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PHYSIOLOGICAL GROWTH AND YIELD EVALUATION IN P-MINERALIZED SUNFLOWER (*HELIANTHUS ANNUS* L.) UNDER SUDANO-SAHELIAN AGRO-ECOLOGY, NIGERIA

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ABSTRACT:- The study was carried out at the Research and Demonstration Farm, Department of Crop Production, University of Maiduguri (11^o 47 'N, 13^o 13 'E) during 2010 and 2011 rainy seasons, to investigate the response of sunflower to phosphorus fertilizer inorganically applied as P_2O_5 @ 0, 20, 40, 60 and 80 kg ha^{-1}. The experimental design was randomized complete block and replicated thrice. It was observed that leaf area per plant and plant dry weight increased with increasing P_2O_5 rates (40-60 kg ha^{-1}) at 6, 8 and 10 weeks after sowing (WAS) . Crop growth rates similarly increased with increasing P_2O_5 rates (40-80 kg ha^{-1}) at 6 WAS in both years and the combined means for the two years, and at 8 WAS in 2011 and the combined analysis. Days to 50% flowering and head dry weight were not significantly influenced by P_2O_5 rates and 1000-grain weights indicated that increased P_2O_5 application (40-80 kg ha^{-1}) enhanced grain filling efficiency and this influenced weight per 1000 grains during both years. The application of 40 kg P_2O_5 ha^{-1} increased grain yield statistically in 2010 rainy season (2289.10 kg ha^{-1}) and the combined analysis (1565.20 kg ha^{-1}). During 2011 rainy season, 80 kg P_2O_5 ha^{-1} recorded statistically higher grain yield (1153.60 kg ha^{-1}). Similarly, the application of 80 kg P_2O_5 ha^{-1} statistically influenced higher fodder yield (4112.60 kg ha^{-1}) in 2010 rainy season; while 60 kg P_2O_5 kg ha^{-1} yielded statistically higher fodder values during 2011 (1873.00 kg ha^{-1}) and combined analysis (2393.30 kg ha^{-1}). Application of 60 kg P_2O_5 ha^{-1} also increased the biological yield statistically in 2010 (3709.70 kg ha^{-1}) and lower P_2O_5 rate of 40 kg ha^{-1} statistically yielded 3980.80 kg ha^{-1} in the combined analysis while biological yield was not statistically significant during 2011 rainy season. Considering 40 kg P_2O_5 ha^{-1} in yield performances for grain and fodder in this experiment, it could be recommended for farmers' adaptive farm trials in the agro-ecological location.

Key Words: Helianthus annuus; Phosphorus; Fertilizer; Crop Yield; Yield Components; Nigeria.

INTRODUCTION

Sunflower (*Helianthus annus* L.) is grown mainly for its oil-rich seeds in different parts of the world and occupies an important position among oilseed crops in the world market. Sunflower protein is comparable only to that of soybeans in terms of digestibility, and is more

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balanced in essential amino acids with its low cholesterol content (Jehan et al., 2010). If planted in areas with adequate sunlight on light textured and well drained loamy soil, sunflower will perform well whether irrigated or cultivated under rainfed conditions (Aduayi et al., 2002). This is because it has an extensive root system which may help increase nutrient uptake efficiency (Al-Thabet, 2006). The application of inorganic fertilizer was reported by Sadras (2006) to have substantially increased yield performance in sunflower. To that effect, phosphorus has been described by Zehra (2011) as necessary for growth, seed formation and yield performances and, in Turkish trials, its application @ 50-100 kg P_2O_5 ha^{-1} consistently increased seed set and kernel yield. Phosphorus is also required for energy transfer in plants through the formation of pyrophosphate bonds, and its compounds (ADP and ATP) play significant roles in many metabolic processes including cell division, leading to the development of good root systems (Meena et al., 2007). This, in turn, increases the ability of a plant to explore soil horizons for growth resources (Salim et al., 1987). Phosphorus supply positively influences nutrient uptake in sunflower, and increases nutrient use efficiency (Gunes and Inal, 2009; Wu et al., 2005).

Reddy et al. (2000) recorded increased plant heights, crop growth rates, leaf area and number of leaves per plant with increasing P_2O_5 rates up to 120 kg ha^{-1}. In a study by Agrawal et al. (2000), the application of 60 kg P_2O_5 ha^{-1} increased grain and fodder yield. Further increase in P_2O_5 rates increased yield performances as Jahangir et al. (2006) recorded maximum number of seed per head and seed yield with 75 kg P_2O_5 ha^{-1}, while Dhoble (1998) increased yield performances with 80 kg P_2O_5 ha^{-1}. Murad et al. (2000) reported significant increases in dry matter production and crop growth rates in sunflower with increase P_2O_5 application, but without a significant effect on leaf area. Similarly, P_2O_5 application did not significantly affect days to 50% flowering and 1000-grain weight (Ali et al., 2000).

Recent reports from Nigeria have indicated that sunflower production holds promise in the forest agro ecology (Adebayo et al., 2012), in northern Guinea (Wabekwa et al., 2011) and in Sudan savanna (Wabekwa et al., 2010). The inherent fertility of the soils in these zones has been reduced due to bush burning, drought and other forms of fertility degradation leading to low organic matter. Thus it is necessary to evaluate the nutrient requirements of sunflower as part of determining its physiological suitability for these areas. As an essential plant element, phosphorus supply plays a significant role in plant growth and yield. There is a particular need to conduct this study to determine the phosphorus requirement of the crop.

MATERIALS AND METHOD

Field studies were conducted for two consecutive (2010 and 2011) rainy seasons at the Research Farm of the Department of Crop Production, University of Maiduguri, Nigeria (110 47 'N, 130 13 'E), vegetationally located within the Sudano-Sahelian savanna fringes. The physio-chemical properties of soil samples taken from the experimental sites at 0-15 cm depth and analyzed in the Soil Science Department laboratory of the University in both years showed that the soil textural classification was sandy-loam. pH in H_2O, organic matter and total nitrogen for 2010 and 2011 rainy seasons respectively were pH (7.6 and 7.7), O.M. (0.12 and 0.10%) and N (0.06 and 0.05%). Also, the available soil phosphorus and exchangeable K were P (4.41 and 3.74 mg kg^{-1} ,Bray 1P) and K (0.21 and 0.24 Mol kg^{-1}) respectively. This indicates that the sites were low in inherent NPK and other major nutrient elements in both rainy seasons. The experimental sites in 2010 and 2011 rainy seasons were separated by a distance of 100 metres.

The treatments consisted of phosphorus fertilizers @ 0, 20, 40, and 80 kg P_2O_5 ha^{-1}, fitted in a randomized complete block design and replicated thrice. The field layout was applied after land clearing and harrowing and single super phosphate (P_2O_5) fertilizer was incorporated as a basal dose to achieve its desired effects. The local, open pollinated and late maturing seed variety (Funtua), which has been tested to have high adaptation to Nigerian savanna soils was sourced from the Institute for Agricultural Research, Ahmadu Bello University, Zaria and hand-sown at 75cm x 25cm on seed beds measuring 4.5m x 4.0m in early July, following heavy rainfall in both years. During sowing, 2-3 seeds were placed per hole and later at two weeks after sowing (WAS), during the first hoe weeding, the plant population was reduced to only one per hole (53,333 plants ha^{-1}). Subsequent hoe-weedings were carried out at 4 and 7 WAS. All other agronomic practices were carried out normally and on time and, as the crops exhibited no sign of pests or diseases, no control measure was taken.

Data collection on leaf area and plant dry weight was obtained from five randomly selected plants from the sampling route, and this was initiated at 4 WAS and continued nightly, and crop growth rates was evaluated from plant dry weight as proposed by Hunt (1978) using the following formula:

$$CGR = \frac{W_2 - W_1}{t_2 - t_1} \ (g\,dm^{-2}\,day^{-1})$$

where:

W_1 and W_2 = dry weights (g m-2) at first and second harvests,

t_1 and t_2 = time corresponding to first and second harvests, respectively.

Days to flowering were determined when about 50% population of the terminal ray disc flowers were fully opened and the bracts became yellow from the sowing date. At harvest (14 WAS in both years), data on head dry weight, 1000-grain weight, grain, fodder and biological yields were all evaluated from net plots. However, grain and fodder yields were separately sampled and evaluated from different plants.

Data were analyzed according to "statistics" version 8.0 analytical software and mean separation was done using DMRT (Duncan, 1955) at 5% confidence level.

RESULTS AND DISCUSSION

Leaf area per plant was not significantly affected by P application at 4 WAS in either year or in the combined analysis, or at 6 WAS in the 2011 wet season (Table 1). However, at 6 WAS in 2010 there was a significant increase in leaf area at 40 kg P_2O_5 ha^{-1} and above and in the combined analysis from 60 kg P_2O_5 ha^{-1} and above. The combined analyses of the 8 and 10 WAS sampling periods showed significant differences between control (0 kg P_2O_5 ha^{-1}) and 60-80 kg P_2O_5 ha^{-1}.

Dry matter production was not significantly influenced by P_2O_5 rates at 4 WAS (Table 2). Application of P_2O_5 at 80 kg ha^{-1} however increased plant dry weight at 6, 8 and 10 WAS, and applications of 60 kg P_2O_5 ha^{-1} gave statistically significant increases at 6, 8 and 10 WAS in the 2010 rainy season and in the combined analysis.

Analysis of crop growth rates showed that there were no statistical differences among P_2O_5 rates at 10 WAS, during 2010 at 8 WAS and in both years and combined analysis at

Table 1. Effect of phosphorus fertilizer rates on leaf area per plant of sunflower in Maiduguri during 2010 and 2011 rainy season and their combined means (cm^2)

	4 WAS			6 WAS			8 WAS			10 WAS		
P_2O_5 (kg ha^{-1})	2010	2011	Mean	2010	2011	Mean	2010	2011	Mean	2010	2011	Mean
0	5.3	3.7	4.5	14.5^{c}	11.9	13.2^{c}	21.9^{c}	16.1^{c}	19.0^{c}	22.9^{b}	16.5^{c}	19.7^{b}
20	5.6	3.6	4.6	15.2^{bc}	14.1	14.7^{ab}	28.2^{a}	17.0^{bc}	22.0^{ab}	25.0^{ab}	17.3^{bc}	21.1^{ab}
40	5.3	4.3	4.8	16.5^{ab}	12.7	14.6^{ac}	25.1^{b}	18.0^{a-c}	21.5^{a-c}	25.1^{ab}	18.8^{ab}	21.9^{ab}
60	5.6	4.3	5.0	17.2^{a}	13.3	15.3^{ab}	26.7^{ab}	18.6^{ab}	22.6^{ab}	25.4^{a}	19.2^{ab}	22.8^{a}
80	6.1	4.3	5.2	17.9^{a}	14.6	16.3^{a}	28.2^{a}	19.3^{a}	23.8^{a}	27.7^{a}	19.5^{a}	23.6^{a}
SE (±)	0.46	0.51	3.83	0.88	1.44	0.97	0.97	0.96	1.33	1.44	0.99	1.31

Means followed by same letters do not differ significantly at $P \leq 0.05$

Table 2. Effect of phosphorus fertilizer rates on plant dry weight of sunflower in Maiduguri during 2010 and 2011 rainy season and their combined means (g)

	4 WAS			6 WAS			8 WAS			10 WAS		
P_2O_5 (kg ha^{-1})	2010	2011	Mean	2010	2011	Mean	2010	2011	Mean	2010	2011	Mean
0	10.0	8.5	9.2	44.2^{c}	42.4^{ab}	43.3^{bc}	105.8^{c}	99.2^{b}	102.5^{c}	176.8^{d}	124.6^{b}	150.7^{c}
20	10.6	8.0	9.3	45.9^{bc}	36.8^{b}	41.3^{c}	109.6^{c}	99.5^{b}	104.6^{c}	195.5^{cd}	125.5^{b}	160.5^{bc}
40	10.8	8.9	9.8	48.0^{b}	39.9^{ab}	44.0^{bc}	122.7^{b}	97.6^{b}	110.1^{bc}	208.7^{bc}	125.8^{b}	167.3^{a-c}
60	10.7	9.9	10.3	51.9^{a}	41.9^{ab}	46.9^{ab}	124.0^{b}	105.7^{b}	114.9^{b}	226.0^{ab}	132.8^{b}	179.4^{ab}
80	11.4	9.6	10.5	53.0^{a}	47.3^{a}	50.2^{a}	144.6^{a}	120.3^{a}	132.4^{a}	238.5^{a}	142.8^{a}	190.6^{a}
SE(±)	1.15	1.01	0.81	1.85	3.87	2.54	6.36	5.77	4.88	10.82	4.33	12.78

Means followed by same letters do not differ significantly at $P \leq 0.05$

10 WAS. At 8 WAS, results for the 2011 rainy season and the combined analysis showed significant growth rate increases only between the 80 kg P_2O_5 ha^{-1} and control treatments (Table 3). At 6 WAS however, the application of 40-80 kg P_2O_5 ha^{-1} produced statistically increased growth rates in 2010 but for 2011 and the combined analysis only 80 kg P_2O_5 ha^{-1} gave a significant increase over the control (although the 40-80 kg P_2O_5 ha^{-1} all gave statistically similar growth rates).

Data showed that number of days to 50% flowering and head dry weights were not significantly influenced by P_2O_5 rates during both years and combined analysis, but result on effects of P_2O_5 rates on 1000-grain weight was significant in both years and in the combined analysis (Table 4). During both rainy seasons, highest 1000-grain weights were recorded at 80 kg P_2O_5 ha^{-1} and this result was statistically comparable with that of 40 and 60 kg P_2O_5 ha^{-1} in the 2010 rainy season (Table 4).

Table 3. Effect of phosphorus fertilizer rates on crop growth rates of sunflower in Maiduguri during 2010 and 2011 rainy season and their combined means

	6 WAS			8 WAS			10 WAS		
P_2O_5 (kg ha^{-1})	2010	2011	Mean	2010	2011	Mean	2010	2011	Mean
0	3.0^{b}	2.0^{b}	2.3^{b}	4.8	4.0^{b}	4.4^{b}	4.2	1.8	3.0
20	3.1^{b}	2.0^{b}	2.5^{b}	4.7	4.4^{ab}	4.5^{ab}	3.9	1.8	2.9
40	3.5^{a}	2.3^{ab}	2.9^{ab}	2.9	4.1^{b}	4.5^{ab}	3.9	2.0	3.0
60	3.6^{a}	2.2^{ab}	2.9^{ab}	5.1	4.4^{ab}	4.7^{ab}	4.3	2.1	3.2
80	3.6^{a}	2.7^{a}	3.1^{a}	5.1	5.2^{a}	5.1^{a}	4.2	1.6	2.9
SE (±)	0.18	0.24	0.22	0.27	0.42	0.31	0.22	0.39	0.44

Means followed by same letters do not differ significantly at $P \leq 0.05$

Table 4. Effect of phosphorus rates on days to first and 50% flowering, head dry weight and 1000-grain weight of sunflower in Maiduguri during 2010 and 2011 rainy season and their combined means

	Days to 50% flowering			Head dry weight (g)			1000-grain weight (g)		
P_2O_5 (kg ha^{-1})	2010	2011	Mean	2010	2011	Mean	2010	2011	Mean
0	71	64	67	79.4	53.6	66.5	49.4^{b}	24.6^{c}	37.0^{bc}
20	70	62	66	66.2	55.7	61.1	49.8^{b}	21.2^{c}	35.5^{c}
40	70	63	66	62.8	54.7	58.7	54.4^{ab}	30.3^{b}	42.3^{bc}
60	68	65	67	62.4	59.7	61.0	51.7^{ab}	34.0^{b}	42.9^{b}
80	69	59	64	74.8	59.9	67.4	55.8^{a}	44.8^{a}	50.3^{a}
SE (±)	1.2	3.3	2.0	19.51	5.19	10.16	2.56	2.46	3.68

Means followed by same letters do not differ significantly at $P \leq 0.05$

The grain yields were much higher in 2010 than in 2011. In 2010, the application of 40-80 kg P_2O_5 ha^{-1} produced significant grain yield increase of 360-630 kg ha^{-1} over the control and 270-490 kg ha^{-1} averaged over both years. In 2011, when yields were lower, the application of the highest P_2O_5 rates of 60 and 80 kg ha^{-1} statistically increased grain yield by 180 and 350 kg ha^{-1}, respectively. Similarly, the application of 80 kg P_2O_5 ha^{-1} gave highest yield (4113 kg ha^{-1}) in 2010 and 2948 kg ha^{-1} in the combined analysis. In 2011, 60 kg P_2O_5 ha^{-1} gave a similar significant increase in fodder yield (540 kg ha^{-1}) (Table 5). Data on biological yield however indicated that results were not statistically different among P_2O_5 rates during the 2011 rainy season, and in 2010, yield increased statistically at P_2O_5 rates of 60-80 kg ha^{-1} with average value of 3709.70 kg ha^{-1}. In combined analysis, the application of 40-80 kg P_2O_5 ha^{-1} produced statistically similar results, but the highest yield (4420.70 kg ha^{-1}) was however recorded at 80 kg P_2O_5 ha^{-1} (Table 5).

The soil textural classes of the experimental sites (light, well drained) and suitable agro-ecological environment were consistent with the ideal condition for yield performances in sunflower as earlier recommended by Aduayi et al. (2002). Also the contrasting soil chemical properties with comparably higher inherent total organic matter, nitrogen and available phosphorus in the 2010 rainy season created seasonal variations, which might have favourably promoted growth and yield performances in 2010 than in 2011 rainy season. Besides, rainfall was higher in 2010 rainy season (689.8 mm) and fairly distributed across vegetative and grain filling phases in contrast to 2011 (547.6 mm) which might have led to yield variation. Since sunflower has an extensive root system if fully developed (Al-Thabet, 2006), this influenced higher phosphorus uptake as reported by Gunes and Inal (2009); and it prepared the plant for overall growth processes of the vegetative parameters, grain yield, fodder production (Agrawal et al.,

Table 5. Effect of phosphorus fertilizer rates on grain, fodder and biological yields of sunflower in Maiduguri during 2010 and 2011 rainy seasons and their combined means

(kg ha^{-1})

	Grain yield			Fodder yield			Biological yield		
P_2O_5	2010	2011	Mean	2010	2011	Mean	2010	2011	Mean
0	1792^{b}	795^{c}	1294^{b}	2482^{b}	1332^{b}	1907^{c}	2678^{c}	4649	3663^{c}
20	1880^{b}	824^{c}	1352^{b}	2624^{b}	1355^{b}	1989^{bc}	2247^{d}	5257	3752^{bc}
40	2289^{a}	841^{c}	1565^{ab}	2494^{b}	1431^{b}	1963^{bc}	3100^{b}	4862	3981^{ab}
60	2157^{ab}	980^{b}	1569^{ab}	2786^{b}	1873^{a}	2329^{ab}	3710^{a}	5039	4374^{a}
80	2422^{a}	1154^{a}	1788^{a}	4113^{a}	1783^{a}	2948^{a}	3535^{a}	5306	4421^{a}
SE (±)	188.3	58.7	198.1	201.6	97.3	209.5	123.9	253.6	307.1

Means followed by same letters do not differ significantly at $P \leq 0.05$

2000) and biological yield performances.

Increased phosphorus supply positively influenced increase in grain formation and kernel filling, and this increased weight per 1000 grains, biological and grain yield performances as reported by Zehra (2011). Leaf area per plant and dry weight increased at increasing phosphorus fertilizer rates due to the key role of phosphorus in plant growth as earlier reported by Reddy et al. (2000), and increased P_2O_5 application also accelerated crop growth (rates) due to increased dry matter production arising from increased photosynthetic efficiency and this finding agrees with that of Meena et al. (2007). As leaf area and plant dry weight were not significantly influenced by P_2O_5 rates during early vegetative growth (4 WAS), this could be ascribed to the fact that the fertilizer applied was not solubilized and made readily available for plant utilization. The non-significant result also reported herein on days to 50% flowering and head dry weight agrees with the findings of Ali et al. (2000).

Conclusively, since the application of 40 kg P_2O_5 ha^{-1} influenced higher increase in grain and flower yield, this could stand as the recommended phosphorus rate for local farm trials among farmers in Sudano-Sahelian agro-ecological zone of Nigeria.

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