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Effect of NPK Fertilizer and Cropping Ratios on Nutrient Uptake and Quality Components of Maize (*Zea mays*) and Egusi Melon (*Colocynthis citrullus*)

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Authors' contributions

This work was carried out in collaboration between all authors. Author JOE designed the study, wrote the protocol and wrote the first draft of the manuscript. Author GOI managed the literature searches. Author EJF managed the experimental process. All authors read and approved the final manuscript.

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ABSTRACT

Field trials were conducted in 2009, 2010 and 2011 in the University of Benin, Nigeria to determine influence of NPK fertilizer and varying cropping ratios on nutrient uptake and quality components of maize and egusi melon. Cropping ratios and application of NPK 20:10:10 fertilizer at 600 kg/ha significantly ($P<0.01$) enhanced the percent oil, protein, N and P in maize grains and egusi melon seeds; except for maize where cropping ratios failed to enhance these qualities relative to the sole maize. Cropping ratios influenced mostly the nutrient uptake by maize grains; while N uptake was highest in sole maize, P (2.10 kg/ha) content was lowest in sole maize. For other nutrients, that is K, Ca and Mg their contents in maize grains was enhanced due to intercropping with egusi melon thus making the egusi melon less competitive with maize for the nutrients.
Increased fertilizer rates (0 to 600 kg/ha) of the NPK 20:10:10 enhanced N and Mg uptake in maize grains in intercrop with egusi melon. The trend was different in nutrient uptake by egusi melon with respect to applied fertilizer. The less uptake of nutrients by the crop may suggest residue of same nutrients for further cultivation.

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1. INTRODUCTION

Maize is an important cereal crop in Nigeria and it ranks first followed by rice, millet, sorghum and wheat. Areas under maize cultivation in Nigeria is expanding and presently occupies more than 7,500,000 hectares of land [1] with yield as much as 1000 million tons annually.

Maize is consumed as staple food in various ways. It can be boiled, roasted or flaked and consumed. Maize can be processed into meals, scurry starchy food or flour for confectionaries [2]. Generally, maize serves as basic source of starch, oil, protein alcoholic beverages and recently as fuel [3]. The green plant when made into silage serves as feed for livestock and forage for ruminant animals. Egusi melon also is an important crop mostly cultivated of the corcubitaceae family followed by fluted pumpkin (*Telfaria occidentalis*) and water melon (*Citrullus lanatus*). Area under egusi melon cultivation in Nigeria is more than 0.36 million hectares annually with yield of 0.45 million tonnes.

Maize and egusi melon are commonly cultivated together in mixtures by farmers in Nigeria for obvious reasons of its advantage in increasing individual crop yield as opposed to cultivating them in sole cropping. Fertilizer application in crop mixtures is usually difficult and not backed by any research information because of the complex nature of intercropping. Nutrient availability and uptake by crops in the complex nature of the intercrop is not understood. It is for this reason that this study aimed to determine the combined or individual effects of NPK fertilizer and varying ratios of intercropping maize-egusi melon on the crops nutrient uptake and quality components.

2. MATERIALS AND METHODS

The experiment was conducted at the university of Benin, Benin City Nigeria (5° 04' and 6°4'3'E, 6°14'S and 7°34'N) in 2009, 2010 and 2011 wet seasons. The treatments consisted of seven cropping ratios (1:0, 0:1, 1:1, 2:1, :3:1, 1:2 and 1:3) of maize (MA) and egusi melon (EM) respectively with plant population ratio as MA 64: 0EM, MA0: 64EM, MA 32:32 EM, MA48:24EM, MA48:16EM, MA24:48EM, and MA16:48EM; the MA and EM were tested under four rates of NPK 20:10:10 fertilizer (0, 200, 400, 600 kg/ha) in 2009 and 2010 as experiments 1 and 2 respectively, thus amounting to 28 treatments replicated three times (84 plots of 16.2m^2 each. And in 2011 as experiment 3, the fertilizer rates were increased to six (0, 200, 400, 600, 800, 1000 kg/ha) to validate earlier results of experiments 1 and 2. The 42 treatments in experiments 3 were replicated three times (126 plots of 16.2m^2 each). The experiments were laid out as factorial fitted into randomized complete block design. Maize variety (DMR-ESR-W) and "serewe" variety [4] of egusi melon were planted at spacing of 90 cm x 75 cm with 3 seeds/stand, later thinned to 2/stand after 5 days of seedling emergence. Fertilizer applications were made at 3 and 8 weeks after planting to coincide with vegetative and reproductive stages respectively to minimize leaching associated with ultisols. Maize was harvested at 85 days after planting (DAP) and egusi melon at 95 DAP, processed and oven dried to 10% and 12% moisture content respectively.

2.1 Determination of Nutrient Uptake

A total of 48 samples (24 each for maize and egusi melon) of maize grains and egusi melon seeds at 10% and 12% moisture convent respectively were used to determine nutrient uptake (N, P, K, Ca, Mg) in experiments 1 and 2; and 72 samples (36 each for maize and egusi melon) for the same nutrient uptake determination. The procedures as described by [5,6] were used for the analysis.

2.2 Determination of Quality Components

Quality components (i.e % oil, protein, N, P, K, Ca, Mg) of maize grains and egusi melon seed were obtained using the procedures described by [6] for protein, N, P, K, Ca and Mg to determine their contents. The oil contents of both maize grain and egusi melon seeds were obtained using the procedures described by [7,5].

2.3 Data Analysis

Differences between treatments and their interactions were separated using standard error of means (S.E) and least significant difference (LSD).

3. RESULTS

3.1 Effects of 20:10:10 NPK Fertilizer Rates on Nutrient Uptake of N, P, K, Ca and Mg (kg/ha) by Maize in Intercrop with Egusi- melon

The uptake of N by maize when intercropped with egusi melon was significantly increased (P<0.001) with increased 20:10:10 NPK fertilizer rates from 0 – 600 kg/ha in Experiments 1 and 2 (Table 1). In Experiment 3, this was decreased at fertilizer rates of 200 – 1000 kg/ha, compared with the control (0 kg/ha) and treatment differences were more pronounced with the high fertilizer rates of 800 and 1000 kg/ha respectively. In all the experiments, P uptake in maize grains generally increased with higher fertilizer rates and treatment differences were significantly (P<0.001) different except in Experiment 2 (Table 1).

For K, there was no clear pattern in its uptake in maize grains in the various experiments. In Experiments 1 and 3, fertilizer rates of 200 – 600 kg/ha significantly decreased its uptake compared with the control treatment (0 kg/ha), while treatment effects were similar in Experiment 2 (Table 1). In Experiment 3, the treatment effects on K uptake were similar at higher fertilizer rates of 800 and 1000 kg/ha respectively compared with the control treatment.

The various fertilizer rates affected Ca uptake in maize grains similarly in all the experiments. However, Mg uptake was severely decreased (P<0.001) in Experiments 1 and 2 in the control treatment compared with when 20:10:10 NPK fertilizer was applied at rates of 200 – 600 kg/ha (Table 1). The Mg uptake in maize grains was similar in all the treatments in Experiment 3.

3.2 Effects of 20:10:10 NPK Fertilizer Rates on Nutrient Uptake of N, P, K, Ca and Mg (kg/ha) by Egusi Melon in Intercrop with Maize

In egusi melon intercropped with maize, 20:10:10 NPK fertilizer rates from 200 – 600 kg/ha (Experiments 1 and 2) and 200 – 1000 kg/ha (Experiment 3) enhanced significantly (P<0.001) the N uptake in egusi melon seeds compared with the control treatment (0 kg/ha), the exception being the 400 kg/ha treatment which severely decreased it in all the experiments (Table 2). Increased fertilizer rates also enhanced the K uptake by egusi melon seeds compared with the control treatment in all the experiments. The uptake of K, Ca, and Mg respectively by egusi melon seeds was generally similar in all the treatments of each experiment.

Table 1. Effects of 20:10:10 NPK fertilizer rates on uptake (kg/ha) in maize grain in intercrop with egusi melon

Parameters	Fertilizer rate (kg/ha)						
	0	200	400	600	800	1000	S.E
Experiment 1							
Nitrogen	15.4	16.2	17.7	19.4	-	-	0.50***
Phosphorus	2.9	3.0	3.2	3.3	-	-	0.08***
Potassium	2.7	2.2	2.5	2.6	-	-	0.04***
Calcium	0.12	0.15	0.16	0.16	-	-	0.04
Magnesium	0.4	1.7	1.8	1.7	-	-	0.04***
Experiment 2							
Nitrogen	15.8	16.6	19.7	19.7	-	-	0.52***
Phosphorus	3.0	3.2	3.1	3.4	-	-	0.03
Potassium	2.6	2.4	2.7	2.7	-	-	0.07
Calcium	0.14	0.16	0.18	0.17	-	-	0.04
Magnesium	0.6	1.8	1.9	1.8	-	-	0.04***
Experiment 3							
Nitrogen	18.7	17.4	17.8	17.4	16.5	16.1	0.75***
Phosphorus	2.8	3.0	3.2	3.1	3.4	3.6	0.13***
Potassium	2.7	2.5	2.1	2.4	2.7	2.6	0.06***
Calcium	0.15	0.17	0.18	0.16	0.15	0.14	0.03
Magnesium	1.8	1.7	1.8	1.8	1.7	1.9	0.02

****(P<0.001)*

Table 2. Effects of 20:10:10 NPK fertilizer rates on crop nutrient uptake (kg/ha) in egusi-melon seeds

Parameters	Fertilizer rate (kg/ha)						
	0	200	400	600	800	1000	S.E
Experiment 1							
Nitrogen	45.2	53.9	34.6	54.6	-	-	0.50***
Phosphorus	4.0	3.9	4.7	4.7	-	-	0.12***
Potassium	4.1	3.3	3.8	3.9	-	-	0.11***
Calcium	0.21	0.23	0.25	0.26	-	-	0.01***
Magnesium	2.1	2.5	2.7	2.5	-	-	0.06***
Experiment 2							
Nitrogen	45.7	54.5	35.2	55.4	-	-	0.48***
Phosphorus	3.9	4.1	4.6	4.8	-	-	0.12***
Potassium	4.2	3.6	4.0	4.1	-	-	0.11***
Calcium	0.22	0.23	0.26	0.26	-	-	0.01***
Magnesium	2.3	2.7	2.8	2.6	-	-	0.7
Experiment 3							
Nitrogen	47.4	52.7	38.3	54.5	51.8	49.6	0.78***
Phosphorus	4.2	4.4	4.4	4.6	4.8	4.9	0.18***
Potassium	3.9	4.1	3.8	4.1	4.0	3.6	0.17***
Calcium	0.20	0.23	0.24	0.22	0.24	0.25	0.03***
Magnesium	2.4	2.7	2.8	2.8	2.6	2.8	0.08***

****(P<0.001)*

3.3 Effects of Cropping Ratios of Maize and Egusi Melon on the Uptake (kg/ha) by Maize

N uptake in maize grains was highest in the sole maize crop compared with values obtained where maize was intercropped with egusi melon in various ratios, treatment differences being significant (P<0.05) in Experiments 2 and 3 ony (Table 3). In contrast, P uptake was significantly decreased (P<0.05) in grains of sole maize compared with those of intercropped maize in all the experiments. The respective K and Ca values in maize grains of the various maize and egusi-melon mixtures and the sole maize were similar in Experiments 1 and 2 while in Experiment 3, a cropping ratio of 3:1 significantly enhanced K content most while this was obtained for Ca with cropping ratios of 3:1, 1:2 and 1:0 (sole maize) respectively (Table 3). Mg uptake in maize grains was significantly influenced (P<0.05) by cropping ratios only in Experiments 1 and 3 and optimum values were obtained with either 3;1, 1:3, 1:0 or 1:2 cropping ratios.

3.4 Effects of Cropping Ratios of Maize and Egusi Melon on Uptake of N, P, K, Ca and Mg (kg/ha) in Egusi Melon

In all the experiments, significant differences (P<0.05) occurred for N uptake by egusi melon seeds owing to cropping ratios (Table 4). The highest value was obtained at a maize-egusi melon mixture of 3:1 although value for the sole egusi melon (0:01) in each experiment was comparable to the former mixture.

The P uptake by egusi melon seeds was highest in the sole crop in Experiment 2 while the values for their treatment in Experiments 1 and 3 respectively were comparable to those of cropping ratios 1:3 and 1:1 respectively. Cropping ratios of egusi melon and maize had no significant effect on the uptake of K, Ca and Mg respectively in egusi melon compared with the sole egusi melon crop (Table 4).

3.5 Effects of 20:10:10 NPK Fertilizer Rates on Percentage (%) of Oil, Protein, N, P, K, Ca and Mg Contents of Grains of Maize Intercropped with Egusi –melon

The trend of response of maize component of crop mixture to 20:10:10 NPK fertilizer rates was in many respects similar in the three experiments, particularly Experiments 1 and 2 (Table 5). Treatment differences were highly significant (P<0.001) for percentage oil, protein, N, P, and K in maize grains in each experiment. In both Experiments 1 and 2, the value for each of these quality parameters in maize grains

increased with increase in fertilizer rates up to the highest rate of 600 kg/ha, except for K where the highest value was obtained at 0 kg/ha. Optimum values were obtained for percentage protein and N respectively at the highest fertilizer rate of 1000 kg/ha. For percentage K content in grains of maize in the crop mixture, the highest value was obtained at 0 kg/ha compared to treatment with fertilizer application.

Table 3. Effects of cropping ratios of maize and egusi melon on crop nutrient uptake (kg/ha) in maize grains

Parameters	Cropping ratios						
	1:0	1:1	2:1	3:1	1:2	1:3	S.E
Experiment 1							
Nitrogen	33.6	31.8	26.5	27.9	26.6	32.2	1.84
Phosphorus	2.1	3.3	2.7	3.3	2.9	3.1	0.12*
Potassium	2.4	2.4	2.5	2.6	2.5	2.5	0.02
Calcium	0.17	0.13	0.14	0.13	0.15	0.15	0.04
Magnesium	1.6	1.4	1.6	1.7	1.6	1.7	0.07
Experiment 2							
Nitrogen	34.7	32.5	27.3	28.6	26.4	32.8	1.92*
Phosphorus	2.2	3.3	3.2	3.2	3.1	3.2	0.05*
Potassium	2.5	2.4	2.5	2.6	2.6	2.5	0.4*
Calcium	016	0.14	0.15	0.14	0.16	0.17	0.03
Magnesium	1.5	1.5	1.6	1.7	1.6	1.6	0.02
Experiment 3							
Nitrogen	31.7	30.6	25.2	28.7	27.2	30.1	3.05***
Phosphorus	2.3	3.1	2.5	3.5	3.1	3.3	0.12***
Potassium	26	27	26	35	31	33	0.11***
Calcium	0.16	0.14	0.15	0.16	0.16	0.15	0.01***
Magnesium	1.7	1.5	1.5	1.6	1.7	1.6	0.07***

***(P<0.05)*
****(P<0.001)*

Table 4. Effects of cropping ratios of maize and egusi melon on crop nutrient uptake (kg/ha) in egusi-melon seeds

Parameters	Cropping ratios						
	1:0	1:1	2:1	3:1	1:2	1:3	S.E
Experiment 1							
Nitrogen	58.8	56.1	48.6	49.8	47.9	59.4	2.00
Phosphorus	4.5	4.5	3.7	4.7	4.1	4.4	4.17
Potassium	3.7	3.7	3.8	4.0	3.8	3.9	0.03
Calcium	0.27	0.21	0.22	0.25	0.23	0.24	0.01*
Magnesium	2.5	2.4	2.4	2.6	2.4	2.6	0.02
Experiment 2							
Nitrogen	59.1	56.0	49.0	50.2	48.0	60.2	2.01*
Phosphorus	4.6	4.5	3.8	4.7	4.3	4.5	0.17*
Potassium	3.8	3.8	3.7	3.9	4.0	4.1	0.04
Calcium	0.25	0.22	0.21	0.26	0.25	0.25	0.03
Magnesium	2.4	2.4	2.4	2.5	2.3	2.4	0.02
Experiment 3							
Nitrogen	56.6	54.7	51.3	47.4	48.3	57.9	1.9***
Phosphorus	4.6	4.7	4.2	4.5	4.4	4.6	0.18***
Potassium	3.9	3.8	3.9	3.8	3.9	4.2	0.16***
Calcium	0.25	0.23	0.24	0.25	0.25	0.26	0.01***
Magnesium	2.6	2.4	2.4	2.3	2.4	2.5	0.01***

**(P<0.05)*
****(P<0.001)*

The percentage Ca and Mg in the grains of maize were not significantly affected by the various fertilizer rates in each treatment (Table 5).

3.6 Effects of 20:10:10 NPK Fertilizer Rates on Percentage (%) Oil, Protein, N, P, K, Ca and Mg of Egusi Melon Intercropped with Maize

Significant ($P<0.001$) treatment differences accrued in seeds of egusi melon intercropped with maize in each experiment for percentage oil, protein, N, P, K, and Mg (Experiments 1 and 2) respectively (Table 6). Except for percentage K, which was highest in the control treatment, the application of various rates of 20:10:10 NPK fertilizer enhanced those other quality components in egusi melon seeds. In Experiment 3, apart from percentage oil content in egusi melon seeds at the fertilizer rate of 800 kg/ha, which was significantly higher than that at either 400 or 600 kg/ha, the values obtained for percentage protein and N respectively at the fertilize rate of 1000 kg/ha were not significantly different from values obtained at either 400 or 600 kg/ha. The results from Experiment 3 on the quality components of egusi melon component of the crop mixture suggest that the additional benefit arising from increased fertilizer rate of 1000 kg/ha was minimal compared with lower rates of 400 and 600 kg/ha respectively. When the yield of egusi melon at the fertilizer rate of 600 kg/ha (Table 8) is taken into consideration vis-à-vis the value of the quality components in Experiment 3, the data suggest that a fertilizer rate of 600 kg/ha was optimum for both yield and quality of egusi melon intercropped with maize.

In each experiment the fertilizer rates had no effect on the percentage Ca and Mg (Experiment 3 only) (Table 6).

3.7 Effects of Cropping Ratios of Maize and Egusi Melon on the Percentage (%) Oil, Protein, N, P, K, Ca, and Mg Contents of Grains of Maize

Treatment differences for cropping ratios were significant ($P<0.01$) for the percentage oil, protein, N, P, and K respectively in maize grains in all the treatments (Table 7). In contrasts, cropping ratios had no significant effect on the respective content of Ca and Mg in maize grains.

The highest value for oil, protein and N contents in maize grain occurred in the sole maize crops in all the experiments while the least values for these quality parameters were obtained mostly in the 1:1 maize-egusi mixture.

The highest values for the P content of maize grains were mostly obtained in cropping ratios of 1:1 and 3:1 while the lowest value was obtained in the 2:1 ratio in the various experiments (Table 7).

The highest content of K in maize grains was obtained with ether cropping ratios of 3:1 or 2:1 maize-egusi melon while the lowest value occurred in the cropping ratio 1:1 in all the experiments.

3.8 Effects of Cropping Ratios of Maize and Egusi Melon on the Percentage (%) Oil, Protein, N, P, K, Ca and Mg Contents of Egusi Melon

The intercropping of egusi melon with maize enhanced significantly ($P<0.05$) the percentage oil, protein, N and P content of egusi melon seeds in the crop mixtures compared with the sole egusi melon crops in all the experiments (Table 8). The highest values for protein and N content of egusi melon were obtained in the 3:1 cropping ratio in all the experiments while those for P were mostly in the 1:3 cropping ratio.

Treatment differences were not significant for K, Ca and Mg under the various cropping ratios in all the experiments (Table 8).

3.9 Interaction Effects of Cropping Ratios of Maize Egusi - Melon and 20:10:10 NPK Fertilizer Rates on Crop Nutrient Uptake in Maize Grains

Significant interaction ($P<0.001$) between cropping ratios and 20:10:10 NPK fertilizer rates occurred only for N and K uptake by maize in Experiments 1, 2 and 3 (Table 9). The respective uptake of these two nutrients in maize grains were therefore, due to the combined effects of cropping ratio and the NPK fertilizer rates. In contrast, cropping ratios of maize and egusi melon and 20:10:10 NPK fertilizer rates acted independently to influence the respective uptake of P, Ca and Mg in maize grains as the interactions for them were not significant.

Table 5. Effects 20:10:10 NPK fertilizer rates on quality components (%) of grain of maize in intercrop with egusi –melon

Parameters	Fertilizer rates (kg/ha)						
	0	200	400	600	800	1000	S.E
Experiment 1							
Oil	3.9	4.0	4.4	4.5	-	-	0.12***
Protein	8.7	8.9	9.9	11.2	-	-	0.24***
Nitrogen	1.5	1.6	1.8	1.9	-	-	0.05***
Phosphorus	0.29	0.30	0.32	0.33	-	-	0.01***
Potassium	0.29	0.22	0.24	0.25	-	-	0.01***
Calcium	0.01	0.02	0.01	0.02	-	-	0.01
Magnesium	0.13	0.17	0.20	0.16	-	-	0.06
Experiment 2							
Oil	4.1	4.2	4.5	4.7	-	-	0.13***
Protein	8.9	9.1	9.8	10.9	-	-	0.24***
Nitrogen	1.5	1.7	1.7	1.9	-	-	0.05***
Phosphorus	0.31	0.32	0.33	0.34	-	-	0.01***
Potassium	0.30	0.24	0.25	0.25	-	-	0.01***
Calcium	0.02	0.02	0.2	0.2	-	-	0.00
Magnesium	0.14	0.18	0.20	0.17	-	-	0.05
Experiment 3							
Oil	4.0	4.2	4.5	4.4	4.6	4.5	0.19***
Protein	9.9	9.4	9.9	11.0	11.3	11.4	0.46***
Nitrogen	1.5	1.6	1.7	1.9	1.9	1.9	0.06***
Phosphorus	0.30	0.31	0.31	0.32	0.33	0.32	0.01***
Potassium	0.31	0.25	0.26	0.25	0.28	0.29	0.02***
Calcium	0.02	0.02	0.01	0.02	0.02	0.02	0.01
Magnesium	0.16	0.16	0.19	0.20	0.20	0.20	0.05

****(P<0.001)*

3.10 Interaction Effects of Cropping Ratios of Maize-Egusi Melon and 20:10:10 NPK Fertilizer Rates on Crop Nutrient Uptake in Egusi Melon Seeds

Significant interactions (P<0.001) of cropping ratios and 20:10:10 NPK fertilizer rates occurred on N and P uptake by egusi melon in Experiments 1, 2 and 3 (Table 10). The non significant interactions for K, Ca and Mg uptake by egusi melon seed indicated that the respective values obtained for the nutrients in egusi melon were due to individual effects of the cropping ratios and 20:10:10 NPK fertilizer rates respectively rather than these combined effects as obtained for N and P uptake.

3.11 Interactions Effects on Cropping Ratio of Maize-Egusi Melon and 20:10:10 NPK Fertilizer Rates of Maize Quality Components

Significant interactions (P<0.05 in Experiments 1 and 2, P<0.001 in Experiment 3) between cropping ratios and 20:10:10 NPK fertilizer rate occurred in the percentage oil, protein and N respectively but not in K, Ca and Mg (Table 11). These indicated that the values obtained for the oil, protein and N contents of maize grains were therefore due to the combined effects of cropping ratios and 20:10:10 NPK fertilizer rates. In contracts, the respective values obtained for percentage K, Ca an Mg in each experiment were due to the individual effects of cropping ratios and fertilizer rate.

3.12 Interaction Effects of Cropping Ratios of Maize-Egusi Melon and 20:10:10 NPK Fertilizer Rates on the Quality Components of Egusi-Melon

The trend of the interaction for egusi melon seed (Table 12) was as obtained for maize grains (Table 11) excepting the respective interactions for percentage oil, protein, N and P were significant at P<0.01 egusi melon.

Table 6. Effects 20:10:10 NPK fertilizer rates on quality components (%) of egusi melon in intercrop with maize

Parameters	Fertilizer rates (kg/ha)						
	0	200	400	600	800	1000	S.E
Experiment 1							
Oil	36.6	41.1	44.7	47.9	-	-	0.43***
Protein	29.1	31.0	31.4	31.3	-	-	0.31***
Nitrogen	5.10	5.40	5.46	5.46	-	-	0.14***
Phosphorus	0.40	0.39	0.47	0.46	-	-	0.01***
Potassium	0.41	0.33	0.37	0.38	-	-	0.01***
Calcium	0.02	0.02	0.02	0.02	-	-	0.00
Magnesium	0.20	0.25	0.30	0.26	-	-	0.01***
Experiment 2							
Oil	37.2	41.6	45.1	48.2	-	-	0.45***
Protein	30.0	31.4	31.9	31.9	-	-	0.33***
Nitrogen	5.15	5.35	5.50	5.48	-	-	0.15***
Phosphorus	0.41	0.42	0.48	0.46	-	-	0.02***
Potassium	0.41	0.35	0.38	0.40	-	-	0.02***
Calcium	0.02	0.01	0.2	0.2	-	-	0.00
Magnesium	0.22	0.26	0.29	0.29	-	-	0.01***
Experiment 3							
Oil	36.8	42.1	44.8	47.4	48.1	47.9	0.67***
Protein	29.6	32.1	32.5	31.7	31.4	31.6	0.48***
Nitrogen	5.14	5.58	5.65	5.51	5.63	5.67	0.21***
Phosphorus	0.42	0.40	0.48	0.44	0.47	0.46	0.03***
Potassium	0.43	0.36	0.38	0.39	0.40	0.41	0.03***
Calcium	0.02	0.02	0.01	0.02	0.02	0.02	0.01
Magnesium	0.22	0.26	0.32	0.28	0.29	0.28	0.09

****(P<0.001)*

4. DISCUSSION

4.1 Quality Components of Maize Grains and Egusi - melon Seeds

Intercropping maize with egusi melon significantly (P<0.01) reduced the % oil, protein, and N respectively in grains of the maize component of the crop mixtures compared with sole maize in the three experiments. This is a disadvantage for the crop mixture in terms of these three quality parameters. The significantly (P<0.01) higher oil, protein and N contents of maize grains, under sole than in the various cropping ratios, may be attributed to maximum utilization of nutrients and other growth resources available to the sole maize [8-10]. For % P, K, Ca and Mg, the values obtained for sole maize and maize components of the crop mixtures were similar with the values for P being significant (P<0.01) in the three experiments and K only in Experiments 1 and 2. Thus no disadvantage has arisen for these four quality components of maize grain from intercropping maize with egusi melon.

Application of fertilizer enhanced significantly (P<0.001) the quality of percentage oil, protein, N and P in grains of maize in the crop mixture with increase in the fertilizer rates, from 400 – 600 kg/ha in Experiments 1 and 2, 600 – 1000 kg/ha in Experiment 3. This tends to support earlier report that oversupplied N, where it fails to increase yield, protein content of the crop may be enhanced [11]. Percentage K was highest with no fertilizer in all the experiments.

The quality of oil, protein, N and K in egusi melon seeds was enhanced in the egusi melon component in intercrops with maize compared with sole egusi melon. This is the opposite of what happened in the maize components in the mixture maize-egusi melon mixture. Thus, the quality of seeds of egusi melon grown in mixture with maize improved for these four quality parameters compared with the sole egusi melon crop. Two aspects of economic yield of egusi melon have earlier been identified to be the seed and oil contents [7]. The observed relatively high content of parameters, particularly oil and protein of the seeds of egusi melon grown in mixtures with maize compared with those of the sole egusi

melon crop in this study suggests that the value of the crop in intercrop with maize rests more on the resultant quality components of the seeds rather than seed yield obtained per hectare.

The high contents of oil and protein in the seeds of egusi melon may canvass the crop to be sold on the basis of its protein and oil contents rather than seed weight as [12,13]; and others have advocated for soybean. For P, Ca and Mg, similar values were obtained in seeds of egusi melon grown in either sole crop or mixture with maize.

Increased fertilizer rates enhanced the quality of intercropped egusi melon as shown by the values for % oil, protein, N, P and Mg, excepting for % oil content, the additional improvement derived from fertilizer rates higher than 600 kg/ha in Experiment 3 was minimal and insignificant. The 20:10:10 NPK fertilizer applied at the rate of 600 kg/ha is best for both the yield and quality of seeds of egusi melon intercropped with maize. In each experiment, the fertilizer rates had no effect on the percentage Ca and mg (Experiment 3 only). The quality (% oil, Protein, N, P and Mg) of maize and egusi melon enhanced in this study may place the value of these crop in future on their qualities rather than quantity [14-16].

4.2 Crop Nutrient Uptake by Maize Grains and Egusi - melon Seeds

The cropping ratios mostly influenced the nutrient uptake by maize grains, while N uptake was highest in sole maize, an indication of greater competition for N with the presence of egusi melon in the mixture, in the three experiments, P content was lowest in sole maize, an indication that intercropping with egusi melon enhanced the capacity of maize component to favourably compete for P, compared with when maize is grown as a sole crop. These results agree withthose of [17] in which maize grain uptake of NPK fertilizer was enhanced by egusi melon due to less competition for growth resources by the associated egusi melon, and also of [18] that high soil N uptake enhanced relative competitiveness of maize. The result of these experiments confirm previous studies which have established that crop mixtures take up higher

Table 7. Effects of cropping ratios of maize and egusi- melon on quality components (%) of maize in intercrop with egusi-melon

Parameters	Cropping ratios						
	1:0	1:1	2:1	3:1	1:2	1:3	S.E
Experiment 1							
Oil	4.5	4.0	3.7	4.1	4.1	4.5	0.16**
Protein	11.7	7.1	8.3	10.5	10.4	11.2	0.38**
Nitrogen	2.0	1.2	1.4	1.8	1.8	1.9	0.07**
Phosphorus	0.31	0.33	0.27	0.33	0.29	0.31	0.01**
Potassium	0.24	0.24	0.25	0.26	0.24	0.25	0.01**
Calcium	0.02	0.01	0.01	0.01	0.01	0.01	0.01
Magnesium	0.16	0.16	0.16	0.17	0.16	0.17	0.02
Experiment 2							
Oil	4.4	4.1	3.9	4.2	4.3	4.4	0.16**
Protein	10.9	8.3	9.2	10.7	10.9	11.7	0.40**
Nitrogen	2.0	1.3	1.5	1.9	1.8	2.0	0.07**
Phosphorus	0.30	0.31	0.28	0.31	0.30	0.32	0.01**
Potassium	0.25	0.24	0.25	0.27	0.25	0.25	0.01**
Calcium	0.01	0.02	0.01	0.01	0.01	0.02	0.01
Magnesium	0.17	0.16	0.17	0.17	0.16	0.18	0.02
Experiment 3							
Oil	4.6	4.2	4.1	4.3	4.1	4.3	0.16***
Protein	11.9	8.3	8.8	11.3	10.6	10.9	0.40***
Nitrogen	2.0	1.4	1.5	1.9	1.8	1.9	0.40***
Phosphorus	0.32	0.34	0.30	0.32	0.31	0.33	0.01***
Potassium	0.25	0.24	0.26	0.25	0.25	0.26	0.01***
Calcium	0.02	0.02	0.01	0.01	0.02	0.02	0.01
Magnesium	0.17	0.16	0.17	0.17	0.16	0.17	0.02

***(P<0.01)*
****(P<0.001)*

amounts of nutrients per unit land area than sole crops [19-22]. Similarly, nutrients (N) uptake by maize in association with cassava was reported higher than where the maize was planted sole [23]; [20] as was the case in this trial.

For the other nutrient elements, that is, K, Ca and Mg, their content in maize grains was enhanced due to intercropping with egusi melon as evidenced particularly in Experiment 3. The reason for the enhancement of K, Ca and Mg, in maize grains due to intercropping with egusi melon may have arisen because of less competitiveness by egusi melon with maize for the same nutrients in this study. This was also evident in similar trial with maize by [18].

The sole cropping of egusi melon generally enhanced N, P, K, Ca and Mg uptake compared with where the egusi melon was intercropped with maize, excepting in its 3:1 ratio with maize where the values of the quality parameters were generally higher than the value of the sole crop. This may have been due to high component of the egusi melon compared to the low component of maize in the mixture.

Table 8. Effects of cropping ratios of maize and egusi - melon on quality component (%) of egusi -melon in intercrop with maize

Parameters	Fertilizer rates (kg/ha)						
	0:1	1:1	1:2	1:3	2:1	3:1	S.E
Experiment 1							
Oil	43.4	40.4	43.3	42.5	43.1	43.4	0.62*
Protein	33.8	32.3	27.9	28.5	27.5	34.1	0.48***
Nitrogen	5.9	5.6	4.9	5.0	4.8	5.9	0.20***
Phosphorus	0.45	0.46	0.37	0.47	0.41	0.44	0.02***
Potassium	0.36	0.36	0.37	0.39	0.38	0.38	0.02
Calcium	0.02	0.02	0.02	0.02	0.02	0.03	0.01
Magnesium	0.24	0.24	0.25	0.25	0.24	0.25	0.02
Experiment 2							
Oil	42.8	40.7	43.6	43.0	43.4	43.2	0.63***
Protein	31.6	31.9	29.3	28.6	27.5	34.0	0.46***
Nitrogen	5.9	5.8	5.0	4.8	4.8	6.0	0.20***
Phosphorus	0.47	0.50	0.41	0.48	0.43	0.46	0.02***
Potassium	0.37	0.36	0.38	0.38	0.37	0.36	0.02
Calcium	0.02	0.02	0.2	0.03	0.02	0.03	0.01
Magnesium	0.25	0.24	0.25	0.24	**0.25**	**0.25**	0.02
Experiment 3							
Oil	43.6	40.6	43.4	43.1	43.7	43.5	0.63***
Protein	34.1	33.6	29.4	29.0	28.8	34.4	0.47***
Nitrogen	5.9	5.8	5.1	5.0	5.0	5.9	0.20***
Phosphorus	0.48	0.49	0.43	0.50	0.47	0.47	0.02***
Potassium	0.38	0.37	0.37	0.38	0.36	0.37	0.02
Calcium	0.02	0.02	0.02	0.02	0.03	0.02	0.01
Magnesium	0.25	0.25	0.24	0.25	0.24	0.25	0.01

(P<0.05)

****(P<0.001)*

Table 9. Interaction effects of cropping ratios of maize-egusi melon and 20:10:10 NPK fertilizer rates on crop nutrient uptake (kg/ha) in maize grains

Parameters	Experiment	Experiment 2	Experiment 3
Nitrogen	0.23***	0.29***	0.33***
Phosphorus	0.25	0.27	0.28
Potassium	0.17***	0.21***	0.27***
Calcium	0.07	0.08	0.06
Magnesium	0.10	0.09	0.12

****(P<0.001)*

Table 10. Interaction effects of cropping ratios of maize-egusi melon and 20:10:10 NPK fertilizer rates on crop nutrient uptake in egusi-melon seeds

Parameters	Experiment	Experiment 2	Experiment 3
Nitrogen	0.42***	9.67***	0.93***
Phosphorus	0.08***	0.14***	0.12***
Potassium	0.12	0.15	0.13
Calcium	0.10	0.08	0.11
Magnesium	0.08	0.09	0.12

****(P<0.001)*

Table 11. Interaction effects of cropping ratios of maize-egusi melon and 20:10:10 NPK fertilizer rates on quality component (%) of maize

Parameters	Experiment	Experiment 2	Experiment 3
Oil	0.30*	0.29*	0.35***
Protein	0.63*	0.70*	0.01***
Nitrogen	0.14*	0.15*	0.18***
Phosphorus	0.03*	0.05	0.06
Potassium	0.02	0.03	0.03
Calcium	0.03	0.04	0.03
Magnesium	0.06	0.05	0.07

**(P<0.05)*
****(P<0.001)*

Table 12. Interaction effects of cropping ratios of maize-egusi melon and 20:10:10 NPK fertilizer rates on the quality components (%) of egusi melon

Parameters	Experiment	Experiment 2	Experiment 3
Oil	1.12***	1.14***	1.17***
Protein	0.84**	0.86**	1.01***
Nitrogen	0.37**	0.39**	0.48***
Phosphorus	0.04**	0.05**	0.08***
Potassium	0.03	0.04	0.03
Calcium	0.02	0.03	0.03
Magnesium	0.05	0.04	0.06

***(P<0.01)*
****(P<0.001)*

Increased fertilizer rates from 0 – 600 kg/ha enhanced N and Mg uptake respectively in maize grains intercropped with egusi melon in Experiment 1 and 2, while the reverse was the case in Experiment 3 with significant (P<0.001) reduction in N uptake in maize grains excepting P uptake in maize grains which was generally enhanced by higher fertilizer rates in all the experiments. The reason for the enhanced N uptake with increase in N rate could be due to the fact that maize production in Nigeria is limited by N deficiency more than any other nutrient element [3]. For the other nutrient elements, K and Ca, their contents in maize grains were generally similar excepting Mg in Experiment 3 only.

The trend was different in nutrient uptake by egusi melon with respect to applied fertilizer rates. Application of 20:10:10 NPK fertilizer from 200 to 600 kg/ha enhanced N uptake by egusi melon compared with the control, excepting the 400 kg/ha rate of the fertilizer which decreased N uptake in all the experiments. This could be explained by failure of the crop to respond positively to the fertilizer applied at that rate or as a result of other soil factors which were not investigated by these experiments. Similar observation was made on egusi melon by [24] and [18] on maize respectively to the effect that N uptake was enhanced when 90 kg.

N/ha was applied to these two crops in respective study, significant (P<0.001) enhancement of egusi melon uptake of P, K, Ca and Mg was obtained in the three experiments. The reason advanced for this was due to the

competitive ability of the maize which improved with increment in N applied.

5. CONCLUSION

Intercropping maize with egusi melon significantly ($P<0.01$) reduced the % oil, protein and N of maize relative to its sole while applied NPK fertilizer with increasing rates (400 to 600 kg/ha) enhanced these quality components of maize in mixture with egusi melon. Application of NPK 20:10:10 fertilizer at 600 kg/ha significantly enhanced the % oil, protein, N and P contents of maize grains and seeds of egusi melon. The less competitive ability of egusi melon with maize for the applied fertilizer indicated left over of same in the soil for further cultivation. The applied fertilizer had no effect on Ca and Mg.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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