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Effects of Phosphorus Levels on Nutritional Composition of Sunflower Grains and Oil Qualities in Wamdeo, Southern Borno, Nigeria

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ABSTRACT

To study the effects of phosphorus rates (0, 20, 40, 60 and 80 kg P_2O_5 ha^{-1}) on nutrient composition and oil quality components of sunflower grains, field experiments were conducted during 2010 and 2011 rainy seasons at Wamdeo (10^0 30'N, 13^0 09'E; 523m above sea level), south of Borno State, Nigeria. The grain samples harvested were analysed for their oil and protein proximate contents; and the fatty acid fractions of the oil were also determined. Results from the various treatments indicates that the application of 60 kg P_2O_5 ha^{-1} recorded statistical increases ($\leq$0.01) in the grain oil contents in 2010 and in the two years mean (28.40%) of the total grain composition. The application of higher P_2O_5 rate of 80 kg ha^{-1} however recorded higher value in 2011 rainy season. Grain protein contents also increased ($\leq$0.01) with the application of 60 kg P_2O_5 ha^{-1} in the two years mean (16.65%) while higher P_2O_5 rate of 80 kg ha^{-1} recorded higher result in 2010, and the difference between 40-80 kg P_2O_5 ha^{-1} were not statistically significant in 2011 rainy season. Phosphorus applied at higher rate of 80 kg P_2O_5 ha^{-1} however recorded statistically higher values ($\leq$0.01) for oleic acid in the individual years and their combined means (33.80%) of the total fatty acid composition of the oil. The application of 60 kg P_2O_5 ha^{-1} also increased linoleic acid in the individual years while higher P_2O_5 rate of 80 kg ha^{-1} recorded statistically ($\leq$0.01) higher value in the two years mean (32.91%). Results for the saturated fatty acid contents indicates that lower P_2O_5 rate of 40 kg ha^{-1} increased palmetic acid concentrations in the individual years, and in the two years mean (7.56%) of the total fatty acid composition. Steric acid, however, increased with an increase in P_2O_5 rate to 60 kg ha^{-1} in 2010 rainy season, and further increase in P_2O_5 rate to 80 kg ha^{-1} resulted to an increase in steric acid content in 2011 rainy season, and in the two years mean (3.42%) of the total fatty acid composition. Considering the performance of P on the oil and protein and the relative compositions of the unsaturated fatty acids (oleic and linoleic) in oil which out-weight the saturated fatty acids (palmetic and steric), it could be suggested that phosphorous when applied at 60-80 kg P_2O_5 ha^{-1} would increase the nutritional quality of the grain. However, further breeding study need to be conducted to eliminate the gene for the saturated fatty acids and emerge with cholesterol-free cultivar.

Key words: Sunflower grains, phosphorus levels, oil, protein, fatty acids, nutritional qualities

INTRODUCTION

Sunflower grains produce oil with high level of essential vitamins and low contents of saturated fatty acids which when high could increase the level of blood cholesterol, and can be a factor for chronic heart diseases (Anon., 2007). It constitutes 28% protein for non-dehulled grains and 24% for the completely dehulled grains, and its protein constitutes higher contents of essential amino acids which is highly soluble and easily fermented in rumen (Mahecha, 2005). Sunflower meal is higher in fibre with low energy value and lysine content; and extracts from its grains have varied medicinal values. Since its discovery, its oil has served in the manufacture of soaps and detergents; as surfacants in agrochemicals, and as an alternative for diesel oils due to its viscosity and excellent lubricating properties (Putman, 2008).

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The performances of grain oil and protein contents, and the fatty acid fractions in sunflower oil may be expressed with variations when grown under different environments, or due to genotypes (Zheljazkov *et al*., 2008). The application of 90kg P_2O_5 ha^{-1} increased grain oil content, and higher rate of 135 kgP_2O_5 ha^{-1} increased protein content in sunflower grains (Amanullah *et al*., 2010). In another study, Amanullah and Khan (2010) maintained that the protein content of sunflower grains is 23.20%. Report from similar study by Murad *et al*. (2000) indicates that phosphorus applied at 100 kg P_2O_5 ha^{-1}yielded higher oil content. Karadogan *et al*. (2009) has also maintained that the potentials for improving grain dry matter seems to be mainly associated with increased phosphorus application, and Rodriguez *et al*. (1998) described phosphorus as an essential element for grain formation. Zhera (2011) has recommended the application of 50 kg P_2O_5 ha^{-1} for grain set and filling efficiency; and Yousaf *et al*. (1986) recorded positive correlations between grain oil content and grain filling, while Wabekwa (2014) recorded positive correlation ($\leq$0.01) between the grain dry matter and the unsaturated fatty acids (oleic and linoleic). Contending reports from Muralidharudu *et al*. (2003) however indicates that phosphorus application did not influence increases in grain oil contents.

The increased demand on Nigeria's foreign reserve to import her quality edible oil remains unchanged even when the yield potentials of non-indigenous oil crops like sunflower and soybeans have been tested to be promising in some parts of the country (Wabekwa *et al*., 2010; Wabekwa *et al*., 2014; Adebayo *et al*., 2012). Since fertilizer application would improve the nutritional composition of the grains and add to its quality in terms of safety from health risk, there is the need to conduct the present study.

MATERIALS AND METHODS

Sunflower grains were produced under various phosphorus treatments (0, 20, 40, 60 and 80 Kg P_2O_5 ha^{-1}) during 2010 and 2011 rainy seasons at Wamdeo (10^0 30'N, 13^0 09'E; 523m above sea level), south of Borno state in the Northern Guinea savanna of Nigeria. The experiment was arranged in a Randomized Complete Block Design (RCBD) and replicated three times. The land was ploughed and cross-ploughed after clearing, and phosphorus in the form of single super phosphate was applied at the appropriate rates after field layout during both years. Seeds were sown at 75cm x 25cm in early July, and over-seeded holes were thinned to a single plant per stand at first weeding. Weed management practices were carried out at 2, 5, and 8 weeks after sowing (WAS) while harvest, threshing, winnowing activities and further sun-drying of grains were carried out at plants maturity. The harvested grains were analysed in the laboratory to determine the effects of the treatments on oil and protein contents of the grains and the nutritional quality components of the oil (oleic, linoleic, palmetic and steric acids) as follows:

The grain oil content

Oil content of the grains was determined using Soxhlet fat extraction method according to Association of Official Analytical Chemist (A.O.A.C., 1990). The following formula was used in calculating the percentage oil contents of the various grain samples after the heating and cooling procedures.
Percentage oil = W3-W1/W2-W1 x 100, Where, W1 = Weight of flask, W2 = Weight of flask + grain, W3 = Weight of flask + oil, 100 = Constant (K) – Percentage expression

The fatty acids

Sample oil obtained above for each treatment was further analyzed to separate the oleic, linoleic, steric and palmetic acid fractions of the oil using oil and fat extraction method by trans-esterification as determined by Hamilton and Rosselle (1986).

The Grain Protein Content

Protein content was determined from the grain samples obtained at harvest using Kjeldahl procedures as described by Association of Official Analytical Chemist (A.O.A.C., 1970). The following formula was used in calculating the percentage crude protein after the digestion procedures.

Percentage protein = (V1-V2)/100W x N x 14 x 6.25 x 100, Where: V1=Sample titration, V2 = Blank titration, N = Normality of standardized H_2SO_4, W = Sample weight, 14 = Constant (K), 6.25 = Constant (K), 100 = Constant (K). Information obtained from the laboratory analysis were further subjected to statistical analysis using the software "Statistix" 8.0 in order to test the level of significance between the treatments and the means were separated using the Duncan's Multiple Range Test (DMRT) at 5% level of probability (Duncan, 1955).

RESULTS

Results from the Table 1 indicate that application of phosphorus influenced increases in oil and protein contents of sunflower in Wamdeo. The application of 60 kg P_2O_5 ha^{-1} recorded statistical increases ($\leq$0.05) in oil contents in 2010 rainy season and in the two years mean, which recorded 28.40% of the total grain composition. Additional P_2O_5 rate of 80 kg ha^{-1} however recorded higher value (at $\leq$0.05) in 2011 rainy season. Similarly, protein contents show statistical increase ($\leq$0.01) with P_2O_5 application up to 80 kg ha^{-1} in 2010, and results for 2011 rainy season indicate that lower P_2O_5 rate applied at 40 kg ha^{-1} recorded optimum value for protein content and mean value for the two years recorded 16.65% at 60 kg P_2O_5 ha^{-1} (Table 1).

Table 1: Effect of Phosphorus levels on oil and protein contents of sunflower grains in Wamdeo during 2010-2011 rainy seasons and their combined means

Treatment	Grain oil content (%)			Protein oil content (%)		
(P_2O_5 kgha^{-1})	2010	2011	Mean[1]	2010	2011	Mean
0	26.79[b2]	19.84[c]	23.32[c]	15.16[bc]	13.65[b]	14.40[c]
30	20.87[c]	19.41[c]	20.14[d]	14.72[c]	13.89[b]	14.30[c]
40	27.94[b]	23.90[b]	25.92[bc]	15.90[c]	15.03[ab]	15.46[bc]
60	34.23[a]	22.56[b]	28.40[ab]	17.46[b]	15.83[a]	16.65[ab]
80	32.92[a]	28.40[a]	30.66[a]	16.39[a]	15.89[a]	17.14[a]
SE (±)	2.95	1.03	1.56	1.22	0.87	0.75

1. Mean value of the means for the two years for 2010 and 2011 data
2. Means in a column followed by the same letter(s) are not significantly different at 5% level of probability according to Duncans Multiple Range Test (DMRT).

Table 2 shows that the contents of unsaturated fatty acids (oleic and linoleic) increased with the application of phosphorus, and the application of higher P_2O_5 rate of 80 kg ha^{-1} recorded higher increases ($\leq$0.01) in the oleic acid contents in the individual years, and in their combined mean which recorded 33.08% of the total fatty acid composition of the oil. Lower phosphorus application of 60 kg P_2O_5 ha^{-1} however recorded statistical increases ($\leq$0.05) in linoleic acid content of oil in 2010 and 2011 rainy seasons, as the application of 80 kg P_2O_5 ha^{-1} recorded statistically ($\leq$0.01) higher value (32.91%) in the two years average (Table 2).

Table 2: Effect of phosphorus levels on unsaturated fatty acid contents (oleic and linoleic) of sunflower oil in Wamdeo during 2010-2011 rainy seasons and their combined means

Treatment	Oleic acid content (%)			Linoleic acid content (%)		
(P_2O_5 kg ha^{-1})	2010	2011	Mean[1]	2010	2011	Mean
0	12.25[e2]	10.79[e]	11.52[e]	9.25[d]	7.08[d]	8.16[e]
30	21.01[d]	13.17[d]	17.09[d]	16.83[c]	10.97[c]	13.90[d]
40	28.70[c]	21.94[c]	25.32[c]	24.96[b]	21.53[b]	23.25[c]
60	34.03[b]	24.29[b]	29.16[b]	33.66[a]	27.07[a]	30.37[b]
80	37.39[a]	30.22[a]	33.80[a]	36.08[a]	29.74[a]	32.91[a]
SE (±)	1.31	1.09	0.85	1.68	1.34	1.08

1. Mean value of the means for the two years for 2010 and 2011 data
2. Means in a column followed by the same letter(s) are not significantly different at 5% level of probability according to Duncans Multiple Range Test (DMRT)

Phosphorus application also influenced the contents of saturated fatty acids (palmetic and steric) in Wamdeo (Table 3). The application of lower phosphorus rate of 40 kg P_2O_5 ha^{-1} recorded statistical increases ($\leq$0.05) in palmetic acid in the two rainy seasons and their average, which recorded 7.56% of the total fatty acid composition of oil. The application of 60 kg P_2O_5 ha^{-1} recorded statistical increase in 2010 rainy season, and additional phosphorus rate of 80 kg P_2O_5 ha^{-1} recorded statistically higher values ($\leq$0.01) in 2011 rainy season and in the two years mean with value of 3.42% of the total fatty acid contents (Table 3).

Table 3: Effect of phosphorus levels on saturated fatty acid contents (palmetic and steric) of sunflower oil in Wamdeo during 2010-2011 rainy seasons and their combined means

Treatment	**Palmetic acid (%)**			**Steric acid (%)**		
(P_2O_5 kg ha^{-1})	**2010**	**2011**	**Mean[1]**	**2010**	**2011**	**Mean**
0	3.33[c2]	2.31[c]	2.82[c]	1.43[c]	1.00[d]	1.22[d]
30	7.03[b]	5.61[b]	6.32[b]	1.47[c]	1.17[d]	1.32[d]
40	8.15[ab]	6.97[a]	7.56[a]	2.42[b]	1.67[c]	2.04[c]
60	8.62[a]	7.77[a]	8.19[a]	2.93[a]	2.23[b]	2.58[b]
80	8.77[a]	7.78[a]	8.28[a]	3.83[a]	3.02[a]	3.42[a]
SE (±)	0.78	0.56	0.48	0.28	2.23	0.18

1. Mean value of the means for the two years for 2010 and 2011 data
2. Means in a column followed by the same letter(s) are not significantly different at 5% level of probability according to Duncans Multiple Range Test (DMRT).

DISCUSSION

Results from this study shows that phosphorus application increased the grain oil content across the years at varying levels compared with no P application which clearly suggests the positive role of phosphorus in oil crops in terms of dry matter contents. Karadogan *et al*. (2009) earlier reported that the potentials for increasing seed dry matter contents seem to be associated with increased phosphorus application, and Rodriguez *et al*. (1998) maintained that phosphorus application have had direct effects on grain properties due to its role in the supply of assimilates. The present study optimum of 60 kg $P_2O_5$5 ha^{-1} for higher oil yield however differs from other previous optimum of 90 kg P_2O_5 ha^{-1}reported by Amanullah *et al*. (2010), and 100 kg P_2O_5 ha^{-1} reported by Murad *et al*. (2000), and the contradicting report by Muralidharudu *et al*. (2003) that phosphorus application did not influence grain oil contents. It has been reported by Zheljazkov *et al*. (2008) that the performances of grain dry matter in sunflower may be expressed with variations when grown under different environments or due to genotypes. Similarly, phosphorus applied at 60 kg P_2O_5 ha^{-1} recorded significant improvement in grain protein content with the two years mean recording 16.65% against the 23.20% earlier reported by Amanullah and Khan (2010), which might as well be due to the expressed reason given by Zheljazkov *et al*. (2008) above, or still due to the level of phosphorus used by the later reporter (Amanullah and Khan, 2010), since their report was based on unspecified fertilizer recommendation. All the above findings could however suggest that phosphorus plays significant roles ingrain protein synthesis and this is most probably because of its obvious functions and ability to promote the steady flow and partitioning of assimilates which could increase grain filling.

The higher values recorded in the unsaturated fatty acid contents of oil in this study when compared to the saturated fatty acid fractions could mean that the grains contain safe and nutritionally balanced oil, and this finding is consistent with that of Anon. (2007). It is also apparent to suggest here, therefore, that the linoleic and oleic acid fractions (unsaturated fatty acids) contributed to the oil in terms of quantity, quality and nutrition and health values as well. Wabekwa (2014) has recorded positive correlation between grain dry matter and the unsaturated fatty acids only. Furthermore, results showing negligible values recorded for the saturated fatty acids in the study (7.56% for palmetic and 3.42% for steric) clearly suggests that sunflower oil recorded low cholesterol of saturated fatty acids and could substitute some of our cholesterol-high vegetable oil of indigenous origin like groundnuts and sesame, since it has been tested to have high degree of adaptability to the diverse Nigerian savanna agro-ecology.

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