204.00	201.33	244.67	
	F: Pr > F = 0.3563 ; LSD = 140.6					**F: Pr > F = 0.5936 ; LSD = 108.16**					**F: Pr > F = 0.6281 ; LSD = 74.61**				
	G: Pr > F = 0.7531 ; LSD = 157.9					**G: Pr > F = 0.7187 ; LSD = 120.92**					**G: Pr > F = 0.5437 ; LSD = 83.42**				
	F X G: Pr > F = 0.5181					**F X G: Pr > F = 0.3384**					**F X G: Pr > F = 0.9712**				
DMP at 90 DAP															
1	1450.00	1416.67	1190.00	1240.00	1324.20 ab	2693.33	2276.67	2020.00	1833.33	2203.30 a	1163.33	576.67	626.67	973.33	835.00
2	1199.33	1203.33	1590.00	1170.00	1289.20 ab	1981.67	1973.33	1236.67	1763.33	1740.00 c	1166.67	910.00	793.33	510.00	845.00
3	1546.00	1206.67	1173.33	1186.67	1276.70 ab	1826.67	1983.33	2190.00	1563.33	1890.80 abc	1336.00	576.67	693.33	926.67	881.70
4	1136.67	953.33	1190.00	1113.33	1098.30 b	1140.00	1526.67	2230.00	2170.00	1766.70 bc	1113.33	1256.67	820.00	1260.00	1112.50
5	1650.00	1636.67	1663.33	1423.33	1593.30 a	1780.00	2160.00	2663.33	1943.33	2136.70 ab	1143.33	953.33	936.67	1093.33	1031.70
Mean	1394.00	1283.30	1361.30	1226.70		1885.30	1984.00	2068.00	1852.70		1183.30	854.70 b	744.00 b	952.70 ab	
	F: Pr > F = 0.7464 ; LSD = 340.21					**F: Pr > F = 0.5756 ; LSD = 343.79**					**F:Pr > F = 0.0602 ; LSD = 309.0**				
	G: Pr > F = 0.1501 ; LSD = 380.37					**G: Pr > F = 0.0596 ; LSD = 384.37**					**G: Pr > F = 0.3871 ; LSD = 345.49**				
	F X G: Pr > F = 0.9856					**F X G: Pr > F = 0. 0196**					**F X G:Pr > F = 0.7443**				

Site 3 (Bangui, Ilocos Norte). The CGR was not significantly affected by fertilizer treatment but significant differences in genotypes was observed at 45 and 90 DAP. Also, no significant interactions between fertilizer treatments and genotypes was obtained.

In this site, plants applied with 50% OF + 50% IF at 30 DAP had the highest CGR with 3.61 g m^{-2} d^{-1}. At 45 and 60 DAP however, plants applied with inorganic fertilizer had the highest (17.32 and 23.33 g m^{-2} d^{-1}, respectively) and at 90 DAP in control plants (68.37 g m^{-2} d^{-1}). These results show that plants depended solely on the soil conditions at its early stage of growth. That the application of 50% OF + 50% IF may had contributed to the improvement of the soil with regards to its ability to retain moisture and increase microbial population for increased biological N fixation leading towards production of nutrients for growth such as N, P, and K. As the plants grew up, their dependence to nutrient form applied fertilizers became more apparent, while at later stage of their growth, they are already capable to suffice their growth needs since being a legume can fix their own nutrient needs.

Genotype 4 in this site had the highest CGR at 30 DAP; Genotype 5 at 45 DAP; Genotype 3 at 60 DAP, and G4 at 90 DAP. Generally in this site again Genotype 4 had the highest CGR at 30 DAP early and late growing stages in this site. Interactions among fertilizer treatment, genotype and sites was not significant.

Dry Matter Production

Dry matter production (DMP) of different yam bean genotypes at 15, 30, 45, 60 and 90 DAP under varying fertilizer treatments are shown in Tables 12 and 13.

Site 1 (Sarrat, Ilocos Norte). Fertilizer treatments significantly affected DMP of yam bean at 45 DAP but not for the rest of the growth stages. At 15 DAP, application of organic fertilizer produced the highest DMP with 15.07 kg ha^{-1} compared with the other treatments, while at 30, 45 and 60 DAP, an application of 50% OF + 50% IF resulted to highest DMP by the plants with 103.67, 282.00 and 697.33 kg ha^{-1}, respectively. It can be stated in here that organic fertilizer alone at early stage of growth of the plants was effective through possible soil improvement, increased soil microbes that helped in the fixation of microbial N, which is a growth necessity of plants especially at early vegetative growth; resulting to higher DMP of the plants.

Highest DMP at 15 and 60 DAP was obtained from Genotype 1 with 16.58 and 684.17 kg ha^{-1}, respectively, while at 30 DAP in Genotype 4 (109.58 kg ha^{-1}); at 45 DAP in Genotype 3 (290 kg ha^{-1}), and at 90 DAP by Genotype 5 (1593.30 kg ha^{-1}). Different genotypes responded differently to DMP level according to sites and growth stages. Thus Genotype 5 had the highest DMP at harvest. Further, no interaction effect was observed in Site 1. Interaction between genotype and fertilizer treatment was not observed in Site 1.

Site 2 (Dingras, Ilocos Norte). In this site, DMP was not affected by fertilizer treatments, but significant differences in test genotypes was observed at 30, 45 and 90 DAP (Tables 12 and 13). The application of 50% OF + 50% IF to plants resulted to highest DMP at 15, 45 and 90 DAP with 26.47, 243.33, and, 2068 kg ha^{-1}, respectively while application of organic fertilizer resulted to highest DMP at 60 DAP with 543.33 kg ha^{-1}.

Site 3(Bangui, Ilocos Norte). The DMP in this site was significantly affected by fertilizer treatment at 45 and 90 DAP and by genotype at 15 DAP (Tables 12 and 13). However, there were no significant variations in DMP was observed in other growth stages due fertilizer treatment or genotypes. The application of organic fertilizer at 15 resulted to highest in DMP (11.33 kg ha^{-1}). Generally, DMP among the plants had variable responses on fertilizer treatments at different growth stages. The same trend also exists in the genotypes used. The genotypic response show their inherent climatic conditions across sites.

Further, ANOVA shows that DMP was significantly affected by site, but with fertilizer and genotype, no significant interaction effects was observed.

The DMP for the three sites was ranked as Site 2 > Site 1 > Site 3.

Based on site characteristics and other growth parameters, the performance of the plants in Site 2 was relatively the best. The soil in this site has adequate and favorable properties such as: properly drained; good proportion of sand, silt and clay; with optimum amount of other nutrients including OM that favors microbial growth, improves soil structure for proper and nutrient moisture retention; and the relatively favorable climatic conditions for crop growth and development.

Harvest Index

Site 1 (Sarrat, Ilocos Norte). Results showed that harvest index (HI) was significantly affected by fertilizer treatments, while genotypes varied significantly, while there are no interaction effects observed (Table 14). The proportion of economic yield to that of biological yield was observed to be highest in plants applied with 50%OF + 50%IF (0.83 kg ha^{-1}) and the lowest was the plants applied with inorganic fertilizer (0.78 kg ha^{-1}). Genotype 4 and Genotype 5 were observed to be the highest in harvest index in this site with 0.83 kg ha^{-1}.

Site 2 (Dingras, Ilocos Norte). HI was significantly affected by fertilizer treatments but not with genotypes, while no interaction effects was observed. In this site, the plants applied with organic fertilizer had the highest HI value (0.86 kg ha^{-1}). The lowest was obtained from plants applied with 50%OF + 50%IF with 0.83 kg ha^{-1}. Among the genotypes, the highest HI was obtained by Genotype 4 with 0. 86 kg ha^{-1} in this particular site.

Site 3(Bangui, Ilocos Norte) . Harvest index in this site was significantly affected by fertilizer treatments but did not vary with genotypes. Unfertilized plants obtained the highest HI among the treatments used with 0.76 kg ha^{-1}, while the lowest was from plants applied with inorganic fertilizer. Among the genotypes, Genotype 4 had the highest HI (0.81 kg ha^{-1}), while the lowest was obtained from Genotype 1.

There was no significant interaction effects on the fertilizer, genotype and site. However, HI varied across sites wherein, site was found out to be significant against the other sites with respect to HI. Site 2 produced the highest HI, followed by Site 1, and the lowest was Site 3. This suggest a better partitioning of dry matter to yield in Site 2.

Yield of Yam Bean Genotypes

Based from the earlier results, **y**ield reflects the cumulative effect of the yield contributing characters previously discussed in this study. Characters such as root and shoot characteristics, as well as CGR, DMP and HI, may have contributed to the yield of the different genotypes as affected by the fertilizer treatments. For the root characteristics, the satisfactory results was due to application of organic, and combination of organic and inorganic fertilizers. The same is true with the other parameters which ultimately translated to yield.

Site 1 (Sarrat, Ilocos Norte). Yam bean yield was significantly affected by fertilizer but not by genotype in this site (Table 14). The application of 50% OF + 50% IF to the plants produced the highest yield (62.90 t ha^{-1}) followed by those applied with organic fertilizer (58.39 t ha^{-1}), the lowest was with inorganic fertilizer (51.21 t ha^{-1}). The genotypes have comparable yields, although Genotype 2 produced the relatively highest yield (58.99 t ha^{-1}) in this site.

Soil in this site is of Umingan type, where balanced proportions of soil particles of sand, silt and clay, an application of 50% OF + 50% IF was found to be favorable which could be traced to root growth, shoot growth, CGR and DMP which contributed to yield. It has a well established effect of organic fertilizer on texture, nutrient/water retention and microbial growth. Combination of OF and IF show immediate availability of fertilizer on variable growth stages. Organic fertilizer provides micronutrients and the other growth factors not normally supplied by inorganic fertilizers (Jones and Wild, 1975).

Site 2 (Dingras, Ilocos Norte). Similar trend results as in Site 1 were obtained. Yield was significantly affected by fertilizer but did not vary by genotypes. No interaction effects of fertilizer treatments by genotype. Highest yield was obtained in plots with 50% OF + 50% IF (65.80 t ha^{-1}). With regards to genotype, Genotype 5 had the highest (64.67 t ha^{-1}) in this site.

With San Manuel silt loam type of soil in this site, it has high silt particle which is favorable for root crops, while this soil is low in available N as well as OM, using a combination of organic and inorganic fertilizer worked since OF is needed for the increase in microbial population for the biological N fixing activity of the plant as well as for the improvement of the soil properties and supply of other important nutrients not supplied by inorganic fertilizer. This is supported by good root, CGR, DMP and shoot development (Tables 8, 9, 10 and 11) under continued application of organic and inorganic fertilizer

Site 3 (Bangui, Ilocos Norte). Fertilizer treatments significantly affected the yield in this site (Table 14). Plants applied with organic fertilizer alone was observed to have obtained the highest yield (52.97 t ha^{-1}), followed by control plants 49.17 t ha^{-1} while the lowest was from inorganic fertilizer applied plants (40.43 t $ha^{-1)}$. Yield did vary across genotypes, although Genotype 4 and 5 appeared to be adapted to the site and condition. Similarly, genotype by fertilizer interaction was not observed on yam bean yields.

Organic fertilizer worked well in Site 3. Based from the pre-soil analysis, this site is high in sand proportion , and has low OM, N and P. In addition, Site 3 has relatively strong windspeed (8.1 ms^{-1} vs. 2-3 ms^{-1} for Sites 1 and 2), thus the area easily dries up because it cannot retain moisture longer due to dominant particle size as well as prevailing strong winds in the area. Based on these results, the application of organic fertilizer alone increased the yield in this site. While the improved soil structure, nutrient/water retention and microbial activity had been attributed to OF, the effect of OF in yield in this site is supported by its effect on root and shoot growth as previously presented (Tables 8 and 9).

Among the sites, the highest average yield was obtained in Site 2 followed by Site 1 and the lowest was obtained in Site 3. The general trends in yield whether attributed to fertilizer treatments is supported by lower root weight, shoot weights, CGR values, DMP, HI that

Table 14: Yield (t ha $^{-1}$) and harvest index of yam bean genotypes grown with different fertilizer treatments at three sites in IlocosNorte. 2008-2009 Cropping Season

GENOTYPE	Harvest Index														
	Site 1 (Sarrat, Ilocos Norte)					Site 2 (Dingras, Ilocos Norte)					Site 3 (Bangui, Ilocos Norte)				
	C	OF	50% OF + 50%IF	IF	Mean	C	OF	50%OF + 50%IF	IF	Mean	C	OF	50%OF + 50%IF	IF	Mean
1	0.80	0.79	0.82	0.78	0.80 b	0.83	0.84	0.84	0.83	0.83	0.76	0.73	0.78	0.72	0.72
2	0.81	0,80	0.81	0.78	0.80 b	0.88	0.88	0.79	0.86	0.85	0.78	0.74	0.73	0.72	0.80
3	0.80	0.80	0.84	0.78	0.81 b	0.85	0.87	0.80	0.85	0.84	0.77	0.72	0.74	0.70	0.79
4	0.84	0.83	0.85	0.80	0.83 a	0.85	0.86	0.88	0.83	0.86	0.73	0.73	0.76	0.72	0.81
5	0.81	0.80	0.85	0.84	0.83 a	0.83	0.87	0.81	0.87	0.84	0.76	0.75	0.72	0.73	0.80
Mean	0.81 b	0.80 bc	0.83 a	0.78 c		0.85 ab	0.86 a	0.83 ab	0.85 ab		0.76 a	0.73 ab	0.74 ab	0.72 b	
	F: Pr > F = 0.002 ; LSD = 0.02					F: Pr > F = 0.001 ; LSD fert = 0.02					F: Pr > F = 0.00021 ; LSD fert = 0.03				
	G : Pr > F = 0.0032 ; LSD = 0.02					G: Pr > F = 0.1123 ; LSD gen = 0.02					G: Pr > F = 0.2134 ; LSD gen = 0.04				
	F x G : Pr > F = 0.1899 ns					F x G: Pr > F = 0.1234 ns					F x G: Pr > F = 0.3212 ns				
Yield (t ha $^{-1}$)															
1	50.67	63.33	70.33	49.67	58.50	57.83	60.00	66.50	62.50	61.71	51.67	49.50	33.67	44.00	44.71 a
2	58.33	61.13	58.83	57.67	58.99	63.00	55.00	66.17	59.00	60.79	54.00	45.33	41.33	42.17	45.71 a
3	61.33	55.00	65.50	50.33	58.04	59.00	56.83	63.67	54.50	58.50	46.33	56.70	43.17	41.17	46.84 a
4	47.50	57.17	62.17	58.67	56.38	51.00	59.50	59.17	58.17	56.96	47.50	56.17	47.67	39.50	47.71 a
5	63.67	55.33	57.67	39.73	54.10	58.00	55.00	73.50	72.17	64.67	46.33	57.17	49.67	35.33	47.13 a
Mean	56.3 bc	58.39 ab	62.90 a	51.21 c		57.77 b	57.27 b	65.80 a	61.27 ab		49.17a b	52.97 a	43.10 bc	40.43 c	
	F: Pr > F = 0.0097 ; LSD = 6.59					F: Pr > F = 0.0441 ; LSD = 6.54					F: Pr > F = 0.0017 ; LSD = 6.52				
	G: Pr > F = 0.6603 ; LSD = 7.37					GP: Pr > F = 0.2637 ; LSD = 7.31					G: Pr > F = 0.9223 ; LSD = 7.29				
	F X G : Pr > F = 0.1235					F X G: Pr > F = 0.6532					F X G: Pr > F = 0.3972				

Within a column (G means) and/or within a row (F means), means followed by different letters are significantly different at 5% level of significance by LSD.

ultimately resulted to lower yields in Site 3. Conversely, relatively higher values of the above parameters were obtained in the relatively high-yielding Sites 1 and 2.
Among the sites, significant difference in yield was observed. However, the interaction effects of fertilizer treatment and genotype was not observed. But, with fertilizer and genotype, there were no significant interaction effects. Based on the results, yield was significantly increased by the application of 50% OF + 50% IF, specifically for Sites 1 and 2, while organic fertilizer application alone was effective in Site 3 which is more prone to water deficit conditions.

Nutrient Uptake and Nutrient-use Efficiency of Yam bean Genotypes

The nutrient uptake and nutrient use efficiency describe how yam bean plant manages the available nutrient (applied and indigenous) under interacting environment (climate and edaphic), and how efficient these nutrients are taken up, assimilated converted to root yield. Nutrient uptake is determined in terms of shoot and root N, P and K uptakes, i. e., dry weight multiplied by the nutrient concentration in root and shoot. Generally, most crops take up nutrients during periods of vegetative growth and translocate stored nutrients to developing fruits during reproductive stage of growth. After the vegetative stage, nutrient uptake slows down until the plant senesce where no further nutrient uptake is apparent (Mengel, 1995). Recovery efficiency (RE) is the plant nutrient uptake (kg ha^{-1}) per unit nutrient applied from fertilizer (kg ha^{-1}). Internal efficiency of nutrients (IEN) is defined as root yield (kg ha^{-1}) per nutrient taken up (kg ha^{-1}) by the plant.

Root and Shoot N Uptake and Nitrogen-use Efficiency

Site 1 (Sarrat, Ilocos Norte). Results show that fertilizer did not affect root N uptake in this site (Table 15). The highest root N uptake was observed in the application of 50% OF + 50% IF (20.16 kg ha^{-1}), while the lowest was obtained in the unfertilized plants with 17.14 kg ha^{-1} (Table 15). Among the genotypes, there was no variation in nutrient uptake. Genotype 1 however, had the highest root N uptake (24.21 kg ha^{-1}), while Genotype 5 had the lowest (16.58 kg ha^{-1}). Fertilizer treatments significantly affected shoot N uptake, but did not differ in genotypes. The application of OF with Genotype showed the highest uptakes with 4.21 and 4.80 kg ha^{-1}, respectively.

With regard to recovery efficiency of applied N (RE_N), significant differences were observed among the fertilizer treatments and genotypes used. The application of IF was observed to have the highest recovery efficiency to applied N (0.26 kg kg^{-1}). Fertilizer treatment significantly affected internal efficiency of applied N (IE_N), such that the application of 50%OF + 50%IF was the most efficient (22 kg kg^{-1}) fertilizer treatment in converting absorbed N into root yield, while IF was the lowest (18 kg kg^{-1}). Among the genotypes, Genotype 1 had the highest RE_N and IE_N with 0.30 and 27 kg kg^{-1}, respectively.

Site 2 (Dingras, Ilocos Norte). Fertilizer treatments significantly affected shoot and root N uptakes as well as RE_N and IE_N. In this site, unfertilized plants had the highest root N uptake (39.10 kg ha^{-1}) and the lowest was in 50%OF + 50%IF treatment (23.67 kg ha^{-1}), while the IF application had the highest shoot N uptake (4 kg ha) compared with the other treatments (3.15-3.54 kg ha^{-1}). The highest RE_N was observed in IF application (0.24 kg kg^{-1}) while for IE_N the highest was in 50%OF + 50%IF with 25.67 kg kg^{-1}.

Site 3 (Bangui, Ilocos Norte). Significant differences due to fertilizer treatment and genotype were observed in root and shoot N uptake, RE_N and IE_N in this site. The highest root N uptake in this site was observed in control plants (15.69 kg ha^{-1}), while the lowest was in IF treated plants

Table 15: Root and shoot nitrogen uptake of yam bean genotypes grown with different fertilizer treatments at three sites in Ilocos Norte. 2008-2009 Cropping Season.

Within a column (G means) and/or within a row (F means), means followed by different letters are significantly different at 5% level of significance by LSD.

GENOTYPE	Root N Uptake (kg ha^{-1})														
	Site 1 (Sarrat, Ilocos Norte)					Site 2 (Dingras, Ilocos Norte)					Site 3 (Bangui, Ilocos Norte)				
	C	OF	50% OF + 50%IF	IF	Mean	C	OF	50%OF + 50%IF	IF	Mean	C	OF	50%OF + 50%IF	IF	Mean
1	8.76	22.59	24.21	19.06	18.66	35.92	50.86	25.28	39.55	37.90 a	16.18	14.13	11.22	14.28	13.96
2	15.29	18.94	22.00	16.67	18.22	35.53	43.36	20.44	30.09	32.35 bc	15.99	13.27	10.09	15.15	13.63
3	19.63	19.10	16.79	18.20	18.43	57.48	40.56	23.72	27.88	37.41 ab	14.66	17.93	13.67	11.76	14.50
4	15.77	16.63	21.22	22.70	19.08	42.56	36.08	24.68	23.05	31.59 c	15.66	18.37	15.88.	11.48	15.35
5	26.24	20.03	16.58	13.59	19.11	24.01	23.14	24.21	27.91	24.82 d	15.96	14.40	15.29	12.26	14.48
Mean	17.14	19.46	20.16	18.04		39.10 a	38.80 a	23.67c	29.70 b		15.69 a	15.62 ab	13.23 bc	12.99 c	
	F: Pr >F = 0.3764 ; LSD = 380.07					F: Pr > F = 0.0001 ; LSD = 469.28					F: Pr > F = 0.0391 ; LSD = 240.1				
	G: Pr > F = 0.9905 ; LSD = 429.94					G: Pr > F = 0.0001 ; LSD = 524.67					G: Pr > F = 0.7440 ; LSD = 268.51				
	F X G: Pr > F = 0.2159					F X G: Pr > F = 0.1303					F X G: Pr > F = 0.2867				
Shoot N uptake (kg ha^{-1})															
1	2.22	4.80	4.33	5.19	4.14	3.40	3.82	3.40	4.49	3.77 a	1.83	1.82	1.19	1.59	1.61 a
2	2.50	4.20	4.45	4.08	3.81	3.81	3.45	3.72	4.96	3.99 a	1.32	1.14	1.74	1.06	1.31 ab
3	4.43	4.17	4.04	3.92	4.14	3.70	3.87	3.11	3.83	3.63 ab	1.88	1.36	1.93	1.12	1.57 a
4	2.66	3.83	3.46	4.16	3.53	2.55	3.12	2.73	3.79	3.05 b	1.57	1.82	0.94	1.53	1.46 ab
5	4.59	4.04	4.18	3.49	4.07	2.80	3.47	2.77	3.20	3.06 b	1.55	1.23	1.01	.97	1.19 b
Mean	3.28b	4.21a	4.09a	4.17a		3.25 b	3.54 ab	3.15 b	4.05		1.63 a	1.47 ab	1.36 ab	1.25 b	
	F: Pr > F = 0.0452 ; LSD = 42.02					F: Pr > F = 0.0115 ; LSD = 56.38					F: Pr > F = 0.0001 ; LSD = 30.61				
	G: Pr > F = 0.5407 ; LSD = 45.32					G: Pr > F = 0.0122 ; LSD = 63.03					G: Pr > F = 0.0937 ; LSD = 34.22				
	F X G: Pr > F = 0.1290					F X G: Pr > F = 0.8596					F X G: Pr > F = 0.0814				

Table 16: Recovery efficiency and Internal efficiency of nitrogen in yam bean genotypes grown with different fertilizer treatments at three sites in IlocosNorte. 2008-2009 Cropping Season

GENOTYPE	Recovery Efficiency of N (kg kg^{-1})														
	Site 1 (Sarrat, Ilocos Norte)					Site 2 (Dingras, Ilocos Norte)					Site 3 (Bangui, Ilocos Norte)				
	C	OF	50% OF + 50%IF	IF	Mean	C	OF	50%OF + 50%IF	IF	Mean	C	OF	50%OF + 50%IF	IF	Mean
1	-	0.12	0.15	0.30	0.19 a	-	0.11	0.16	0.23	0.17 b	-	0.10	0.12	0.20	0.14 a
2	-	0.11	0.15	0.25	0.17 c	-	0.11	0.14	0.27	0.18 a	-	0.10	0.12	0.17	0.13 b
3	-	0.11	0.15	0.23	0.16 d	-	0.11	0.14	0.22	0.15 d	-	0.09	0.12	0.18	0.13 b
4	-	0.11	0.17	0.24	0.17 c	-	0.10	0.14	0.22	0.15 d	-	0.11	0.11	0.20	0.14 a
5	-	0.11	0.17	0.28	0.18 b	-	0.11	0.14	0.23	0.16 c	-	0.09	0.06	0.18	0.11 c
Mean	-	0.11 c	0.16 b	0.26 a		-	0.11 c	0.15 b	0.24 a		-	0.01 c	0.10 b	0.19 a	
	F: Pr > F= 0.002**					F: Pr > F= 0.003**					F : Pr > F= O.002**				
	G: Pr > F= 0.003**					G: Pr > F= 0.004**					G: Pr > F= 0.0024**				
	F X G: Pr > F = 0.124					F X G: Pr > F= 0.0219					F X G: Pr > F = 0.2365**				
Internal Efficiency of N (kg kg^{-1})															
1	20.98	21.91	27.23	15.02	21.29	19.12	22.58	23.75	23.99	22.69	22.18	21.26	15.61	19.94	19.75
2	23.77	23.28	21.57	20.62	22.32	24.24	20.95	26.13	19.44	22.36	25.23	18.97	20.39	21.97	21.64
3	19.21	21.53	25.60	20.11	21.61	21.81	20.49	25.71	22.25	22.57	17.44	24.86	20.95	20.53	20.95
4	22.67	22.52	20.75	22.31	22.06	18.63	24.00	23.91	23.64	22.55	21.37	21.45	24.85	17.71	21.34
5	23.93	21.35	19.68	12.74	19.42	24.52	20.15	28.86	27.98	25.38	21.32	26.87	45.92	17.59	27.93
Mean	22.11 a	22.12 a	22.97 a	18.16 b		21.66 b	21.63 b	25.67 a	23.46 ab		21.51 bc	22.68 ab	25.55 a	19.55 c	
	F: Pr > F = 0.001					F: Pr > F = 0.002					F : Pr > F= 0.001				
	G : Pr > F= 0.0001					G:Pr > F= 0.237					G: Pr > F= 0.328				
	F X G: Pr > F = 0.216					F X G:Pr > F= 0.263					F X G:Pr > F = 0.3245				

Within a column (G means) and/or within a row (F means), means followed by different letters are significantly different at 5% level of significance by LSD.

(12.99 kg ha^{-1}). Unfertilized plants showed the highest shoot N (1.63 kg ha^{-1}). Among the genotypes used, no significant variations in shoot N uptake was observed. Genotype 4 had the highest root N uptake (15.35 kg ha^{-1}) while Genotype 5 had the highest shoot N uptake (1.19 kg ha^{-1}).

Plants applied with IF had the highest RE_N (0.19 kg kg^{-1}) while the lowest was with OF (0.01 kg kg^{-1}). Highest IE_N was obtained from plants applied with 50%OF + 50%IF (25.55 kg kg^{-1}) and the lowest was in IF applied plants (19.55 kg kg^{-1}). Among the genotypes, Genotype 4 and Genotype 5 had the highest RE_N and IE_N with 0.14 and 45 kg kg^{-1} , respectively.

Among the three sites, yam bean plants had the highest RE of applied N with IF application and at the same time, while an application of 50%OF + 50% IF results to highest in IE_N For the genotypes, Genotype 1 was found to be efficient in Site 1, while Genotype 4 and 5 were efficient in Sites 1 and 2.

No significant interaction effect observed across sites.

Root and Shoot Phosphorous Uptake and Phosphorous-use Efficiency

Phosphorous together with Nitrogen are most serious limiting factors for food legumes The amount of P added was above the plant requirement to ensure the optimal conditions for N-fixation. As the P anion is relatively immobile in the soil (Ahn, 1993), P does not move very far from the place of origin. Any surplus in P will therefore not do any harm, but will be available under favorable condition in the soil to the subsequent planting seasons. The behavior in the soil of P therefore is different from N, and this vary along sites.

Site 1 (Sarrat, Ilocos Norte). Table 17 shows the result of root, shoot P uptake, RE_P and IE_P. Fertilizer treatments significantly affected root uptake while variations were not observed across genotypes. The application of OF had the highest root P uptake (3.19 kg ha^{-1}), while highest shoot P uptake in the unfertilized plants (0.60 kg ha^{-1}), and the lowest were from plants applied with 50%OF + 50%IF for the root P uptake (2.31 kg ha^{-1}) and with IF plants for shoot P uptake (0.35 kg ha^{-1}). Among the genotypes, Genotype 5 was the most responsive as shown in its highest root and shoot P uptakes (3.45 and 0.60 kg ha^{-1}). RE_P and IE_P were significantly affected by fertilizer treatments. Plants applied with 50%OF + 5%IF had the highest IE_P (2.43 kg kg^{-1}), while RE_P was high with the application of OF (0.01 kg kg^{-1}). Among the genotypes, significant variations were observed for RE_P and IE_P. Genotype 3 had the highest RE_P (0.009 kg kg^{-1}) and IEP (3.27 kg kg^{-1}), respectively.

Site 2 (Dingras, Ilocos Norte). Shoot and Root P uptake were significantly affected by fertilizer treatments and differed with genotypes. The application of 50%OF + 50% IF had the highest root P uptake (4.18 kg ha), while IF application had the highest shoot P uptake (0.36 kg ha^{-1}). Among the genotypes, Genotype 2 had the highest root P uptake (4.82 kg $^{ha-}$1),while Genotype 1 had the highest shoot P uptake (0.46 kg ha^{-1}). RE_P and IE_P were significantly affected by fertilizer treatments in this site. The application of OF had the highest RE_P (0.008 kg kg^{-1}), while the lowest was obtained in IF applied plants (0.002 kg kg^{-1}) among the genotypes, Genotype 1 had the highest RE_P. With IE_P, the application of 50%OF + 50%IF showed the highest (2.95 kg kg^{-1}) while the lowest was with OF applied plants (2.26 kg kg^{-1}). Among the genotypes, Genotype 2 was the most responsive in IE_P in this site (3.7 kg kg^{-1}).

Site 3 (Bangui, Ilocos Norte). Root and shoot P uptakes were significantly affected by fertilizer treatments but did not vary with genotypes. Unfertilized plants in this site had the highest root P uptake and 50%OF + 50%IF had the highest shoot P uptake (2.92 and 0.19 kg ha^{-1}, respectively). Genotype 2 had the highest root uptake (3.43 kg ha^{-1}), while Genotype 3 had the highest shoot P uptake (0.24 kg ha^{-1}). The RE_P and IE_P were significantly affected by fertilizer. The application of OF had significantly the highest RE_P and IE_P with 0.008 and 1.94 kg kg^{-1},

Table 17: Root and shoot phosphorous uptake of yam bean genotypes grown with different fertilizer treatments at three sites in Ilocos Norte. 2008-2009 Cropping Season.

GENOTYPE	Root P Uptake (kg ha^{-1})														
	Site 1 (Sarrat, Ilocos Norte)					Site 2 (Dingras, Ilocos Norte)					Site 3 (Bangui, Ilocos Norte)				
	C	OF	50% OF + 50%IF	IF	Mean	C	OF	50%OF + 50%IF	IF	Mean	C	OF	50%OF + 50%IF	IF	Mean
1	3.02	2.88	2.10	2.18	2.54	2.97	3.71	3.61	3.57	3.47 b	2.74	2.70	2.17	2.38	2.50
2	2.01	3.40	2.70	2.32	2.61	3.41	3.43	4.82	3.43	3.77 ab	3.43	2.55	2.58	2.64	2.80
3	2.11	3.42	2.55	2.40	2.62	3.51	4.46	4.56	3.62	4.04 a	2.73	2.80	2.83	2.29	2.66
4	2.34	2.82	2.14	2.88	2.55	3.60	4.58	3.83	3.73	3.94 ab	2.99	3.18	3.02	2.30	2.87
5	4.54	3.45	2.08	2.10	3.04	3.49	3.52	4.07	3.59	3.67ab	2.69	2.25	2.27	2.44	2.41
Mean	2.81 ab	3.19 a	2.31 b	2.38b		3.40c	3.94ab	4.18 a	3.59 bc		2.92 a	2.70ab	2.57 ab	2.41 b	
	F: Pr > F= 0.0127 ; LSD = 57.41					F: Pr > F = 0.0052 ; LSD = 44.68					F: Pr >F= 0.1264 ; LSD = 42.97				
	G: Pr > F = 0.4791 ; LSD = 64.18					G: Pr > F = 0.1811 ; LSD = 49.95					G: Pr > F = 0.2672 ; LSD = 48.04				
	F X G: Pr > F = 0.0571					F X G: Pr > F = 0.3641					F X G:Pr > F = 0.1724				
Shoot P Uptake (kg ha^{-1})															
1	.28	.50	.53	.45	.44	.29	.38	.31	.46	.36 a	.19	.22	.15	.18	.19
2	.25	.51	.50	.44	.43	.35	.33	.26	.34	.32 ab	.14	.12	.21	.13	.15
3	.40	.54	.31	.45	.42	.36	.35	.32	.38	.35 a	.20	.15	.24	.14	.18
4	.54	.47	.28	.46	.44	.24	.29	.25	.30	.27 b	.20	.18	.13	.13	.16
5	.60	.53	.50	.35	.48	.26	.33	.23	.31	.28 b	.20	.17	.24	.12	.18
Mean						.30 bc	.33 ab	.27 c	.36 a		.19	.17	.19	.14	
	F: Pr > f = 0.1229 ; LSD = 3.34					F: Pr > f = 0.0119 ; LSD = 5.19					F:Pr > F = 0.2356 ; LSD = 4.03				
	G: Pr > f = 0.6170 ; LSD = 4.31					G: Pr > f = 0.0110 ; LS 5.80*					G:Pr > F = 0.2145 ; LSD = 4.51				
	F X G: Pr > f = 0.0237					F X G:Pr > F = 0.2973					F X G:Pr > F = 0.2314				

Within a column (G means) and/or within a row (F means), means followed by different letters are significantly different at 5% level of significance by LSD.

Table 18: Recovery efficiency and Internal efficiency of phosphorous in yam bean genotypes grown with different fertilizer treatments at three sites in Ilocos Norte. 2008-2009 Cropping Season

GENOTYPE	Recovery Efficiency of P (kg kg^{-1})														
	Site 1 (Sarrat, Ilocos Norte)					Site 2 (Dingras, Ilocos Norte)					Site 3 (Bangui, Ilocos Norte)				
	C	OF	50% OF + 50%IF	IF	Mean	C	OF	50%OF + 50%IF	IF	Mean	C	OF	50%OF + 50%IF	IF	Mean
1	-	0.009	0.003	0.002	0.0049 bc	-	0.008	0.003	0.002	0.0043 a	-	0.009	0.003	0.002	0.005 a
2	-	0.01	0.003	0.002	0.005 b	-	0.008	0.002	0.001	0.0037 c	-	0.008	0.003	0.002	0.004 b
3	-	0.01	0.002	0.002	0.0048 bc	-	0.008	0.003	0.002	0.0043 a	-	0.008	0.003	0.002	0.004 b
4	-	0.01	0.002	0.002	0.0047 c	-	0.007	0.003	0.001	0.0036 c	-	0.008	0.003	0.001	0.004 b
5	-	0.01	0.004	0.002	0.006 a	-	0.008	0.002	0.002	0.004 b	-	0.009	0.003	0.002	0.005 a
Mean	-	0.01 a	0.003 b	0.002 c		-	0.008 a	0.003 b	0.002 c		-	0.008 a	0.003 b	0.002 c	
	F: Pr > F= 0.0003					F :Pr > F= 0.0001					F:Pr > F= 0.001*				
	G : Pr > F= 0.004*					G:Pr > F= 0.001					G: Pr > F= 0.82*				
	F X G:Pr > F = 0.1028					F X G:Pr > F= 0.215					F X G:Pr > F= 0.2234				
Internal Efficiency of P (kg kg^{-1})															
1	1.59	2.09	2.24	1.72	1.91 ab	2.19	2.25	2.59	2.31	2.33 b	2.05	1.68	1.23	1.70	1.67
2	2.32	1.87	1.91	1.90	2.00 a	2.59	2.18	3.72	2.78	2.82 a	2.26	1.77	1.61	1.70	1.84
3	2.10	1.67	3.27	1.74	2.20 a	2.22	2.24	2.45	2.21	2.28 b	1.67	2.18	1.66	1.55	1.76
4	1.11	1.80	3.09	2.00	2.00 a	1.90	2.57	2.53	2.91	2.48 ab	1.65	2.13	1.68	1.96	1.85
5	1.82	1.61	1.64	1.25	1.58 b	2.55	2.07	3.44	2.89	2.74 a	1.66	1.94	1.91	1.37	1.72
Mean	1.79 b	1.81 b	2.43 a	1.72 b		2.29 c	2.26 c	2.95 a	2.62 b		1.86 ab	1.94 a	1.62 b	1.66 b	
	F:Pr > F = 0.002 ; LSD =36.42					F :Pr > F = 0.0001 ; LSD = 31.7**					F:Pr > F = 0.0012 ; LSD = 24.37*				
	G: Pr > F = 0.00327 ; LSD= 40.72					G:Pr > F = 0.0002 ; LSD = 35.44					G:Pr > F = 0.001 ; LSD = 27.24ns				
	F X G: Pr > F = 0.7216					F X G:Pr > F= 0.138					F X G:Pr > F = 0.2845				

Within a column (G means) and/or within a row (F means), means followed by different letters are significantly different at 5% level of significance by LSD.

respectively. Among the genotypes, Genotype 5 showed the highest and RE_P (0.009 kg kg^{-1}) while Genotype 3 showed the highest IE_P with 2.18 kg kg^{-1}.

Generally, the application of OF to yam bean plants resulted to highest in RE_P, while 50%OF + 50%OF + 50% IF application to the plants resulted to highest in IE_P. With regards to genotypes, Genotypes 2 and 3 had the highest IE_P, while Genotypes 1 and 5 had the highest RE_P. There was no significant interaction effects among the experimental sites used. Yam bean plants are generally low in recovery as well as internal efficiencies to applied phosphorous added effect to soil properties, while with OF, it has to pass some processes before it can be converted to be used by the plant and it is beneficial to both plant and soil.

Root and Shoot Potassium Uptake and Potassium-use Efficiency

Potassium (K) is equally important specifically with increasing crop yield because it has great role in increasing root growth and improves drought tolerance; aids in photosynthesis and food formation, helps translocate sugar and starches, and maintains turgor, reduces water loss and wilting (Ahn, 1993).

Site 1(Sarrat, Ilocos Norte). Fertilizer treatments did not show significant effect on root and shoot K uptake, while genotypes did not vary. However, plants applied with OF had significantly the highest root K uptake (15.09 kg ha^{-1}) while the application of 50% OF + 50%IF had the highest shoot K uptake (1.68 kg ha^{-1}). The lowest root and shoot K uptakes were observed in plants applied with IF (11.91 and 0.87 kg ha^{-1}, respectively). Among the genotypes, Genotype 5 had the highest root K uptake (17.35 kg ha^{-1}), while Genotype 5 had the highest shoot K uptake (2.29 kg ha^{-1}).

Fertilizer treatments significantly affected RE_K and IE_K. For the REK. The application of 50%OF + 50% IF had the highest RE_K (0.06 kg kg^{-1}), while the lowest was in OF applied plants (0.003 kg kg^{-1}). Among the genotypes, the highest was with Genotype 5 (0.09 kg kg^{-1}). Highest IE_K was obtained from plants applied with OF (0.95 kg kg^{-1}), while the lowest was in unfertilized plants. Among the genotypes, the highest was obtained by Genotype 3 with 1.06 kg kg^{-1}.

Site 2 (Dingras, Ilocos Norte). In this site, fertilizer treatments significantly affected the root and shoot K uptakes, while variations due to genotypes were not observed. Unfertilized plants had the highest in root and shoot K uptakes (6.46 and 1.66 kg ha^{-1}, respectively). Genotype 3 had the highest root and shoot K uptakes. The application of IF and OF have both high REK. Among the genotypes, Genotype 3 had the highest REK (0.08 kg kg^{-1}). In terms of IEK, the highest conversion efficiency was those plants applied with 50%OF + 50%IF (0.76 kg kg^{-1}), while the lowest was with unfertilized plants (0.44 kg kg^{-1}). The highest IE_K was observed in genotype 2 with 1.35 kg kg^{-1}.

Site 3 (Bangui, Ilocos Norte). Fertilizer treatments significantly affected root and shoot K uptakes but did not vary among genotypes. In this site, control plants had the highest root K uptake (12.71 kg ha^{-1}). 50%OF + 50% IF fertilized plants had the highest shoot K uptake with 0.12 kg ha^{-1}. The lowest root and shoot K uptakes were obtained in plants applied with IF (4.97 and 0.08 kg kg^{-1}, respectively). Genotype 1 had the highest root K uptake (13.94 kg ha^{-1}) while Genotype 2 had the highest shoot K uptake (0.15 kg ha^{-1}) .

For the efficiency parameters, fertilizer treatments did not affect RE_K and IE_K. Plants applied with OF and 50%OF + 50%IF have similar RE_K, while the application of IF alone produced the highest IE_K in this site. Genotype 2 had the highest IEK (8.68 kg kg^{-1}) and the lowest was obtained in Genotype 3 (1.54 kg kg^{-1}).

In terms of the efficiencies, results vary among the sites used. For site 1, the application of 50%OF + 50% IF had the highest RE_K, while OF application resulted to high IE_K. Genotype 3 and Genotype 5 are suitable for IE_K and RE_K, respectively in terms of their efficiencies. In site 2, RE_K is high with either application of IF or OF, while Genotype 2 and 3 are the most efficient. In site 3,

Table 19: Root and shoot potassium uptakes of yam bean genotypes grown in different fertilizer treatments at three sites in Ilocos Norte. 2008-2009 Cropping Season.

Within a column (G means) and/or within a row (F means), means followed by different letters are significantly different at 5% level of

	Root K Uptake (kg ha^{-1})														
	Site 1 (Sarrat, Ilocos Norte)					**Site 2 (Dingras, Ilocos Norte)**					**Site 3 (Bangui, Ilocos Norte)**				
GENOTYPE	**C**	**OF**	**50% OF + 50%IF**	**IF**	**Mean**	**C**	**OF**	**50%OF + 50%IF**	**IF**	**Mean**	**C**	**OF**	**50%OF + 50%IF**	**IF**	**Mean**
1	5.12	16.38	14.56	12.42	12.12	8.37	4.58	6.92	3.51	5.84 a	13.94	6.22	8.47	6.90	8.88
2	14.21	13.87	13.69	9.71	12.87	4.69	4.53	5.36	3.08	4.42 a	12.13	6.44	11.56	5.96	9.02
3	15.46	13.48	12.36	12.00	13.33	8.45	6.11	5.81	4.67	6.26 a	12.67	4.82	11.87	5.19	8.64
4	14.52	14.37	12.03	15.05	13.99	5.13	4.27	4.90	3.52	4.66 b	12.88	8.13	8.34	5.11	8.62
5	21.56	17.35	11.75	10.36	15.25	5.67	4.77	5.48	2.72	4.66 b	11.92	0.98	5.22	1.68	4.95
Mean	14.17ab	15.09a	12.88ab	11.91 b		6.46 a	4.85 b	5.69 ab	3.50 c		12.71 a	5.32 c	9.09 b	4.97 c	
	F: Pr > F = 0.0002 ; LSD = 288.79					**F: Pr > F = 0.001 ; LSD = 89.30**					**F: Pr > F = 0.0012 ; LSD = 161.92****				
	G: Pr > F =0. 3452 ; LSD = 322.87ns					**G:Pr > F =0.001 ; LSD = 99.84**					**G: Pr > F = 0.3291 ; LSD =181.04ns**				
	F X G: Pr > F = 0.2831					**F X G: Pr > F= 0.1723**					**F X G: Pr > F = 0.7123**				
Shoot K Uptake (kg ha^{-1})															
1	1.33	0.85	2.23	1.56	1.49	1.03	1.44	1.28	1.87	1.40 b	0.01	0.28	0.05	0.06	0.10 a
2	1.28	1.04	1.95	1.69	1.49	2.10	1.16	0.71	1.49	1.37 b	0.01	0.04	0.15	0.01	0.05 b
3	1.59	0.85	0.68	1.02	1.03	2.30	1.87	1.46	1.61	1.81 a	0.12	0.06	0.14	0.15	0.12 a
4	1.46	1.22	1.26	1.21	1.29	1.32	1.54	1.03	1.45	1.34 b	0.08	0.03	0.13	0.13	0.09 a
5	1.72	0.99	2.29	0.87	1.47	1.55	1.48	1.18	1.35	1.39 b	0.07	0.20	0.14	0.05	0.11 a
Mean	1.48	0.99	1.68	1.27	1.35	1.66 a	1.50 a	1.13 b	1.55 a		0.06 b	0.12 a	0.12 a	0.08b	
	F:Pr > F = 0.2178 ; LSD = 13.24					**F:Pr > F = 0.001 ; LSD = 24.97**					**F:Pr > F = .01 ; LSD = 3.30**				
	G: Pr > F = 0.1287 ; LSD = 11.98					**G: Pr > F= 0.0021 ; LSD = 27.92**					**G: Pr > F = 0.0002 ; LSD = 3.69**				
	F X G: Pr > F = 0.2632					**F X G: Pr > F = 0.2987**					**F X G: Pr > F = 0.213**				

significance by LSD.

Table 20: Recovery efficiency and Internal efficiency of yam bean genotypes grown with different fertilizer treatments at three sites in IlocosNorte. 2008-2009 Cropping Season

GENOTYPE	Recovery Efficiency of K (kg kg^{-1})														
	Site 1 (Sarrat, Ilocos Norte)					Site 2 (Dingras, Ilocos Norte)					Site 3 (Bangui, Ilocos Norte)				
	C	OF	50% OF + 50%IF	IF	Mean	C	OF	50%OF + 50%IF	IF	Mean	C	OF	50%OF + 50%IF	IF	Mean
1	-	0.003	0.07	0.06	0.054 b	-	0.05	0.06	0.07	0.05 c	-	0.02	0.006	0.005	0.01 a
2	-	0.003	0.07	0.07	0.057 a	-	0.05	0.03	0.05	0.04d	-	0.005	0.01	0.006	0.007 b
3	-	0.003	0.02	0.04	0.03 d	-	0.07	0.07	0.06	0.07 a	-	0.006	0.009	0.02	0.01 a
4	-	0.004	0.06	0.05	0.05 c	-	0.06	0.05	0.07	0.06c	-	0.006	0.01	0.01	0.01 a
5	-	0.003	0.09	0.05	0.057 a	-	0.06	0.061	0.06	0.06 b	-	0.02	0.028	0.006	0.01 a
Mean	-	0.003 c	0.06 a	0.05 b		-	0.06 a	0.05 b	0.06 a		-	0.01	0.01	0.009	
	F:Pr > F= 0.002					F:Pr > F= 0.003					F:Pr > F = O.002				
	G:Pr > F= 0.003					G:Pr > F= 0.004					G:Pr > F= 0.0024				
	F X G: Pr > F = 0.012**					F X G:Pr > F = 0.132					F X :Pr > F= 0.0013				
Internal Efficiency of K (kg kg^{-1})															
1	0.34	1.23	0.52	0.18	0.65 b	0.62	0.59	0.63	0.56	0.60 b	4.23	1.33	3.27	4.84	3.42
2	0.46	0.93	0.49	0.49	0.59 b	0.44	0.62	1.35	0.65	0.76 a	4.15	5.06	2.26	8.68	5.04
3	0.54	1.06	1.54	0.78	0.98 a	0.35	0.42	0.54	0.53	0.46 c	3.34	5.09	2.76	1.54	3.18
4	0.41	0.70	0.57	0.76	0.61 b	0.35	0.48	0.63	0.61	0.52 bc	3.71	6.00	1.79	2.62	3.33
5	0.63	0.86	0.36	0.51	0.59 b	0.44	0.46	0.67	0.67	0.56 b	4.50	1.60	3.30	3.44	3.21
Mean	0.48 b	0.95 a	0.69 b	0.61 b		0.44 c	0.51 c	0.76 a	0.60 b		3.99	3.82	2.67	4.22	
	F:Pr > F= 0.002 ; LSD =2.61					F:Pr > F = 0.0002 ; LSD =2.47**					F: Pr > F= 0.2617 ; LSD= 2.94				
	G:Pr >F = 0.001 ; LSD =2.93ns					G:Pr > F = 0.001 ; LSD = 2.7ns					G:Pr > F= 0.2431 ; LSD = 3.28				
	F X G:Pr > F = 0.2311					F X G:Pr > F:Pr > F = 0.321					F X G: Pr > F = 0.2167				

Within a column (G means) and/or within a row (F means), means followed by different letters are significantly different at 5% level of significance by LSD.

the highest RE_K was observed in 50%OF + 50% IF applied plants, while IE_K was highest with IF application. Genotype 2 is the most efficient in conversion among the genotypes in this site.

Cost and Return Analysis

The parameters used were total production cost, gross income, net income and return on investment (ROI) as shown in Table 21. The analysis was done to determine the economic viability of each genotype under varying fertilizer treatments across all sites. Cash and non-cash cost were recorded and considered as total cost. Pre-land preparation, material and labor costs were included. Gross income was computed by multiplying the total produce in each treatment per genotype with the price per kilogram yield = PhP60 per kg. The net income was obtained by subtracting the total production cost from the gross income. The return on investment was also determined per treatment per genotype by dividing the net income by the total cost multiplied by 100. Thus, ROI reflects the amount of return per peso invested for each treatment (Table 21).

Site 1 (Sarrat, Ilocos Norte). The highest total production cost in this site was obtained from the plots applied with inorganic fertilizer (PhP 60,370), while the lowest was the control (PhP 47,692). Among the genotypes used, Genotype 3 incurred the highest (PhP 55,077) total production cost, while Genotype 2 and Genotype 5 were equally the lowest. Genotype 3 is large-seeded, thus less number of seeds are contained per kg, such that heavier weight of planting material is needed to satisfy the seed requirement (e. g. 21,000 seeds per ha^{-1}), more were used in terms of kilogram, thus, higher seed cost. Highest gross income was obtained in plants with 50% IF + 50% OF (PhP 314,500, while the lowest was in IF applied treatment (PhP 256,070). Genotype 2 had the highest gross income (PhP 294,950), while Genotype 5 had (PhP 270,500), the lowest in yield.

Plants applied with 50% OF + 50% IF produced the highest net income (PhP 257879), while the lowest was obtained in IF applied plants (PhP 195,700). Among genotypes, the highest net income was obtained in Genotype 2 (PhP 241049), while the lowest was in Genotype 5 (PhP 216599).

Control plants had the highest ROI (4.9), while the IF applied plants had the lowest ROI (3.24). Among the genotypes, the highest ROI was from Genotype 2 and the lowest was from Genotype 5.

Site 2 (Dingras, Ilocos Norte. Among the fertilizer treatments, the highest total production cost in this site was obtained in treatment with inorganic fertilizer application (PhP 59770), while the lowest was from the unfertilized treatment with PhP 47,092. Among the genotypes, the highest was incurred by Genotype 3 (PhP 54,327), while the lowest was from Genotype 2 (PhP 53,151).

The highest was obtained from plants applied with 50% OF + 50% IF (P329010), while the lowest was with OF application (PhP 286,330). For the genotypes, the highest gross was obtained from Genotype 5 (PhP 323,337) and the lowest was from Genotype 4 with PhP 284800. In this case Genotype 5 had the highest root yield so it had the highest income.

The highest net income per hectare, was obtained in plants applied with 50% OF + 50% IF (PhP 273,088) and the lowest was with OF (PhP 234,238). With regards to genotypes, Genotype5 had the highest net income (PhP 269,436) and the lowest was Genotype 4 with PhP 231,073. High net income in Genotype 5 is due to its high yield while low net income of Genotype 4 was due to its low yield.

The ROI was highest in unfertilized plants (5.13)and the lowest was with IF (4.13). Among the genotypes, the highest was from Genotype 5 (4.99) and the lowest was from Genotype 4 with 4.32.

Site 3 (Bangui, Ilocos Norte). Similar to the other sites, the highest total cost of production in this site was obtained from plants applied with inorganic fertilizer (PhP 74,120) and the lowest was with the unfertilized plants (PhP 61,442). Among the genotypes, the highest was incurred by Genotype 3 (PhP 68,827) while the lowest was from Genotype 2 and Genotype 5.

For the gross income, the highest was computed from the plants applied with organic fertilizer (PhP264870) due to higher yield while the lowest was with inorganic fertilizer (PhP202170). Among the genotypes, Genotype 4 got the highest gross with PhP 238,550 while G1 had the lowest with PhP 223,550.

Plants applied with organic fertilizer had the highest net income (PhP 198,428), while the lowest was from the plants applied with inorganic fertilizer with PhP128050 due to the high production cost incurred in their fertilizer treatment.

The highest ROI was obtained from the unfertilized plants (3.00) but is comparable with the plants applied with organic fertilizer (2.99), and the lowest was with inorganic fertilizer (1.73). For the genotypes, the highest ROI was from obtained from Genotype 4 (2.53) and the lowest was from Genotype 1 with 2.33.

Considering the fertilizer treatments, the application of inorganic fertilizer incurred the highest production cost and lowest returns. This is attributed to the high cost of synthetic chemical fertilizer materials used as compared to other locally available fertilizer materials such as organic fertilizer and its cost is minimal. The use of organic fertilizer material usually improve the soil characteristics as well as microbial N fixation of the plant. Application of organic fertilizer alone or in combination with inorganic fertilizer was found to increased yield at lesser cost particularly in Site 3.

On the other hand, unfertilized plants appeared to have comparable with the high results obtained from organic fertilization. This proves that even without added fertilizer, yam bean plants can still produce with returns because this plant being a legume, has the ability to fix for its own food nutrient using the available material from the soil and its environment. However, for purposes of soil improvement especially in the areas which are less productive like in Site 3, the use of OF is favored.

Table 21: Summary table of cost and return analysis of yam bean genotypes grown with four fertilizer treatments in three sites Ilocos Norte Philippines. 2008-2009 Cropping Season.

Geno type	Site 1 (Sarrat, Ilocos Norte)					Site 2 (Dingras, Ilocos Norte)					Site 3 (Bangui, Ilocos Norte)				
	Control	**OF**	**50%OF + 50%IF**	**IF**	**Mean**	**Control**	**OF**	**50%OF + 50%IF**	**IF**	**Mean**	**Control**	**OF**	**50%OF + 50%IF**	**IF**	**Me**
Total Production Cost (PhP ha^{-1})															
1	47610	52610	56440	60288.2	54237.05	46860	51860	55690	59538.2	53487.05	61360	66360	70190	74038.2	67
2	47274	52274	56104	59952.2	53901.05	46524	51524	55354	59202.2	53151.05	61024	66024	69854	73702.2	67
3	48450	53450	57280	61128.2	55077.05	47700	52700	56530	60378.2	54327.05	62200	67200	71030	74878.2	68
4	47850	52850	56680	60528.2	54477.05	47100	52100	55930	59778.2	53727.05	61600	66600	70430	74278.2	68
5	47274	52274	56104	59952.2	53901.05	47274	52274	56104	59952.2	53901.05	61024	66024	69854	73702.2	67
Mean	47691.6	52691.6	56521.6	60369.8	54318.65	47091.6	52091.6	55921.6	59769.8	53718.65	61441.6	66441.6	70271.6	74119.8	68
Gross Income (PhP ha^{-1})															
1	253350	316650	351650	248350	292500	289150	300000	332500	312500	308537.5	258350	247500	168350	220000	22
2	291650	305650	294150	288350	294950	315000	275000	330850	295000	303962.5	270000	226650	206650	210850	22
3	306650	275000	327500	251650	290200	295000	284150	318350	272500	292500	231650	283500	215850	205850	23
4	237500	285850	310850	293350	281887.5	255000	297500	295850	290850	284800	237500	280850	238350	197500	23
5	318350	276650	288350	198650	270500	290000	275000	367500	360850	323337.5	231650	285850	248350	176650	23
Mean	281500	291960	314500	256070	286007.5	288830	286330	329010	306340	302627.5	245830	264870	215510	202170	23
Net Income (PhP ha^{-1})															
1	205740	264040	295210	188061.8	238262.95	242290	248140	276810	252961.8	255050.45	196990	181140	98160	145961.8	15
2	244376	253376	238046	228397.8	241048.95	268476	223476	275496	235797.8	250811.45	208976	160626	136796	137147.8	16
3	258200	221550	270220	190521.8	235122.95	247300	231450	261820	212121.8	238172.95	169450	216300	144820	130971.8	16
4	189650	233000	254170	232821.8	227410.45	207900	245400	239920	231071.8	231072.95	175900	214250	167920	123221.8	17
5	271076	224376	232246	138697.8	216598.95	242726	222726	311396	300897.8	269436.45	170626	219826	178496	102947.8	16
Mean	233808.4	239268.4	**257978.4**	195700.2	231688.85	241738.4	234238.4	**273088.4**	246570.2	248908.85	184388.4	**198428.4**	145238.4	128050.2	16
Return on Investment (PhP return per peso invested)															
1	4.32	5.02	5.23	3.12	4.42	5.17	4.78	4.97	4.25	4.79	3.21	2.73	1.40	1.97	2.3
2	5.17	4.85	4.24	3.81	4.52	5.77	4.34	4.98	3.98	4.77	3.42	2.43	1.96	1.86	2.4
3	5.33	4.14	4.72	3.12	4.33	5.18	4.39	4.63	3.51	4.43	2.72	3.22	2.04	1.75	2.4
4	3.96	4.41	4.48	3.85	4.18	4.41	4.71	4.29	3.87	4.32	2.86	3.22	2.38	1.66	2.5
5	5.73	4.29	4.14	2.31	4.12	5.13	4.26	5.55	5.02	4.99	2.80	3.33	2.56	1.40	2.5
Mean	4.9	4.54	4.56	3.24		5.13	4.5	4.88	4.13		3.00	2.99	2.07	1.73	

Formula: Total cost of production=total cash and non-cash; Gross income=YieldxPrice/kg
Net income = Gross income-Total production cost ; ROI = Net income / Total Production Cost

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