MEDWELL PUBLISHING
Agricultural Journal 4 (1): 14-21, 2009
ISSN: 1816-9155

Recommended Fertilizer Levels on Bambara Groundnut (*Vigna subterranea* (L) *Verde*) in Yola Adamawa State, Nigeria

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Abstract: Research was conducted during the 2002, 2003 and 2004 cropping seasons at the Federal College of education Teaching and Research Farm. The experiments were located within latitude 9^{0}19'N and longitude 12^{0}30'E, at an altitude of 185.9 m above sea level. The research was conducted on 2 cultivars of bambara groundnuts *Vigna subterranean* (L) *Verde*), cream and variegated with the aim to determine the recommended fertilizer levels on bambara groundnut in Yola Adamawa State, Nigeria. Soil samples were collected at different spots within the experimental sites before and after harvesting every year by throwing a quadrant and collecting 0-15 cm depth of soils, which was subjected to Laboratory analysis. Four levels of single super phosphate fertilizer at 0, 30, 60 and 90 Kg ha^{-1} of P_2O_5 coded L_1, L_2, L_3 and L_4 were used. Establishment counts and growth parameters on number of plants/stand, plants heights and leaves numbers, fresh and dry weights of the crop, root length, nodules number and yield in kg ha^{-1} as affected by P_2O_5 levels were determined. During the three years of experimentation, it was observed that fertilizer application at the rate of 60 kg ha^{-1} of P_2O_5 gave the highest yield of 432.5 kg ha^{-1}, even though the fertilizer level at 90 kg ha^{-1} gave higher yield in some treatments, it was found not to be economically profitable. Therefore, based on the results the fertilizer level of 60 kg ha^{-1} of P_2O_5 is recommended for bambara groundnut in Yola, Adamawa State Nigeria.

Key words: Soil samples, bambara groundnuts, *Vigna subterranean*, Adamawa State, Nigeria

INTRODUCTION

Bambara is a pulse crop of immense potential in enhancing food security, especially in drought-prone agricultural systems. Its drought tolerance makes it ideal for production by resource poor farmers, especially in communal and resettlement areas. As a result, it can grow well in communal areas where pest and disease control are not given serious attention (Vusumuzi, 1992). The crop features prominently in the traditional farming systems all over the country as an intercrop of cereals and other crops. Also, it is planted as sole crop in many areas (Linnamann, 1988). Even though, majority of the farmers produce bambara groundnut primarily for food, they may sell part of their produce when they have produced excess of their food needs or when they are pressed for money to pay taxes, loans or school fees (Linnamann, 1988).

As one of the 2 most drought-tolerant legumes and despite the numerous local uses the crop is put to and the numerous advantages derived from research work on Bambara groundnut, research information, especially with regard to Nigeria in general and Adamawa State in particular, is scanty because not much work has been done on the crop.

Stigmatized a 'poor man's crop' by the National Academy of Science (NAS, 1979) the plant has never been accorded a large scale research priority. Initial and preliminary evidence and fragmented research suggest that bambara groundnut is a crop with much promise.

Bambara groundnut can and does play an important role as a protein source. It also, ameliorates the soil through nitrogen fixation. This is particularly important for resource-poor farmers, who cannot normally afford artificial fertilizers (Peoples and Herridge, 1990). As a leguminous crop, bambara groundnut is also useful in crop rotation as it acts as a source of residual nitrogen for the next croppong season (Linnamann and Azam-Ali, 1993).

This research is therefore designed to study and find the appropriate fertilizer level of the crop in Yola Adamawa State.

Crop morphology: Bambara groundnut *Vigna subterranean* (L) *verdec* is a small bunched leguminous annual crop that is similar to groundnut *Arachis hypogea* L. The plant bears numerous erect leaves produced from small creeping stems (Cobley and Steel, 1976). The first pair of true leaves are simple and opposite, but exhibits

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considerable variation in size and shape. A special feature of this crop is that the fruit begins as a fertilized flower above ground but pods and seeds mature in the ground.

Soil requirement: The crop can grow on poor soils in hot climate, but performs best in well-drained, light loam, with good supply of calcium (Ca). It can also, be grown on dry-regions which are marginal to other pulse crops. Such as groundnuts and gives higher yields than the later on degraded soils.

Fertilizers: Research results suggest that N.P.K fertilizer can be applied before sowing while nitrogen and potash can also be applied at 3 weeks after sowing as surface dressing; this stimulates growth as stated by Johnson (1968). Rassel (1960), stated that the number of pods/plant and number of seeds/pod of bambara groundnut are both influenced by the fertility of the soil. Bambara groundnut being a leguminous crop meets its nitrogen requirements by fixing the atmospheric-nitrogen. This implies that phosphorus becomes the most important fertilizer element that has to be applied on the crop (Tanimu, 1996).

Role of phosphorus on plant growth: Phosphorus is generally essential to plant growth and is an active ingredient of protoplasm. It stimulates early growth and root formation, hastens maturity, promotes seed production, gives stability of the stem and contributes to the general hardiness of plants.

MATERIALS AND METHODS

Field experimental site: This research was conducted between 2002 and 2004 cropping seasons at the Federal College of Education, Yola Teaching and Research Farm.

The experiments were located within latitude $9^0$19'N and longitude $12^0$30'E, at an altitude of 185.9 m above sea level and lies within the Northern Guinea Savanna Zone of Nigeria (Bashir, 2000).

The weather data including rainfall, relative humidity, daily temperature and sunshine hours from 2002, 2003 and 2004 were collected from the weather stations of Geography Department, Federal University of Technology, Yola and Upper Benue River Basin and Rural Development Authority (UBRBRDA), Yola.

Experimental treatments and designs: The treatments consisted of two cultivars of bambara groundnut, namely cream and variegated. The cultivars were coded as C_1 and C_2 for cream color and variegated color, respectively. These were assigned to the plots. Four Levels of single super phosphate fertilizer at 0, 30, 60 and 90 Kg ha^{-1} of P_2O_5 coded as L_1, L_2, L_3 and L_4, respectively were used. These were laid out in a 2×4 factorial combination in a Randomized Complete Block Design (RCBD).

Source of seeds and sowing: Two local cultivars of bambara groundnut cream and variegated commonly cultivated in the state were used for the study. The seeds were purchased at Yola market, cleaned and treated with Fanasan D (Thiram and lindane) at the rate of 3 kg of seed/sachet of chemical prior to sowing.

Bambara groundnut was sown at one seed/hole, using hand with a marked planting rope which was made at a spacing of 25×30 cm, giving a stand of 133.333 ha^{-1}.

Weed control was done manually at 3 and 6 weeks after sowing by hoeing and hand pulling.

Chemical and physical property of the soil site: Soil samples were collected at different spots within the experimental sites before sowing and after harvesting by throwing a quadrant and collecting 0-15 cm depth of soils. These were bulked, sun-dried and sieved with a 2 mm mesh. These were taken to Laboratory and subjected to analysis. For physical and chemical properties in the Soil Science Laboratory, Federal University of Technology, Yola. The physical and chemical properties of soils analyzed.

Establishment count: The number of plants/stand was counted within the net plot at 6, 8 and 10 WAP to assess the effective establishment of the crop. Heights were measured from ground level to tip of the plant at weekly intervals from 6 weeks after emergence. A total number of 30 plants in a quadrant of 1×1 m were used, to determine the numbers of leaves/plant.

Number of flowers/plant was counted at 5 days interval cumulatively, from the day when the first flower was formed. The roots were carefully dug to recover all the roots and the length was measured using a ruler.

The above ground dry and fresh weights of the plants were removed from the thrown quadrant at an interval of one week. The leaves were detached from the soil and the stems. The fresh weight were determined. They were then oven dried and weighed to determine the dry matter.

Statistical analysis: All the data collected from the experiments were subjected to statistical analysis using the split-split plot analysis of variance to test the significant effects as described by Gomez and Gomez (1984).

RESULTS

Soil analysis of the experimental site: The result of the soil analysis at the experimental site indicates that the soil was sandy loam with 43.3% sand, 62.2% silt and 14.5% clay with mean values of 14.3, 36.0 and 53.5% for clay, silt and sand, respectfully. The total nitrogen and available phosphorus were l ow with mean values 0.07 and 1.02 meq 100 g^{-1}, respectively. Available phosphorus increased from 0.9 meq 100 g^{-1} in 2002 to 1.3 meq 100 g^{-1} in 2004. The average P^H of the study area was 6.23 Average organic matter (%) and organic carbon were 2.5% and 1.7 (g kg^{-1}), respectfully.

Growth parameters

Effects of P_2O_5 fertilizer on number of plants and stem height (cm) of bambara groundnut: The effects of fertilizer levels on the number of stems of bambara groundnuts in 2002, 2003 and 2004 indicated that there were no significant ($p = 0.05$) effects on the number of stems at 6, 8 and 10 WAS in 2002 (Table 1). In 2003, there were no significant effects of P_2O_5 fertilizer levels on number of stems at 6 WAS. However, at 8 and 10 WAS, there were significant effects of P_2O_5 fertilizer levels on the number of stems at $p = 0.05$. In the control plots, invariably had the least number of stems across the years. There was an increase in number of stems with increased levels of fertilizer, with the highest mean number of stems at 60 kg P_2O_5 ha^{-1}. Thereafter, there was a slight decline in number of stems with additional increased in fertilizer levels. There was however, no significant difference in the number of stems recorded at 60 and 90 kg P_2O_5 ha^{-1}.

At 10 WAS in 2003 growing season, 0 kg P_2O_5 ha^{-1}, had the lowest number of stems ($p = 0.05$) with a mean value of 34.5. With increase in fertilizer levels, there was increase in number of stems with the highest number of stems at the 90 kg P_2O_5 ha^{-1}, although there were no significant difference between 60 and 90 kg P_2O_5 ha^{-1}.

In 2004 growing season, there were no significant ($p = 0.05$) effects of fertilizer levels on the number of stems at 8 and 10 WAS except at 6 WAS that significant effects of fertilizer on number of stems was observed at $p = 0.05$. At 6 WAS, the control plots had the lowest number of stems (22.9). The 60 kg P_2O_5 ha^{-1} plots had the highest mean number of stems (29.6) although this was not significantly different from values observed from plots that received 30 and 90 kg P_2O_5 ha^{-1}. The combined means indicates that plant height increased with an increase in weeks of sowing, with the highest recorded at 10 WAS. The 30 and 60 kg P_2O_5 ha^{-1} combined plots had the highest mean value of 44 plants.

Plant height of bambara groundnut as affected by P_2O_5 fertilizer: Table 1 also shows that the fertilizer levels significantly ($p = 0.05$) affected the plant height at most of the sampled periods.

Fertilizer rates of 90 kg P_2O_5 ha^{-1} consistently gave the tallest plants with a mean plant height of 20.4 cm. This was followed by 60 kg P_2O_5 ha^{-1} that had a mean plant height of 16.1 cm.

Generally, as P_2O_5 level decreased there was decrease in plant height with the shortest plants at 0 kg P_2O_5 ha^{-1}. There were no significant ($p = 0.05$) difference between 0, 30 and 60 kg P_2O_5 ha^{-1}. A similar trend was observed at 6 WAS in both 2003 and 2004. At 8 WAS in 2002 the tallest plants were observed at 90 kg P_2O_5 ha^{-1} with a mean height of 24.8 cm. These were however not significantly ($p = 0.05$) different from plant height observed in the control plots. There were also, no significant ($p = 0.05$) difference between means from 0, 30 and 60 kg SSP ha^{-1} in most of the sampled periods. This trend was observed at 10 WAS in 2002, 8 WAS in 2003 and 10 WAS in 2003. The shortest plants were either at 60 or 30 kg P_2O_5. The control plots had the lowest mean plant height during the period under experimentation.

Table 1: Number of plants/stand and stems height (cm) of bambara groundnuts as affected by P_2O_5 fertilizer

	2002			2003			2004			Combined means		
P_2O_5 levels (kg ha^{-1})	6 WAS	8 WAS	10 WAS	6 WAS	8 WAS	10 WAS	6 WAS	8 WAS	10 WAS	6 WAS	8 WAS	10 WAS
Plants/stand												
0	23.2	39.7	45.7	8.0	23.0	34.5	22.9	38.3	43.2	18.0	37.7	39.7
30	27.8	39.7	47.8	8.2	24.3	35.7	27.2	40.2	47.8	21.1	34.7	43.7
60	46.5	40.8	48.0	8.7	29.4	39.3	29.6	41.2	43.7	28.3	37.2	43.7
90	28.7	42.4	46.8	8.5	27.2	39.8	28.4	41.2	45	21.9	36.9	43.9
$LSD_{0.05}$					3.3	2.6	3.0					
Stem height (cm)												
0	14.6	24.7	25.6	14.5	24.8	25.7	14.5	24.7	25.5	14.5	24.8	25.6
30	15.2	23.9	24.9	15.7	23.8	24.9	15.3	23.6	24.8	15.4	23.8	24.9
60	16.1	23.7	25.2	16.7	23.9	25.7	16.3	23.2	16.6	16.3	23.6	22.5
90	20.4	24.8	26.8	20.8	24.8	27.3	20.8	21.1	26.6	20.7	23.6	26.9
$LSD_{0.05}$	2.0	2.0	1.3	1.8		1.2	2.2	2.2	2.0	2.1		2.3

Table 2: Effects of P_2O_5 fertilizer on number of leaves of bambara groundnuts

	2002			2003			2004			Combined means		
P_2O_5 levels (kg ha^{-1})	6 WAS	8 WAS	10 WAS	6 WAS	8 WAS	10 WAS	6 WAS	8 WAS	10 WAS	6 WAS	8 WAS	10 WAS
0	69.3	114.1	131.6	24.2	66.2	99.9	71.9	114.8	131.1	55.2	98.4	120.9
30	83.5	116.1	139.7	24.8	72.4	105.4	83.9	119.9	142.6	64.1	102.8	129.2
60	88.8	117.7	139.4	25.3	86.3	114.4	87.7	123.9	142.6	67.3	109.3	132.3
90	85.6	122.9	134.4	24.7	79.4	116.5	74.6	121.3	140.6	61.6	107.9	130.5
$LSD_{0.05}$					10.3	8.1	7.3	12.5	9.9		11.2	12.4

WAS = Weeks After Sowing

Table 3: Effects of P_2O_5 fertilizer on fresh and dry leaves (g) of bambara groundnuts

	2002		2003		2004		Combined means	
Kg P_2O_5 ha^{-1}	15 DAS	30 DAS	15 DAS	30 DAS	15 DAS	30 DAS	15 DAS	30 DAS
Fresh weight (g)								
0	28.9	28.4	31.0	34.7	29.2	31.6	29.7	31.6
30	31.2	33.5	31.5	36.1	28.9	33.2	30.5	34.3
60	31.2	31.4	33.0	35.3	32.3	33.8	32.2	33.5
90	33.5	33.4	32.1	36.2	32.4	33.1	32.6	34.2
$LSD_{0.05}$	2.5	4.1					2.6	
Dry weight (g)								
0	3.2	3.8	4.2	3.7	3.4	4.0	3.6	3.8
30	3.5	4.1	2.9	4.1	3.6	4.4	3.3	4.2
60	5.7	4.3	3.2	4.2	5.7	5.8	4.9	4.8
90	5.4	4.4	3.2	4.3	5.6	5.7	4.8	4.8
$LSD_{0.05}$	1.0	0.4	2.2	0.4	0.8	0.6		2.1

DAS = Days After Sowing

The combined means indicates that 90 kg P_2O_5 gave the highest mean plant height of 26.6 cm at 6 WAS. There were no significant (p = 0.05) difference at 8 and 10 WAS.

Effects of P_2O_5 fertilizer on number of leaves of bambara groundnuts: The effects of fertilizer levels on number of leaves of bambara groundnuts had no significant effects (p = 0.05) during the 2002 cropping season as indicated on Table 2. There were no significant effects (p = 0.05) on number of leaves of bambara groundnuts at 6, 8 and 10 WAS. This trend was followed in the 2003 cropping season at the 6 WAS. However, at the 8 and 10 WAS significant (p = 0.05) effects of fertilizer on number of leaves of bambara groundnuts were recorded. The highest mean number of leaves was recorded at 60 kg P_2O_5 ha^{-1} at 8 WAS, while at 10 WAS it was recorded at 90 kg ha^{-1} of P_2O_5 with mean number of leaves/stand of 86.2 and 116.5, respectively. At 0 fertilizer levels, the number of leaves was lowest at 6, 8 and 10 WAS.

These trend followed in the 2003-cropping season at the 6 WAS. However, at the 8 and 10 WAS significant (p = 0.05) effects on fertilizer on number of leaves of bambara groundnuts were recorded. The highest mean number of leaves was recorded at 60 kg ha^{-1} at 8 WAS, while at 10 WAS it was recorded at 90 kg ha^{-1} of P_2O_5 with mean number of leaves/stand of 86.2 and 116.5, respectively. At 0 fertilizer level, the number of leaves was lowest 6, 8 and 10 WAS. In 2004, significant (p = 0.05) effects of fertilizer levels on number of leaves at 6 and 10 WAS were observed. At these periods there was an increase in number of leaves with increase in fertilizer levels from 0-90 kg P_2O_5 ha^{-1}. The highest mean number of leaves of 104.5 was recorded 10 WAS at fertilizer levels of 60 kg P_2O_5 ha^{-1}. There was however, no significant difference in number of leaves/plant recorded at 8 WAS.

Fresh and dry weight of bambara groundnuts as affected by P_2O_5 levels: Table 3 presents the effects of fertilizer on the fresh weight of leaves of bambara groundnuts in 2002, 2003 and 2004 cropping seasons. In 2002, significant effects at p = 0.05 of fresh weight were recorded in fertilizer levels at 15 and 30 DAS. Increase in fresh weight was recorded with increase in P_2O_5 fertilizer levels from 0-90 g P_2O_5 ha^{-1} at 15 DAS in 2002 only. This trend was followed at 30 DAS. The highest fresh weight of leaves was recorded at 30 DAS with a mean leaves fresh weight of 33.5 g at 90 kg P_2O_5 ha^{-1}. The 0 kg P_2O_5 ha^{-1} gave the lowest fresh weight of leaves at both 15 and 30 DAS. There was no significant difference at p = 0.05 recorded on leaves fresh weight at 15 and 30 DAS during the 2003 and 2004 cropping seasons. The combined means indicates that fresh weight was highest at 15 DAS with mean number of leaves of 32.2 and 32.6 was recorded at 60 and 90 Kg P_2O_5 ha^{-1}. At 30 DAS the highest fresh leaves was recorded at 30 and 60 Kg P_2O_5 ha with a mean fresh number of 34.3 and 34.2, respectfully.

Effects of P_2O_5 fertilizer on dry weight of leaves of bambara groundnuts: The effects of fertilizer on dry weight of leaves of bambara groundnuts was significant (p = 0.05). The P_2O_5 Kg ha^{-1} were recorded on dry weight

Table 4: Effects of P_2O_5 fertilizer on mean number of flowers and root depth/plant of bambara groundnuts

	2002			2003			2004			Combined means		
P_2O_5 levels (kg ha^{-1})	15 DAS	30 DAS	60 DAS	15 DAS	30 DAS	60 DAS	15 DAS	30 DAS	60 DAS	15 DAS	30 DAS	60 DAS
Number of flowers												
0	5.4	11.1	19.3	5.5	4.8	12.8	5.5	11.6	18.9	5.5	9.2	17.0
30	5.3	11.6	19.2	5.8	5.4	12.4	5.6	11.2	21.2	5.6	9.4	17.6
60	5.6	12.3	19.4	5.6	6.6	15.8	5.5	12.3	20.8	5.5	10.4	18.7
90	5.2	11.2	21.5	5.8	6.9	13.9	5.3	11.6	19.3	5.5	9.9	18.2
$LSD_{0.05}$	1.1	1.6	1.9		1.4	2.1		0.9	1.0		1.2	1.0
Root depth												
0	6.0	7.0	8.8	6.1	11.0	10.8	6.1	7.2	9.1	6.1	8.4	9.6
30	7.4	8.0	9.9	9.5	10.6	12.6	7.6	8.3	10.1	8.2	9.0	10.1
60	8.4	8.5	10.9	11.6	13.5	13.8	9.5	8.8	10.8	9.8	10.3	11.9
90	7.4	8.0	9.8	9.9	12.2	13.7	8.3	8.4	10.0	8.5	9.6	11.2
$LSD_{0.05}$	1.2	0.8	0.8	1.3	1.1	1.0	1.2		2.1	1.3	1.2	1.3

DAS = Days After Sowing

of leaves at 15 and 30 DAS as presented in Table 4. The lowest mean dry weight of leaves were recorded at the control levels of 0 kg P_2O_5 ha^{-1} with mean (3.2 g) and 3.8 g at both 15 and 30 DAS in 2002. The highest mean value of 5.7 g dry weight of leaves was observed at 60 kg P_2O_5 ha^{-1} at 15 DAS but at 30 DAS it was recorded at 90 kg P_2O_5 ha^{-1} even though there was no significant difference (p = 0.05) between the 90 and 60 kg P_2O_5 ha^{-1} during the period. Significant differences (p = 0.05) were also recorded at the 2003 cropping season as regards dry weight of leaves of bambara groundnuts. The control level gave the highest dry weight of leaves with 4.1 g, followed by 60 and 90 kg $P_2O_5^{-1}$ ha with 3.2 g at 15 DAS. At 30 DAS there was an increase in dry weight of leaves with and increase in fertilizer levels up to the 90 kg P_2O_5 ha^{-1} as presented in Table 3. Significant difference at p = 0.05 were observed at the 2004 cropping season.

The dry weights of leaves increased with and increase levels of fertilizer from the control to the 90 kg P_2O_5 ha^{-1} at both the 15 and 30 DAS during the 2004 cropping season. The highest mean dry weight of leaves was recorded at 60 kg P_2O_5 ha^{-1} at 15 DAS with a mean dry weight of leaves of 5.7 g and 5.8 g at 30 DAS, it which is closely followed by 60 kg P_2O_5 ha^{-1} with a mean dry weight value of 5.7 g.

The combined means showed that 60 kg P_2O_5 ha^{-1} gave the highest dry weight of 4.9 g at 15 DAS while at 30 DAS 60 and 90 kg P_2O_5 ha^{-1} gave the highest dry weights of 4.8 g, respectfully.

Effects of P_2O_5 fertilizer on root length of bambara groundnuts: Significant (p = 0.05) effects of fertilizer P_2O_5 levels on root length were recorded in 2002 at all sampling period (15, 30 and 60 DAS) as presented in Table 4.

The lowest root length (5.9 cm) was recorded at the control levels of 0 kg ha^{-1} of P_2O_5 at 15 DAS, while the highest mean root length with a value of 8.4 cm was recorded at 60 kg P_2O_5 ha^{-1}. The trend of root length followed the same pattern at 30 DAS. In 2002, the lowest mean root length were recorded at the control levels at 15, 30 and 60 DAS, with mean values of 5.9, 6.9 and 8.1 cm, while, the highest mean root length were recorded at 60 Kg P_2O_5 ha^{-1} with the mean values of 8.3, 8.5 and 10.9 cm. Significant effects at p = 0.05 were recoded in 2003 on the effects of fertilizer P_2O_5 on root length of bambara groundnuts at 15, 30 and 60 DAS. There was increased in root length with and increased levels of fertilizer with the highest mean root length recorded at 60 kg P_2O_5 ha^{-1}, there after there was a decline in root length with additional levels of fertilizer. These trends followed the same pattern in the 2004-cropping season at 15 DAS. However, there was no significant (p = 0.05) effects recorded at 30 DAS. At 60 DAS, significant effects at p = 0.05 was recorded on effects of fertilizer levels on root length. The control levels of 0 Kg P_2O_5 ha^{-1} gave the lowest mean root length of 9.2 cm. The highest root length was recorded at 60 kg P_2O_5 ha^{-1}. There was however, no significant difference at p = 0.05 recorded between 30-90 Kg P_2O_5 ha^{-1}.

At the combined means 60 Kg P_2O_5 ha^{-1} gave highest mean root depth of 9.8 cm at 15 DAS. At 30 DAS and 60 DAS the highest root length were observed at 60 Kg P_2O_5 ha^{-1} with 10.3 and 11.9 cm, respectfully.

Effects of P_2O_5 fertilizer on number of nodules of bambara groundnuts: Phosphorus fertilizer significantly affected nodulation of bambara groundnut with increase in nodulation as P_2O_5 fertilizer increased from the control (0 P_2O_5) treatment to 90 Kg P_2O_5 ha^{-1} in 2002 growing season is presented in Table 5.

At 0 fertilizer levels the control plots gave the lowest number of nodules at both 15 and 30 DAS with mean values of 5.7 and 8.6, respectively. There was an increase in number of nodules with increased levels of fertilizer, with the highest mean number of nodules observed at 60 and 90 kg P_2O_5 ha^{-1} at 15 and 30 DAS.

Table 5: Effects of P_2O_5 fertilizer on number of nodules of bambara groundnuts

	2002		2003		2004		Combined means	
Kg P_2O_5 ha^{-1}	15 DAS	30 DAS	15 DAS	30 DAS	15 DAS	30 DAS	15 DAS	30 DAS
0	5.7	8.6	5.7	8.1	6.3	8.1	5.9	8.6
30	6.2	9.3	5.2	8.2	6.6	9.4	6.0	9.0
60	6.7	9.7	5.8	9.3	6.6	10.2	6.4	9.7
90	6.3	9.5	5.8	8.4	7.2	10.1	6.1	9.3
$LSD_{0.05}$	1.0	1.1		0.9	0.7	1.2		1.1

DAS = Days After Sowing

Table 6: Interactions between P_2O_5 Fertilizer on two cultivars of bambara groundnuts dry weight of leaves and on number of flower/plant for the pooled data

	Bambara groundnut (15 DAS)		Bambara groundnut (10 WAS)		Bambara groundnut (30 DAS)	
P_2O_5 Levels	Cream	Variegated	Cream	Variegated	Cream	Variegated
0	3.4	4.2	116.4	125.3	5.5	5.4
30	3.9	4.5	122.7	135.8	5.1	6.0
60	4.2	5.3	117.6	146.6	5.3	5.8
90	4.0	5.5	122.3	138.6	4.7	6.2
$LSD_{0.05}$	0.2		8.0		0.3	

DAS = Days After Sowing, WAS = Weeks After Sowing

There were no significant (p = 0.05) effects of fertilizer levels on number of nodules at 15 DAS in 2003 growing season. However, significant effects at p = 0.05 was recorded at 30 DAS, with highest mean number of nodules (9.3) at 60 kg P_2O_5 ha^{-1}. The lowest number of nodules (8.1) was recorded at the control plot. In 2004, significant effects were recorded at p = 0.05 on the effects of fertilizer levels on number of nodules of bambara groundnuts at 15 and 30 DAS.

The number of nodules increased with increase levels of fertilizer from the control levels of 0-90 kg P_2O_5 ha^{-1} at 15 and 30 DAS during the year. At 15 DAS the highest number of nodules (7.2) was recorded at 90 kg P_2O_5 ha^{-1} while at 30 DAS plots, which received 60 kg P_2O_5 ha^{-1}, gave a mean number of nodules of 10.2. There was no significant (p = 0.05) difference at 15 DAS in the combined means.

However, significant number of nodules at p = 0.05 was observed at 30 DAS, with the control plot giving lowest nodules number of 9 and 60 kg P_2O_5 ha^{-1} giving the highest nodules number of 10.

Interactions between P_2O_5 fertilizer and cultivars on number of leaves/plant for the pooled data: Interactions between P_2O_5 fertilizer levels and bambara groundnut cultivars on number of leaves at 10 WAS for the pooled data over three years. Variegated had the highest mean number of leaves of 146.6 at 60 kg P_2O_5 ha^{-1}, while cultivar one gave the highest mean number of leaves of 122.7 at 30 Kg P_2O_5 ha^{-1}. In all the P_2O_5 levels applied, there were significant (p = 0.05) difference between cream and variegated.

Interactions between P_2O_5fertilizer levels and cultivars on dry weight of leaves at 15 DAS for the pooled data: An interaction between fertilizer levels and cultivars on dry weight of leaves at 15 DAS for the pooled data over the three growing seasons is presented in Table 6. There was significant (p = 0.05) increase in dry weight of leaves with the highest value of 4.2 g at 60 kg P_2O_5 in cultivar one. Thereafter there was a decline in dry weight of leaves even though there was no significant difference between values obtained from 60 and 90 kg P_2O_5 ha^{-1}. In cultivar two, there was increase in dry weight of leaves with increased fertilizer rate with the highest value at 90 kg P_2O_5 ha^{-1}. At all the fertilizer levels, there were higher dry weights of leaves in cultivar two than cultivar one, with 4.2, 4.5, 5.3, 5.5 and 3.4, 3.9, 4.2, 4.0 g, respectively at 0, 30, 60 and 90 kg P_2O_5 ha^{-1}.

Interactions between P_2O_5 fertilizer levels and sowing dates on dry weight of leaves at 15 DAS for the pooled data: The interactions between fertilizer levels and sowing date on the dry weight of leaves at 15 DAS for the pooled data over the three growing seasons is presented in Table 6. The early planting date of 6th July gave the highest (p = 0.01) dry weight of leaves at all the P_2O_5 levels applied. This was followed by the second planting date of 17th July. The lowest dry weight of leaves was recorded in the late planting date of 28th July.

At early sowing date of 6th July, 90kg P_2O_5 ha^{-1} produced the highest dry weight of leaves with mean value of 5.9 g. At the intermediate sowing date of 17th July, the highest dry weight of leaves (5.0 g) was recorded from 60 kg P_2O_5 ha^{-1}. A similar trend was observed at the late sowing date of 28th July, with the highest mean dry weight of leaves (4.0 g) recorded at 60 kg P_2O_5 ha^{-1}. Thereafter, there was a significant decrease in dry weight of leaves with additional levels of P_2O_5.

Interactions between P_2O_5 fertilizer levels and sowing date on root depth at 15 DAS for the pooled data: Table 7 presents the interactions between fertilizer and sowing date on root length at 30 DAS for the pooled data over the

Table 7: Interactions between P_2O_5 levels and sowing date on root depth (cm) of two cultivars of bambara groundnuts at 15 DAS and grain yield (kg ha^{-1}) for the pooled data

	15 DAS sowing dates			Yield (kg ha^{-1}) sowing dates		
P_2O_5 kg ha^{-1}	6th July	17th July	28th July	6th July	17th July	28th July
0	6.1	6.5	5.6	322.1	300.9	134.4
30	8.5	8.6	7.3	467.3	394.7	210.7
60	10.5	10.3	8.7	622.1	506.6	298.0
90	10.9	8.4	6.7	483.6	470.3	232.9
$LSD_{0.05}$	1.3			56.0		

DAS = Days After Sowing

3 seasons. The early sowing date of 6th July, gave the higher p = 0.01 root depth at all the P_2O_5 levels applied. This was followed by the intermediate sowing date of 17th July. The lowest root depth at 30 DAS was recorded at the late planting date of 28th July. At the early sowing date of 6th July, 90 Kg P_2O_5 ha^{-1} produced the highest mean root depth of 10.9 cm. During the intermediate sowing date of 17th July, the highest root depth was recorded at 15 DAS with a mean value of 10.3 cm, at 60 kg P_2O_5 ha^{-1}. Similar trend was observed at the late sowing date of 28th July, with the highest root length of 8.7 cm, recorded at 60 kg P_2O_5 ha^{-1}. The control plots produced the lowest root length in the interactions between fertilizer levels and sowing dates at all the three sowing dates during the period under study. However, 60 Kg P_2O_5 ha^{-1} gave the highest root depth at 15 DAS even though there was no significant (p = 0.01) difference with 90 Kg P_2O_5 ha^{-1} during the 3 growing seasons.

DISCUSSION

Generally, the performance of bambara groundnut during the years of the research, 2002, 2003 and 2004 was encouraging. High Relative Humidity (RH) of 83 was observed during the period of experimentation. The lowest RH of 28 was observed during the month of February at 2002. The highest was in at 2003 cropping season with 88 RH in the month of October.

The soil texture on which the research was conducted is a sandy loam, with a P^H (H_20) 6.20, organic matter 2.53%, available P (meq 100 g^{-1}) 1.02 and total N (g kg^{-1}) 11.7%, respectively.

There were significant differences at p = 0.05 in 2003 and 2004 cropping seasons. The higher nodules number observed at 60 and 90 kg P_2O_5 ha^{-1} also, signifies that there is a tendency for more response of Phosphorus by the crop with more levels of fertilizer. The significant (p = 0.05) effects of fertilizer levels on root length at 15, 30 and 60 DAS during the period under study indicates that Phosphorus is required to boost the root growth and subsequently the root length of bambara groundnuts. The result of soil analysis of the experimental site also indicates that there was low phosphorus in the area as Phosphorus plays a major role in the physiological processes of root production, nodulation and N-fixation (Sanker *et al*., 1984).

Interactions between P_2O_5 fertilizer levels and cultivars on foliage, fresh and dry weight (g): The interactions between fertilizer levels and cultivars on number of leaves at 10 WAS for the pooled data over three growing seasons showed a significant (p = 0.05) interactions between fertilizer levels and cultivar. The result indicates that Phosphorus application results in higher source capacity which may translate into higher dry matter production which may latter be allocated to the pods for higher yields.

The significant (p = 0.05) interactions of fertilizer and sowing date and fertilizer and cultivar on dry weight of leaves at 15 DAS for the pooled data, indicates that Phosphorus is required to boost the growth of the crop. These trends were followed at 30 and 60 DAS for the pooled data. The interactions between fertilizer and sowing date on root depth for the pooled data indicates that 90 kg Phosphorus ha^{-1} produced the highest root depth of 10.9 cm, even though there was no significant difference at p = 0.01 between 60 and 90 kg P_2O_5 ha^{-1}.

Higher number of flowers/plant was also recorded at the pooled data on the interactions between sowing date and fertilizer levels on days to 50% flowering over the 3 years, with the highest flower/plant recorded at 60 and 90 kg P_2O_5 ha^{-1}. The result indicates that fertilizer Phosphorus is necessary for legumes development.

CONCLUSION

Research was carried out for 3 years, 2002, 2003 and 2004, at Yola, located within (9^019'N, 12^030E) of Adamawa State in the Guinea savanna zone of Nigeria to study the effects of levels of phosphorus (P_2O_5) fertilizer on the yield of 2 cultivars of bambara groundnuts.

The experimental treatments consisted of two cultivars of bambara groundnuts, namely cream and 'variegated.

The result of the field study showed that there was a significant difference due to fertilizer levels in number of stem, plant height, leaves number and root depth.

The effects of P_2O_5 fertilizer on number of leaves and plant height were significantly higher at 8 and 10 WAS.

During the three years under experimentation, it was observed that fertilizer application at the rate of 60 kg ha^{-1} of P_2O_5 is recommended for bambara groundnut in Yola, Adamawa State because it gave the best results during the research period.

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