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Evaluation of Pigeonpea Genotypes for Intercropping with Maize and Sorghum in Southern Guinea Savanna: Economic Benefits

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Abstract The economics of production and profitability of intercropped pigeonpea [Cajanus cajan (L.) Millsp] genotypes with maize [Zea mays L.] and sorghum [Sorghum bicolor (L.) Moench] were studied in two separate field experiments in 2007 and 2008. Each experiment was a 2 x 15 factorial set out in split plot design in three replications with the main objective of evaluating the economic potentials of recently introduced pigeonpea genotypes from International Crops Research Institute for Semi-Arid Tropics (ICRISAT) with a view to increasing and diversifying household income in Southern Guinea Savanna of Nigeria. Though it depressed pigeonpea grain yields, intercropping consistently gave higher net benefits than sole cropping in the pigeonpea/maize systems. ICPL 87 gave the highest net benefits in both pigeonpea/maize and pigeonpea/sorghum intercropping systems (N200, 082.00/ha and N110, 399.00/ha respectively). It also produced the highest marginal rate of returns and returns per naira investment in the pigeonpea/maize systems. Sole pigeonpea was more remunerative than many intercropped pigeonpea with sorghum. Most of the new varieties proved superior to the Farmer's variety in both cropping systems, with consequent higher profitability. This implies potential increase in household incomes and alternative farm enterprise with the adoption of any of these new varieties in the intercropping systems studied.

Keywords Intercropping, Pigeonpea, Net Benefits, Marginal Rate of Returns

1. Introduction

Globally pigeonpea (*Cajanus cajan* (L.) Millsp) is the fifth most important pulse crop mainly grown in the developing countries by resource-poor farmers in drought prone areas and on degraded soils. It is a multipurpose leguminous crop that can provide food, fuel wood and fodder for the small-scale farmer in subsistence agriculture (Tabo *et al.*,1995;Egbe,2005).Pigeonpea is a deep-rooted and drought tolerant grain legume that adds substantial amount of organic matter to the soil (Egbe,2005) and has the ability to fix up to 235 kg N/ha (Peoples *et al.*, 1995) and produces more N per unit area from plant biomass than many other legumes. Pigeonpea has been reported to fix between 36.10 and114.04 kg N/ha when intercropped with maize and 35.94-164.82 kg N/ha under intercropping with sorghum at Otobi (Egbe, 2007). In Southern Guinea Savanna agro-ecological zone of Nigeria, where poverty level is high and income generation opportunities are few, pigeonpea is often grown as field crop in both sole and intercropping systems with maize and sor ghum (Egbe, 2005; Egbe and Kalu, 2006).Intercropping popularity among small-scale farmers in Benue, Kogi, Nasarawa, Taraba and Kaduna States of Nigeria, probably because of its multiple-end uses, despite low yields (0.5-1.0 t/ha) under the traditional cropping systems.

Estimation of farm income benefits provides an alternative measure of potentials for various intercropping combinations (Anders *et al.*,1996).Some workers had estimated benefits that accrued to pigeonpea producers as farm income by calculating the monetary advantage (Rafey and Prasad,1992) or by estimating the net returns (Ramakrishna *et al.*, 2005; Marer *et al.*, 2006; Guedes and Araujo,2010). Egbe (2010) had estimated economic benefits of intercropped soybean with sorghum by calculating gross returns, net returns, and returns per naira investment, soybean equivalent ratio and marginal rate of returns. Information on the biological efficiencies of intercropping pigeonpea with sorghum and maize in Nigeria are available (Egbe, 2005; Egbe and Adeyemo, 2006; Egbe and Bar- Anyam, 2011), but there is dearth of documented information on the economic benefits of these intercropping systems in the Southern Guinea agro- ecological zone of Nigeria. The work reported here was undertaken to document the economic benefits of intercropping

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some newly introduced improved pigeonpea genotypes with maize and sorghum in Southern Guinea Savanna of Nigeria with a view to increasing and diversifying household incomes of farmers in the region.

2. Materials and Methods

Two separate field experiments were set up in 2007 and 2008 at the National Root Crops Research Institute Sub-Station,Otobi (07^o 10$'$ N,08^o 39$'$ E, elevation 105.1 m) in Benue State, located in Southern Guinea Savanna of Nigeria (Kowal and Knabe,1972).The objectives of the experiments were to estimate the economic benefits of intercropping improved pigeonpea genotypes separately with maize and sorghum. These pigeonpea genotypes obtained from International Crops Research Institute for Semi-Arid Tropics (ICRISAT), India, were recently introduced to farmers in Benue State, Nigeria. The experimental site received a total rainfall of 1712.00 mm and 1665.60 mm, respectively, within the period of June-November, 2007 and 2008. The soil at the experimental site was classified as Typic Paleustaff (USDA).

Ten core soil samples were taken randomly from the experimental site and bulked into a composite sample for physical and chemical analysis at the National Vertinerary Research Institute, Vom near Jos, Nigeria in each year of the experiment. The soil was characterized as sandy-loam with pH of 7.60 (H_2O). Total nitrogen, available phosphorus (Bray 1) and potassium values were 350, 36,122 mg kg^{-1} soil, respectively, in 2007. In 2008, the soil was similarly characterized as sandy loam with pH of 6.90(H_2O), total nitrogen, available phosphorus (Bray 1), and potassium values were 510, 51,150 mg kg^{-1}, respectively.

2.1. Experiment 1: Pigeonpea/Maize Intercropping

The experiment was 2 x 15 split-plot laid out in randomized complete block design with three replications. Cropping systems at two levels [sole cropping (pigeonpea ,maize) and intercropping (pigeonpea + maize) constituted the main plot treatments, while 15 pigeonpea genotypes of different maturity groups [ICPL 85010,ICPL 84031,ICPL 87,ICPL 161 (short duration),ICPL 8863,ICPL 85063,ICPL 87119,ICPL 7120,,ICEAP 00068 (medium duration),ICPL 7035,ICPL 8094,ICPL 87051,ICPL 9145,ICEAP 00040 (long duration) and the Farmers' variety] including a local check constituted the sub-plot treatments. The maize variety used was the *Striga*-tolerant CY TZL.COMP.1C4 obtained from the International Institute for Tropical Agriculture (IITA), Ibadan, Nigeria.

The gross plot comprised of 3 ridges spaced 1 m apart and 4 m long (12 m^2),while the net plot was made up of the middle ridge (4 m^2). Land preparation was done manually using traditional implements. Pigeonpea was planted at a spacing of 1 m x 0.3 m with three seeds per hole and later thinned to two plants/stand (66,666 plants /ha),while the maize was planted at a spacing of 1 m x 0.5 m with three seeds per hole and later thinned to two plants/stand (40,000 plants/ha). The same population of pigeonpea and maize were maintained in both intercrop and sole crop treatments. Intercropping had a 1:1 (pigeonpea: maize) row proportion. In the intercrop treatments, both pigeonpea and maize were planted on the same ridge. Pigeonpea occupied the crest of the ridge, while maize was planted on the side. Both crops were planted on the same day, on 23rd and 24th June 2007 and 2008, respectively. All plots received a basal application of 100 kg of NPK: 15:15:15 at the rate 15 kg N, 6.45 kg P and 12.45 kg K per hectare (ha) by broadcasting. The sole and intercropped maize were top-dressed four weeks after planting (w.a.p) with 46 kg N/ha by opening the soil around each plant and banding at 5-8 cm depth and covering with the dug-out soil. Two manual weeding were done at 3 w.a.p. and 6 w.a.p., respectively. Data on grain yields of pigeonpea and the grain yield of maize were collected at harvest for analysis.

2.2. Experiment 2: Pigeonpea/Sorghum Intercropping

The experimental site was separated from that of Experiment 1 by a distance of 10 m. The pigeonpea genotypes used, land preparation methods, experimental design, planting methods and dates, spacing, crop husbandry practices and procedures for data collection were the same as adopted in Experiment 1. The sorghum cultivar used in this experiment was the tall, photoperiod-sensitive red sorghum commonly used by the farmers in Southern Guinea Savanna. Data on grain yields of both pigeonpea and sorghum components were collected for analysis.

In both experiments, application of insecticide to check pod borers was need-based.

2.3. Economic Performance of Pigeonpea/Maize and Pigeonpea/Sorghum Intercropping

The economic performance of the intercropping systems were evaluated to decide if grain yields of intercropped pigeonpea with maize and sorghum in 2007 and 2008 at Otobi and additional maize and sorghum yields justified adoption of this intercropping system by farmers in Southern Guinea Savanna of Nigeria. Total variable cost (TVC) and net benefits were computed as described by Egbe (2010). Returns per naira invested (RI) was computed as RI = gross returns ⁄ TVC. The higher the value of RI the more profitable is the cropping system. Furthermore, the economic analysis was carried out as described by CIMMYT (1998) to estimate the marginal rate of returns. A dominance analysis was done and the non-dominated treatments were further subjected to marginal rate analysis. For the dominance analysis, only the top ten treatments (i.e., treatments with the highest computed net benefits) were used. The local market price of pigeonpea, maize and sorghum per kg in 2008 and 2009 were ₦150, ₦120, and ₦100 (Nigerian naira) which are equivalent to 1.25, 1.00 and0.83 USD respectively. The Nigerian naira values were used to obtain the calculated cash values.

2.4. Statistical Analysis

Data collected were analyzed using GENSTAT Release 11.1 (PC/Windows) (2008 VSN International Ltd., London) and standard errors of differences of means (Sed) were used to compare treatment means. Student's t-test was used to compare values of economic parameters (TVC, net benefits and RI) of pigeonpea/maize and pigeonpea/sorghum intercropping systems. Year x treatment effects were not significant and so results of both years were pooled before analysis.

Table 1. Grain yield (t/ha) of pigeonpea intercropped with maize and sorghum at Otobi

Genotype (GE)	Cropping systems (CR)					
	Pigeonpea/maize intercrop			Pigeonpea/sorghum intercrop		
	Sole	Inter crop	Mean	Sole	Inter crop	Mean
ICPL 85010	1.99	2.19	2.09	1.28	1.24	1.26
ICPL 84031	2.19	1.63	1.91	1.66	0.74	1.20
ICPL 87	3.11	2.96	3.03	2.15	2.16	2.15
ICPL 161	1.93	1.99	1.97	1.38	1.36	1.37
ICPL 8863	2.45	2.21	2.33	1.73	0.92	1.32
ICPL 85063	2.26	1.86	2.06	1.88	1.07	1.47
ICPL 87119	2.72	1.53	2.12	2.05	1.07	1.54
ICPL 7120	1.57	2.05	1.81	1.04	0.77	0.90
ICEAP 00068	1.59	1.19	1.39	1.17	1.19	1.18
ICPL 8094	2.25	2.03	2.14	1.31	0.85	1.08
ICPL 7035	2.32	1.99	2.16	1.81	1.02	1.41
ICPL 87051	1.47	1.21	1.34	2.47	0.70	1.59
ICPL 9145	1.59	1.59	1.59	0.92	1.04	0.98
ICEAP 00040	1.38	1.20	1.29	2.85	0.80	1.83
'Igbongbo white' (check)	1.85	1.01	1.43	1.17	0.78	0.97
Mean	2.05	1.78	1.91	1.66	1.05	1.35
Sed (0.05)						
CRS	0.06			0.06		
GE	0.07			0.47		
CRS X GE	0.12			0.64		
Paired t test (0.05)						
Pigeonpea/maize intercrop vs pigeonpea/sorghum intercrop	3.29ns					

ns: not significant at 5% probability level

3. Results

The yield of pigeonpea genotype varied with the cropping systems adopted (Table 1). Generally, intercropping depressed the yield of pigeonpea. However, some genotypes (ICPL 85010, ICPL 161 and ICPL 7120) had higher significant yield under intercropping than in sole cropping in the pigeonpea/maize systems. ICPL 87 produced the highest mean yield in both pigeonpea/maize and pigeonpea/sorghum cropping systems. While ICEAP 00040 gave the lowest yield (1.29 t/ha) in the pigeonpea/maize cropping systems, ICPL 7120 did so in pigeonpea/sorghum systems. There was no significant difference between pigeonpea/maize and pigeonpea/sorghum in the grain yields of pigeonpea produced (Table 1).

Intercropped maize and sorghum with ICPL 8863 produced the highest grain yields of both maize (3.43 t/ha) and sorghum (3.21 t/ha) (Table 2). Grain yields of the cereal components of the pigeonpea/maize and pigeonpea/sorghum were similar (Table 2).Only two intercrop combinations (ICPL 85063 + sorghum and ICEAP 00068 +sorghum) gave cereal yield figures of less than 2.0t/ha; all the other combinations had above 2.0 t/ha (Table 2).

Table 2. Yields (t/ha) of intercropped maize and sorghum with pigeonpea at Otobi

Cropping systems	Maize component yield	Sorghum component yield
Sole crop	3.30	2.41
Intercropping:		
ICPL 85010	2.93	2.04
ICPL 84031	2.33	2.14
ICPL 87	2.70	3.21
ICPL 161	3.43	3.10
ICPL 8863	3.20	1.89
ICPL 85063	2.75	2.69
ICPL 87119	2.58	2.34
ICPL 7120	3.24	1.81
ICEAP 00068	2.45	2.67
ICPL 8094	3.13	2.26
ICPL 7035	3.13	2.62
ICPL 87051	2.38	2.09
ICPL 9145	2.75	2.65
ICEAP 00040	2.48	2.53
'Igbongbo white' (check)	2.40	2.36
Mean	2.81	2.42
Sed (0.05)	0.30	0.25
Paired t-test (0.05)		
Maize in pigeonpea vs sorghum in pigeonpea	2.36ns	
Intercropping vs sole	-0.92ns	

Table 3. TVC (₦/ha) of sole maize, sorghum, pigeonpea, pigeonpea/maize and pigeonpea/sorghum intercropping systems in Otobi

Cropping systems	TVC
Sole maize	24,582.00
Sole sorghum	24,991.00
Sole pigeonpea	49,942.00
Pigeonpea/maize intercropping	43345.00
Pigeonpea/sorghum intercropping	44,604.00
S.E.	658.80

The TVC of sole pigeonpea (₦49942.00) was significantly higher than the TVC of the other treatments including intercropped treatments of pigeonpea with maize and sorghum (Table 3). Also, TVC of pigeonpea/sorghum (₦44604.00) intercropping was significantly higher than that of pigeonpea/maize (₦43345.00). The TVCs of sole maize and sole sorghum were statistically at par (Table 3).

Intercropping consistently gave higher net benefits than sole cropping in the pigeonpea/maize systems (Figure1). Intercropped ICPL 87 gave the highest net benefit (₦200, 082.00/ha) while '*Igbongbo white*' had the lowest (₦68, 667.00/ha). Net benefits averaged ₦89, 489.00/ha in the pigeonpea/maize cropping systems. Net benefits of pigeonpea intercropped with sorghum varied from ₦38, 549.00/ha to ₦110, 399.00/ha, with a mean of ₦57, 965.00/ha while the sole crop values were ₦36, 168.00/ha – ₦115, 5354.00 and averaged ₦58, 489.00. The trends of net benefits produced by pigeonpea/sorghum systems were inconsistent. Several sole pigeonpea genotypes gave higher net benefits values than the intercropped treatments (e.g. ICPL 85010, 84031, ICPL 8863, ICPL 85063, ICPL 87119, ICPL 7035, ICPL 87051 and ICEAP 00040), but the other seven genotypes had the reverse trend. ICPL 87 gave the highest net benefit (N110, 399.00/ha) under intercropping while ICEAP 00040 had the highest (₦115, 354.00/ha) under sole cropping (Figure 2). In the pigeonpea/sorghum systems, the mean net benefit was ₦58, 227.00/ha.

Intercropped ICPL 87 was the only non-dominated treatment of the top ten treatments, all the others nine were. (Table 4).

Marginal analysis of the best intercrop and sole crop treatments produced a marginal rate of return value of 1375%(Table5).

Table 4. Dominance analysis, top ten treatments in pigeonpea/maize systems

Treatments	TVC(₦/ha)	Net benefits (₦/ha)
Intercropped ICPL 87	43,345.00	200,082.00
Intercropped ICPL 8094	43,345.00	164,232.00 D
Intercropped 7035	43,345.00	160,235.00 D
Intercropped 7120	43,345.00	153,330.00 D
Intercropped 8863	43,345.00	143,712.00 D
Intercropped 85010	43,345.00	143,497.00 D
Intercropped 161	43,345.00	137,388.00 D
Intercropped 85063	43,345.00	121,639.00 D
Intercropped 84031	43,345.00	118,030.00 D
Sole crop ICPL 87	49942.00	109,354.00 D

D: *dominated treatment*

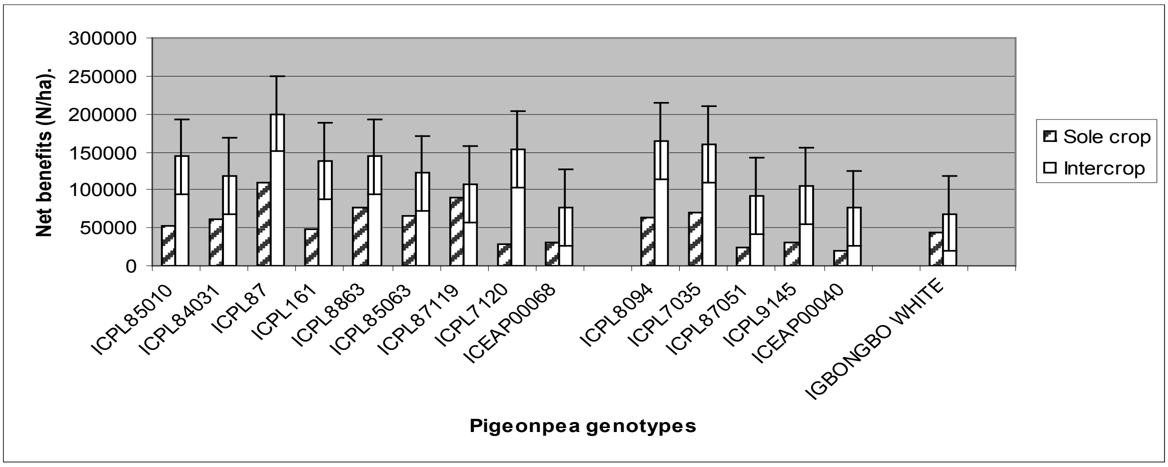

Figure 1. Net benefits of pigeonpea/maize intercropping systems at Otobi

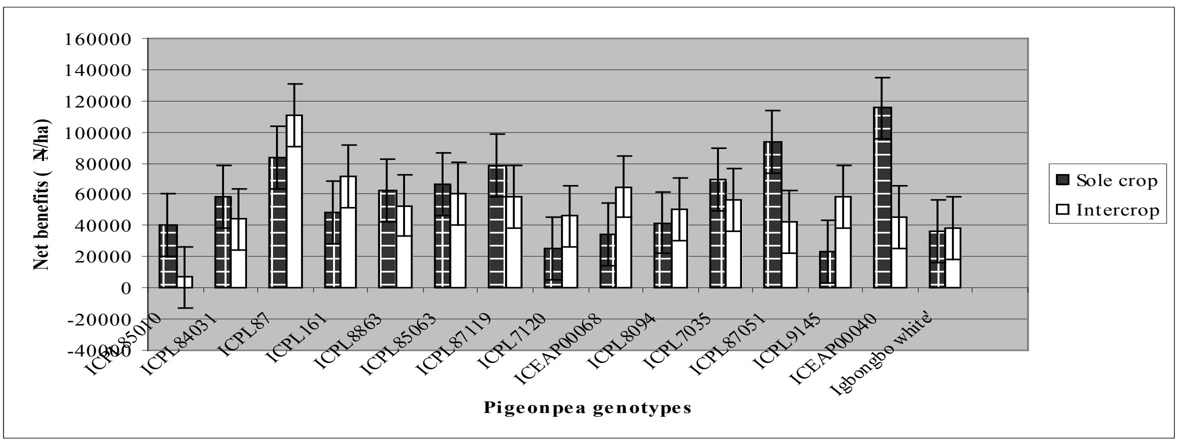

Figure 2. Net benefits of pigeonpea/sorghum intercropping systems at Otobi

Table 5. Marginal analysis, best intercrop and sole crop treatments in pigeonpea/maize cropping systems

Treatment	TVC (₦/ha)	MC (₦ /ha)	NB(₦ /ha)	MNB (₦ /ha)	MRR(%)
Intercropped ICPL 87	43,345.00	6597.00	200,082.00	90,728.00	1375
Sole ICPL 87	49,942.00		109,354.00		

Key: TVC: Total variable cost
MC:Marginal costs
NB:Net benefits
MNB:Marginal net benefits
MRR: Marginal rate of return

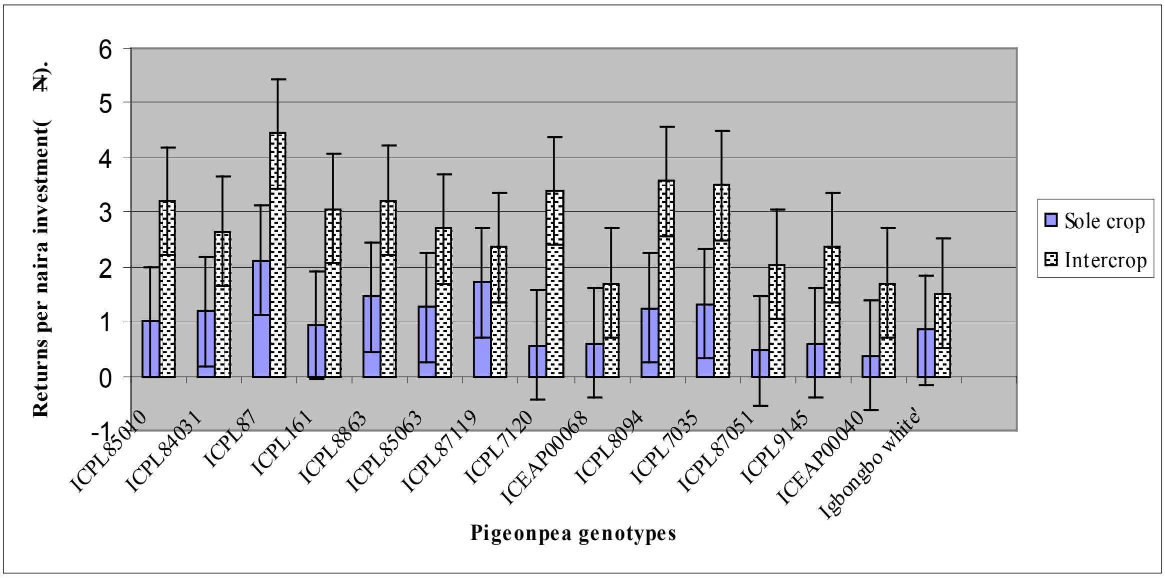

Figure 3. Returns per naira investment of pigeonpea/maize intercropping systems at Otobi

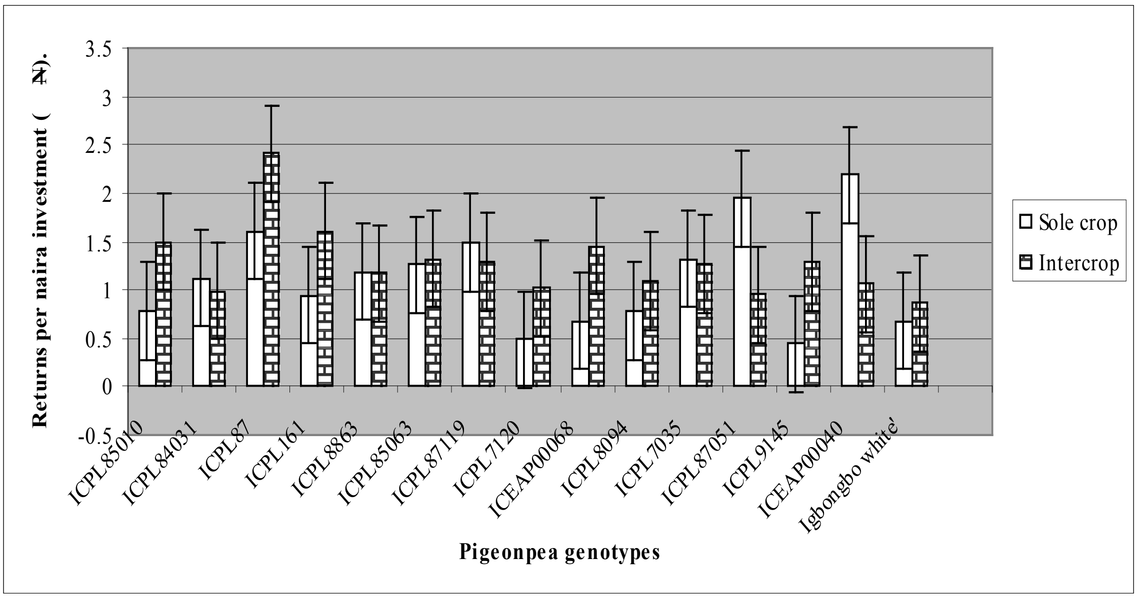

Figure 4. Returns per naira investment of pigeonpea/sorghum intercropping systems at Otobi

Table 6. Dominance analysis, top ten treatments in pigeonpea/sorghum systems

Treatments	TVC(₦/ha)	Net benefits (₦/ha)
Sole crop ICEAP 00040	49,942.00	115,354.00
Intercropped ICPL 87	44,604.00	110,399.00 D
Sole crop ICPL 87051	49,942.00	93,538.00 D
Sole crop ICPL 87	44,604.00	83,784.00 D
Sole crop 87119	49,942.00	78,371.00 D
Intercropped ICPL 161	44,604.00	71,556.00 D
Sole crop ICPL 7035	49,942.00	69,311.00 D
Intercropped ICPL 85010	44,604.00	67,979.00 D
Sole crop ICPL 85063	49,942.00	66,141.00 D
Intercropped ICEAP 00068	44,604.00	64,933.00 D

D: *dominated treatment*

Sole ICEAP 00068 was the only non-dominated treatment of the ten top treatments in the pigeonpea/sorghum systems. All the other treatments were dominated including intercropped ICPL 87(Table6).

Marginal analysis of the best intercrop and sole crop treatments produced a marginal rate of return value of 92%(Table7).

In the pigeonpea/ maize systems, intercropping consistently gave higher returns on investment (RI) than sole cropping (Figure 3). RI was highest in ICPL 87 (₦4.44) intercropped with maize at Otobi, while it was lowest in sole cropped ICPL 7120 (₦0.57). In the pigeonpea/sorghum cropping systems at Otobi, RI was erratic, as some pigeonpea sole crop systems had higher RI than intercropping (Figure 4).The highest RI in pigeonpea/sorghum systems was obtained from intercropped ICPL 87 (₦2.41), while the lowest was from sole ICPL9145 (₦0.44).

Table 7. Marginal analysis, best intercrop and sole crop treatments in pigeonpea/maize cropping systems.

Treatment	TVC (₦/ha)	MC (₦ /ha)	NB(₦ /ha)	MNB (₦ /ha)	MRR(%)
Sole ICEAP 00068	49,942.00	5338.00	115,354.00	4955.00	92.00
Intercropped ICPL 87	44,604.00		110,399.00		

Key: TVC: Total variable cost
MC:Marginal costs
NB:Net benefits
MNB:Marginal net benefits
MRR: Marginal rate of return

4. Discussion

The depression in the grain yields of intercropped pigeonpea treatments as compared to sole crop resulted from decline in plant height, dry pod weight and total plant biomass (data not shown) of the pigeonpea component due to inter-specific competition. The taller cereal components (maize and sorghum) grew faster at the early stages and shaded the slower growing pigeonpea, lowering photosynthetic activities of the pigeonpea. Similar observations have been made in earlier studies (Egbe and Adeyemo, 2006; Dasbak and Asiegbu, 2009).These authors opined that inter-specific competition for light, nutrients, water, air and other growth resources often resulted in depressed yields of the intercrop components. The higher TVC observed for sole pigeonpea as compared to intercrop could be ascribed to higher labour costs for picking the sole crop. The higher TVC of intercropped pigeonpea with sorghum than pigeonpea with maize was attributed to higher labour costs for harvesting, threshing and winnowing sorghum than maize. The greater net benefits and RI that accrued to pigeonpea/ maize intercropping as compared to the sole crop derived principally from the additional high yields and values of the maize component. Some authors have reported higher income and benefits of pigeonpea intercropping; especially when new pigeonpea lines were introduced into the maize cropping systems (Marer *et al*., 2007; Dasbak and Asiegbu, 2009). Sanginga and Woomer (2009) had stated in their work on integrated soil fertility management in Africa, that pigeonpea/maize intercropping in Malawi had and could improve farm income by 50-70% compared to continuous maize cultivation. Sole pigeonpea seemed to have been more remunerative than pigeonpea/sorghum intercropping probably because of intense inter-specific competition from the sorghum component that lowered intercrop yields and subsequently reduced profits. Sorghum is endowed with unique proliferation of robust fine root network equipped for better competition for below-ground growth resources than pigeonpea. Also, the sorghum variety used was long duration and this prolonged the period of competition between the component crops. Anders *et al*. (1996) had stated that successful intercropping combinations are often times those that capitalize on both spatial and temporal complimentarity, thus resulting in an overall increase in light intercepted by the system during a season. The better performance of ICPL 87 than the other genotypes in both intercropping systems in terms of grain yields, net benefit, RI and returns per naira investment may stem from its aggressive early growth, early maturity and profuse pod production several times in a production season. The dominance analysis indicated that it is important to pay attention to net benefits, rather than yields. The marginal rate analysis revealed that the two intercropping systems were profitable and the introduction of the new genotypes enhanced productivity and profitability of the pigeonpea/cereal intercropping systems in the region, especially the pigeonpea/maize intercropping. To minimize competition in the pigeonpea/sorghum intercropping and enhance profitability, reduction of the sorghum density may be considered for investigation.

5. Conclusions

Intercropping pigeonpea with maize consistently resulted in higher net benefits, marginal rate of returns and returns per naira investment than sole cropping. The trend in pigeonpea/sorghum was erratic, although several genotypes showed promise. Sole pigeonpea was more remunerative than intercropped pigeonpea with sorghum. Most of the new varieties proved superior in both cropping systems than the farmer's variety, with consequent higher profitability, suggesting potential increase in household incomes and alternative farm enterprise with adoption of any of these intercropping systems.

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