

Effect of Low Rates of Nitrogen and Phophorus Fertilizers on Growth and Yield of Intercropped Pigeonpea with Sorghum in Makurdi, Nigeria

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Abstract
Nitrogen (N) and phosphorus (P) are the most limiting nutrient elements in the soils of the tropics. A field experiment was conducted at the Teaching and Research Farm of the University of Agriculture, Makurdi during the 2013 and 2014 cropping seasons to determine the influence of low rates of nitrogen and phosphorus fertilizers on the performance of pigeonpea intercropped with sorghum. The treatments comprised of two cropping systems (sole and intercropped pigeonpea with sorghum) in factorial combination with two nitrogen rates (10, 15 kg/ha), two phosphorus rates (20, 30 kg/ha) and N + P (N10P20, N10P30, N15P20, N15P30) and the check (N0P0) laid out in Randomized Block Design. The treatments were replicated three times. Results indicated that intercropping decreased pigeonpea nodule number and root weight at 50%flowering, dry pod and grain weights at harvest. The combinations of N and P fertilizers produced significantly higher nodule number, root weights, dry pod and grain weights of pigeonpea than either N or P alone in both cropping systems. N10P30 produced significantly higher dry grain yield of pigeonpea than all other treatments, except N15P20 and N15P30. Sorghum grain yield was highest at N15. These results showed that low rates of N and P has potential for the production of intercropped pigeonpea with sorghum. The significant interaction between cropping systems and fertilizer indicated further research needs for intercropping systems as distinct from monoculture.
Key words: nitrogen, phosphorus, pigeonpea, sorghum, intercrop

1. Introduction
The decline in soil productivity in the tropics and particularly in dry land areas continue to be a major concern due to its direct implication on food security. Mixed culture of legumes and cereals is a common practice in tropical agriculture that serves as a solution to infertile soils (Olujobi and Oyun, 2012). Egbe and Bar-Anyam (2010) reported that reasonable yields are obtained from pigeonpea/sorghum intercropping with zero fertilizer application in the Southern Guinea Savanna ecology of Nigeria. This is because legumes such as pigeonpea meet some of their N requirement through N_2 fixation, thus sparing some of the soil N to the subsequent crops in addition to the residual N that accrues, due to nodule decay, senescence and fallen leaves. However, the amount of soil nutrients supplied by these systems is not sufficient to solve the crop productivity problem in a sustainable manner because of sustained nutrient export in harvested products (Sanginga *et al.*, 1997).
To feed the continuously growing world population requires sustainable food production in both nutrient stressed environments (low-fertility soils) and fertile soils. It is therefore important to add fertilizers to our crops to ensure higher yields. Nitrogen (N) and Phosphorus (P) are the most limiting nutrient elements in the soil of the tropics. However the costs of these N and P fertilizers are continuously increasing due to limited supply. Farmers resort to zero application of fertilizers to their farms since they cannot afford these fertilizers in the needed quantities. However, a potential for high yields may exist even when low rates of these fertilizers are applied in some crops. Low N and P in nutrient stressed environments have been reported to increase yields by some researchers (Nakano et *al.,* 2002). This study therefore sought to explore this possibility through the use of pigeonpea and sorghum intercropping at low rates of fertilizer. The objective of the study was to determine the influence of low rates of nitrogen and phosphorus fertilizers on the performance of pigeonpea intercropped with sorghum in Makurdi environment.

2. Materials and methods
A field experiment was conducted during the growing seasons of 2013 and 2014 at the Teaching and Research farm of the Federal University of Agriculture, Makurdi (Latitude 07° 45`-07° 50` N, Longitude 08° 45`-08° 50 E, elevation 98m) in Benue State, located in the Southern Guinea Savanna of Nigeria. The objective of the experiment was to determine the influence of low rates of nitrogen and phosphorus fertilizers on the performance of pigeonpea intercropped with sorghum.

2.1 Treatment and Experimental Design

The experiment consisted of two cropping systems [sole cropping (pigeonpea, sorghum) and intercropping (pigeonpea + sorghum)] factorially combined with eight fertilizer rates [N10, N15, P20, P30, N10P20, N10P30, N15P20, N15P30 and N0P0 (check)] and laid out in Randomized Complete Block Design with three replications. Each experimental plot consisted of four (4) ridges spaced 1m apart and 3m long (4m x 3m=12m^2). A pre-plant soil sample was taken. This was made up of eight core samples randomly collected from different parts of the experimental field from 0-15cm depth. This was bulked into a composite sample and used for the determination of the physical and chemical properties of the soil. The physical and chemical analyses of the soil sample were done in the NICANSOL Soil Testing Laboratory of the University of Agriculture Makurdi.

Table 1. Physical and chemical properties of the surface soil (0-15 cm) at the experimental site in 2013.

Parameter	Value	
Sand (%)	69.60	Hydrometer Method (Bouyoucos, 1962)
Silt (%)	16.20	
Clay (%)	15.20	
Textural class	Sandy Loam	
pH (H_2O)	6.60	Glass electrode pH meter (Jackson,1973)
pH (KCl)	5.84	
Organic Carbon (%)	1.10	Improved Chromic Acid Digestion and Spectrophotometric Method (Heanes,1984)
Organic Matter (%)	1.90	Multiplying the organic carbon figure by 1.724
Total Nitrogen (%)	0.097	Phenols Color Formation Method (Chaykin,1969)
Available Phosphorus (ppm)	3.90	Bray 1 Method (Bray and Kurtz,1945)
Ca^{2+} (Cmol kg^{-1}soil)	3.75	Method described by Jou (1983)
Mg^{2+} (Cmol kg^{-1}soil)	1.68	Method described by Tel and Rao (1982).
K^+ (Cmol kg^{-1}soil)	0.29	Method described by Jou (1982)
Na^+ (Cmol kg^{-1}soil)	0.75	Flame photometer (Mc Lean, 1982)
CEC (Cmol kg^{-1}soil)	6.85	Summation Method
Base Saturation (%)	85.60	Total Exchangeable Bases/CEC X 100

2.2 Source of Planting Material and Crop Husbandry

Pigeonpea variety, ICPL 88039 was obtained from the International Crops Research Institute for Semi-Arid Tropics (ICRISAT), India. The traditional tall red sorghum was obtained from a local market in North Bank Area of Makurdi, in Benue State, Nigeria. Three pigeonpea seeds were sown at a spacing of 30cm intra-row at the crest of each ridge and thinned to two plants per stand ten (10) days after planting (66,000 plants/ha). Similarly, three sorghum seeds were planted on the side of each ridge at an intra-row spacing of 50cm. Sorghum was thinned to two (2) plants per stand (40,000 plants/ha) after ten days of sowing. Both pigeonpea and sorghum were planted on the same day (2nd July, 2013 and 4th July,2014, respectively). Intercropping had a 1:1(pigeonpea:sorghum) row proportion. Fertilizers were applied according to the specifications for each of the treatment by side placement, 10 cm away from each plant stand. Two hoe weeding were done at 3 and 7 WAP (weeks after planting) for all plots. At first flower opening, pigeonpea plants were sprayed with an insecticide Best® at a dose of 60 mls in 10 litres of water .This was repeated at fortnightly intervals for a maximum of six weeks. At physical maturity, total plot harvest was done for each treatment and later converted to yield/ha. The following data were taken: number of nodules and root weight per plant at 50% flowering, dry pod and seed weights/ha of pigeonpea, panicle weight and dry grain yield of sorghum component.

2.3 Data analysis.

Year effect was not significant; therefore data for both years were pooled together for analysis. The data collected were analyzed using GENSTAT 11.1 Statistical Software. Fishers Least Significant Difference (FLSD) was used to separate the treatment means at 5% probability level.

3. Results

3.1 Number of Nodules of Pigeonpea at 50% Flowering

Cropping systems and fertilizer as well as cropping systems x fertilizer had significant effects ($P \leq 0.05$) on the number of nodules of pigeonpea at 50% flowering (Table2). Pigeonpea nodulated at all rates of fertilizer applied. Intercropping decreased nodulation of pigeonpea under all rates of fertilizer application tested. The combined N and P rates produced significantly higher number of nodules than either sole application of N or P (Table 2).

N0P0 (check) plants produced comparable number of nodules with sole application of N or P under both cropping systems.

3.2 Weight of Pigeonpea Roots at 50% Flowering

Table 3 presents the cropping systems x fertilizer interaction effects on the root weight of pigeonpea intercropped with sorghum in Makurdi. Intercropping consistently reduced root weight of pigeonpea under all fertilizer rates, except at N15P20 which had reverse trend. The combination of N and P produced significantly higher root weight of pigeonpea than the single N and P elemental fertilizers.

3.3 Dry Pod Weight of Pigeonpea

Table 4 shows the effects of cropping systems x fertilizer rates on the dry pod weight of pigeonpea in Makurdi. Intercropping consistently decreased the dry pod weight of pigeonpea at all rates of the fertilizer tested. The combinations of N and P produced significantly higher dry pod weights of pigeonpea (mean= 1.36t/ha) than N applied alone (0.78t/ha), which in turn gave higher dry pod weight than when only P was applied (0.75t/ha). N15P30 produced the highest mean dry pod weight (1.36t/ha) while P20 had the lowest mean dry pod weight (0.63t/ha)

Table 2. Number of Nodules of Pigeonpea at 50% Flowering as Affected by Cropping System x Fertilizer Interaction in Makurdi.

Fertilizer	Nodules at 50% flowering		
	Sole Cropping	Intercropping	Mean
N10	10.20	7.10	8.70
N15	13.20	4.20	8.70
Mean for N	11.70	5.65	8.70
P20	25.20	3.60	14.40
P30	33.10	11.40	22.30
Mean for P	29.15	21.00	18.35
N10 P20	40.70	33.10	36.90
N10 P30	125.20	72.60	98.90
N15 P20	67.70	72.80	70.20
N15 P30	139.20	39.20	89.20
Mean for N+P	93.20	54.43	73.80
N0P0 (check)	13.70	12.40	13.10
Mean for Cropping System	52.02	21.40	36.70
Grand Mean	40.30		
CV (%)	19.30		
F-LSD (0.05)			
CRS	4.31		
FERT	9.14		
CRS X FERT	12.92		

Key: CRS: Cropping systems; FERT: Fertilizer.

Table 3. Effects of Cropping System x Fertilizer Interaction on the Weight of Pigeonpea Roots (kg) at 50% Flowering in Makurdi.

	Weight of Roots at 50% Flowering		
Fertilizer	Sole Cropping	Intercropping	Mean
N10	17.20	12.77	14.98
N15	23.83	22.20	23.02
Mean for N	20.52	17.49	19.00
P20	24.30	9.17	16.73
P30	24.20	16.60	20.40
Mean for P	24.25	12.89	18.57
N10 P20	28.40	25.70	27.06
N10 P30	40.30	30.13	35.22
N15 P20	27.23	33.40	30.32
N15 P30	37.70	25.20	31.45
Mean for N+P	33.40	28.60	62.03
N0P0 (control)	23.70	13.17	18.43
Mean for Cropping System	27.43	20.93	24.12
Grand Mean	24.18		
CV (%)	0.30		
F-LSD (0.05)			
CRS	0.05		
FERT	0.10		
CRS X FERT	0.14		

Key:CRS:Croppingsystems;FERT:Fertilizer.

3.4 Dry Grain Weight of Pigeonpea

Table 5 presents the influence of cropping systems x fertilizer on the dry grain weight of pigeonpea in Makurdi. Intercropping depressed the dry grain weight of pigeonpea at all levels of fertilizer tested. The combinations of N and P produced significantly ($P \leq 0.05$) higher dry grain yield of pigeonpea (0.86t/ha) than either N or P alone. Sole pigeonpea to which N10P30 was applied had the highest grain yield (0.97t/ha), while intercropped pigeonpea to which P20 fertilizer was applied produced the lowest grain yield (0.25t/ha).

Table 4. Cropping Systems x Fertilizer Interaction Effects on the Dry Pod Weight of Pigeonpea in Makurdi.

	Dry Pod Weight (t/ha)		
Fertilizer	Sole Cropping	Intercropping	Mean
N10	0.87	0.74	0.81
N15	0.94	0.56	0.75
Mean for N	0.90	0.65	0.78
P20	0.83	0.43	0.63
P30	1.12	0.62	0.87
Mean for P	0.98	0.53	0.75
N10 P20	1.26	1.12	1.19
N10 P30	1.55	1.44	1.50
N15 P20	1.42	0.88	1.15
N15 P30	2.12	0.95	1.54
Mean for N+P	1.59	1.12	1.36
N0P0 (check)	1.35	0.52	0.94
Mean for Cropping System	1.27	0.81	1.04
Grand Mean	1.04		
CV (%)	0.90		
F-LSD (0.05)			
CRS	0.01		
FERT	0.01		
CRS X FERT	0.02		

Key: CRS: Cropping systems; FERT: Fertilizer

3.5 Panicle Weight (t/ha) of Sorghum

The effect of low N and P on the panicle weight of intercropped sorghum with pigeonpea in Makurdi was erratic with a grand mean of 1.01 t/ha. The control had the highest panicle weight of sorghum (1.72t/ha) and this was significantly ($P \leq 0.05$) higher than all other treatments. N10P30 produced the lowest panicle weight (0.53t/ha). Apart from the check, application of N15 alone proved superior to all other treatments including the combinations of N and P (Table 6)

Table 5. Effects of Cropping Systems x Fertilizer Interaction on the Dry Grain Weight of Pigeonpea Intercropped with Sorghum in Makurdi.

	Dry Grain Weight (t/ha)		
Fertilizer	Sole Cropping	Intercropping	Mean
N10	0.54	0.45	0.49
N15	0.56	0.35	0.46
Mean for N	0.55	0.40	0.48
P20	0.52	0.25	0.39
P30	0.67	0.41	0.54
Mean for P	0.59	0.33	0.47
N10 P20	0.77	0.72	0.75
N10 P30	0.97	0.94	0.96
N15 P20	0.87	0.83	0.85
N15 P30	1.15	0.62	0.89
Mean for N+P	0.94	0.78	0.86
N0P0 (check)	0.76	0.33	0.55
Mean for Cropping System	0.76	0.54	0.65
Grand Mean	0.65		
CV (%)	17.00		
F-LSD (0.05)			
CRS	0.06		
FERT	0.13		
CRS X FERT	0.18		

Key:CRS:Croppingsystems;FERT:Fertilizer

3.6 Dry Grain Weight (t/ha) of Sorghum

The dry grain weight of sorghum intercropped with pigeonpea in Makurdi varied between 0.32t/ha and 1.36 t/ha with a grand mean of 0.72t/ha. N15 gave significantly higher dry grain weight of sorghum than the control which in turn gave significantly higher dry grain weight than all the other treatments. Generally, N fertilizer gave higher dry grain weight than either P or N+P.

Table 6. Panicle Weight (t/ha) and Dry Grain Weight (t/ha) of Sorghum Intercropped with Pigeonpea as Affected by Fertilizer in Makurdi.

Treatment	Panicle Weight	Dry Grain Weight
N 10	0.72	0.43
N 15	1.42	1.36
Mean for N	1.07	0.90
P 20	0.66	0.37
P 30	0.95	0.68
Mean for P	0.81	0.53
N10 P20	1.38	0.94
N10 P30	0.53	0.32
N15 P20	1.07	0.75
N15 P30	0.62	0.44
Mean for N + P	0.90	0.61
N0P0 (check)	1.72	1.15
Grand Mean	1.01	0.72
CV (%)	1.00	1.2
F-LSD (0.05)	0.02	0.02

4. Discussion

The decreases observed in the number of pigeonpea nodules and root weight per plant at 50% flowering and the reduction of pod and grain weights at harvest by intercropping might be due to the shading effect by the tall sorghum used for intercropping; which reduced light interception by pigeonpea and subsequently photosynthesis and crop yield. Some authors had reported reduction in growth and yield of pigeonpea by intercropping with sorghum (Ali, 1996; Egbe ,2007). The superior performance of pigeonpea in both sole and intercrop situations where N+P were used showed the synergistic effects of the two essential elements for plant growth. Nitrogen and phosphorus have long been regarded as essential elements that must be provided to crops to obtain good growth and yields. This is because virtually all of the compounds that participate in metabolism, cell growth and tissue development contain N and/or P. Sinclair and Vadez (2002) had indicated that diminished levels of N and P have many ramifications that result in quantitative decreases in the rate of growth, and ultimately yield. These authors had also stated that decreases in either N or P, which is likely under low-nutrient conditions, would lead directly to decreases in the levels of critical compounds required to sustain high rates of growth. The non-significant difference among the N + P treatments in grain yields of pigeonpea indicated that any of these rates could be used to obtain similar yields. This finding translates to higher yields of pigeonpea at lower cost of production in terms of fertilizer usage. The low yields of pigeonpea observed in this study may be attributed to the low rates of N and P used, although pigeonpea is known to fix its own N requirements in the presence of P and “booster” N. The higher yield of sorghum at N15 than all other treatments might be indicative of N being the most deficient element in the study site as P may have been present at the required level and response to it (P) or when in combination with N was insignificant. It also underscores the importance of N in grain filling in cereals.

5. Conclusion

The study showed that intercropping decreased number of nodules and root weight of pigeonpea at 50% flowering as well as its pod and grain yields. The combinations of N and P at low rates proved superior to N or P alone in both sole and intercropping systems. Sorghum grain yield was highest where N alone at 15 kg/ha was used. The significant interaction between cropping systems and fertilizer indicated further research needs for intercropping systems as distinct from monoculture.

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