FINE-TUNING SPECIALTY FERTILIZATION STRATEGIES TO LOCAL WHEAT PRODUCTION THROUGH ON-FARM EXPERIMENTATION IN NIGERIA #9536

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ABSTRACT

Wheat specialty fertilizer validation trial was conducted in 8 Local Government Areas (LGAs) of Kano State, Nigeria on farmers field. The specialty fertilizer validation project is implemented to improve the productivity and profitability of small-scale wheat smallholder farmers. Four treatments - absolute control (AC), local control (LC), OCP1 and OCP2 were replicated four times in a RCBD on a plot of 25m^2. The AC was based on the indigenous nutrient supply from the soil (no application of fertilizer); the LC was the generic recommendation of (120:40:40 kg/ha using NPK 15:15:15); OCP 1 was a specialized formulation for wheat with N, P, K, Ca, Mg and S; and OCP 2 was another specialized formulation with micronutrients (B, Zn and Mo) formulated from soil mapping projects from 300 farmer's fields. The test crop was Norman Borlaug breeder's seed. In each LGA, apart from the farmers visual observation of yield during the brown field day, a 1m-by-1m quadrant was used to harvest and estimate yield, while a portion of the grain and stover were collected for nutrient uptake analysis. The highest grain yield (3787 kg/ha) was observed with the OCP2 fertilizer formulation treatment; a similar trend was observed when the data was pooled across LGAs. The result of total above ground biomass (kg/ha) showed that OCP1 and OCP2 gave the highest biomass of 10,026 and 10,092 respectively, while the least biomass was observed with the absolute control plot. Application of N, P, K with other macro and micronutrients has good profit potential in Nigeria since a reduced amount of the N (100 kg) less than the generic recommendation (120 kg N) gives higher yield due to the introduction of other nutrients (Mg, S, Zn, B and Mo). Additional information is needed to determine which deficiencies of Mg, S, Zn, B and Mo are most important. Wheat grain yield responses to applied nutrients tended to be greater in soils with medium to high clay content. Apart from soil nutrient deficiency, the synergistic effect of some macro and micronutrients with N, P and K will greatly influence yield of wheat.

Keywords: Wheat, specialty fertilizer, on-farm experimentation, yield, OCP

INTRODUCTION

Wheat (Triticum aestivum L.) is an important rainfed crop of Nigeria and Sub-Saharan Africa with both large and small-scale production (Abubakar et al 2018, Nziguheba et al. 2016) but production is far less than the regional demand. Mean yields are low, often with inadequate nutrient availability as a constraint (Tittonell and Giller 2013), but numerous other biotic, abiotic, and management constraints are also important. Wheat is a crop of major interest in Nigeria as it is the main component of bread and other wheat-based products such as cakes, biscuits, macaroni, spaghetti, pasta, etc. In Northern Nigeria, because of high temperature, the local climatic conditions have not been favorable for optimum growth and yield of wheat. Accordingly, the climatic potential for wheat production generally decreases equator-wards due to consistently high temperature and humidity (Oche, 1998). Thus, production is presently restricted to areas between latitudes 10-140N (covering the Sudan and Sahel savanna zones), during the cold harmattan period between the months of November and February, under irrigation (Abbas, 1988). According to Anonymous (2006) the increasing consumption and demand for wheat in Nigeria was largely due to increase and expansion in bread and pasta industries, and for the manufacture of crackers, noodles etc. Presently, domestic wheat demand in the country is far more than local production; consequently 90-95% of wheat consumed is imported from the United States of America. For example, the country imported 4.3 million tons of wheat in 2007 as against 3.8 million tons in 2006.

Increasing wheat production in Nigeria requires prior investigation of the crop's requirements. In places with relatively low technology as obtainable in developing countries, a naturally favorable environment is paramount for optimum production. Fertilizer is commonly used for wheat production, but rates of application are low and the recommendations are generalized and inadequately based on field research results. Fertilizer recommendations are not sufficiently profit oriented and do not consider farmers' financial ability for fertilizer use (Rware et al. 2016). Farmers who face severe financial constraints need high returns on their investment at low risk.

(CIMMYT 1988, Miko et al 2006) and often find better opportunities to use their limited monetary resources than for fertilizer application to wheat at the recommended rates (Jansen et al. 2013). Farmers' fertilizer use decisions need to aim for maximization of net return to nutrient application (Wortmann and Kaizzi 2016). Much research has been done globally on wheat response to applied nutrients, but this has little relevance in the dry lands of Nigeria where numerous unmitigated constraints result in a median grain yield of less than 2 tons ha^{-1}

Fertilizer application can often be profitable for wheat production in northern Nigeria, but responses vary. Optimization of fertilizer use for profit maximization requires robust information of the nature of wheat response to different nutrients in different recommendation domains. The objectives of this research were to: quantify the yield response of wheat to N, P and K; test 2 new fertilizer formulations for wheat and to diagnose the importance of secondary and micronutrient on wheat productivity.

MATERIALS AND METHODS

Study area

The study areas are within the Sudan savanna agro ecological zone. The experiments were conducted on farmer's fields across 8 local government areas of Kano state, the communities are Bagwai, Bunkure, Garun Malam Dambatta, Garko, Kura, Takai Warawa and the research farm of Bayero University Kano (BUK). These fields represent the major wheat producing communities of Kano state.

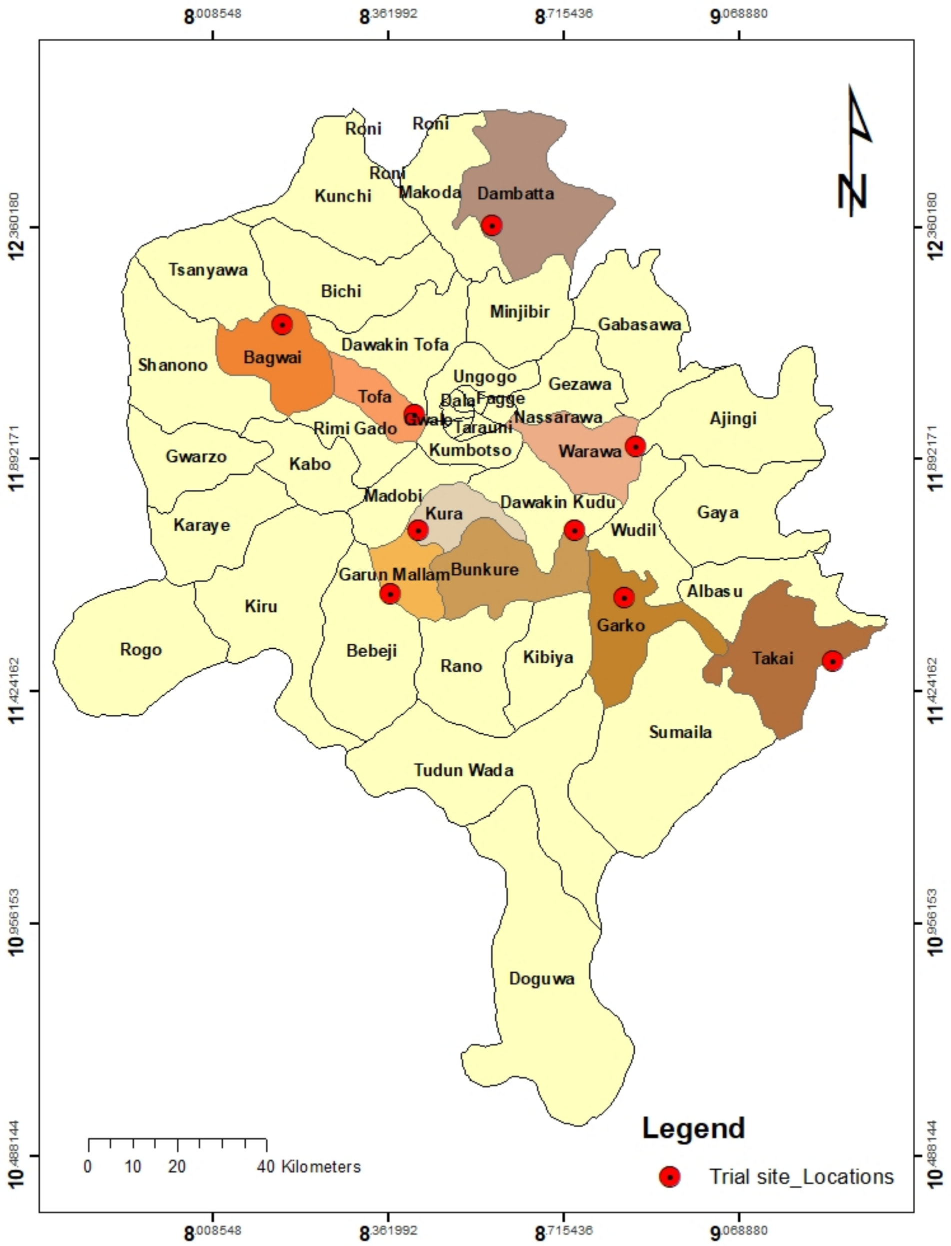

Fig 1. Map of Kano State showing the study area.

Agronomic practices

A basin of 5m x5m was prepared for the 4 treatments and replicated 4 times. The seeds are drilled within this basin for ease of irrigation. Wheat is sown in a row spacing of 22.5 cm and a planting depth of between 5 and 6 cm for good germination and density. The field trials were managed by the farmers at various LGAs based on the normal farmers' practices including irrigation.

Treatments and experimental design

The treatments were arranged in a Randomized complete Block Design (RCBD) replicated across communities. There were four treatments as follows:

i. Absolute Control (AC)- no fertilizer application

ii. Local Control (LC) – Generic recommendation of N, P and K
iii. OCP 1- Specialized OCP wheat formula 1 (N, P, K, Mg and S)
iv. OCP 2 - Specialized formula 2 (N, P, K, Mg, S, Zn, B and Mo

The AC was based on the indigenous nutrient supply from the soil (that is no application of fertilizer). The LC was based on the generic recommendation of (120:40:40 kg/ha using NPK 15:15:15), while the OCP 1 was based on the specialized formulation for wheat with magnesium (Mg) and sulphur (S) applies at the rate of 100 kg N 100 kg P_2O_5, 50 kg K_2O, 8 kg Mg, 5 kg S per hectare. OCP 2 was another specialized formulation for wheat with magnesium (Mg), sulphur (S) and micronutrients (B, Zn and Mo) applied at the rate of 100 kg N 100 kg P_2O_5, 50 kg K_2O, 8 kg Mg, 5 kg S, 3 kg Zn, 1 kg B and 1 kg Mo per hectare.

The wheat variety used was Norman Borlaug breeder's seed sourced from LCRI. Fertilizer was applied once during sowing for OCP 1 and OCP 2. Top dressing with urea was only done for the local control plot at 24 days after sowing. All agronomic data collection were done by the field officer. The wheat specialty fertilizer formulations were developed based on spatial soil analysis of the entire wheat belt of Kano state. Recommendations were generated based on wheat nutrient demand and amount of plant available nutrient in the soil.

Data analysis

Data Generated were subjected to Analysis of variance to see the effect of fertilizer treatment and communities alongside their interactions. Means were separated using Tukey HSD on GenStat version 17 software. The software JMP was used to create bar charts.

RESULTS AND DISCUSSION

It was observed that the soils in Dambatta, Bagwai, Garun Mallam, Kura and Warawa trial sites are having high sand content of more than 50 % and low clay content of less than 16 % (Table 1). The particle size distribution of soils in BUK, Bunkure, Garko and Takai are best for wheat production, this is because wheat does better in a medium clay soil as reported by Athanase et al (2018). It was observed that the mean pH in water value across the study sites were categorized as slighlty acidic (NSPFS, 2005). There was a very low variability in pH across the farms. This pH values are within the acceptable range for availability of most of the essential nutrients needed by majority of plants. The average total nitrogen across the study area were categorized as low (NSPFS 2005). The low nitrogen content of the soils was because of the sandy nature of the soil. The mean organic carbon across the farms was categorized as low (NSPFS 2005). The available phosphorus across the farms fell under the low fertility class according to NSPFS (2005). The exchangeable potassium across the farms is rated as medium according to Esu (1991). The exchangeable calcium, magnesium and sodium across the farm are shown on Table 1. Calcium and sodium were rated as low, while magnesium was also rated as low according to Esu (1991). The average effective cation exchange capacity of the farms was categorized as low (Esu, 1991). The low effective cation exchange capacity implied low nutrient holding capacity of the soil which necessitates proper nutrient management in terms of fertilizer application timing to coincide with active period of the wheat nutrient demand.

Grain yield of wheat varied significantly ($p<0.001$) across the different fertilizer treatments and across communities (Table 2). Among the fertilizer treatments, OCP1, OCP2 and local control (LC) produce significantly higher yields than the absolute control (AC). Although not statistically different, OCP2 gave higher grain yield than both OCP1 and LC. The difference in yield among the OCP fertilizer formulations may be because of addition of micronutrients (Zn, B and Mo), a similar observation was made by Athanase et al 2018 on wheat and Bello et al (2019) on maize. Among the farming communities, the highest grain yield (3984 kg/ha) was observed in Garko followed by Takai (3700), this high response may not be unconnected to the low sand and medium clay content of the two communities as shown on Table 1, a similar observation was made by Abubakar et al (2000). The effect of total above ground biomass as affected by fertilizer treatment is shown on Table 2, it will be observed that the highest total biomass OCP2 gave the highest total biomass (10,092 kg/ha) which is statistically at par with OCP1 and LC, a similar trend with grain yield. Among communities, Takai gave the highest above aground biomass (12,247 kh/ha) while the lowest was observed in Kura. For both grain yield and total biomass, there is a similar trend of yield increase with the introduction of a new macro or micronutrient from LC through OCP1 and OCP2. With the aforementioned trend, the probability of response to an added nutrient may be increasing in the region, likely to gradual limiting nutrient depletion and mitigation of other constraints to allow higher yields and greater responses to applied nutrients (Zingore 2011, Wortmann et al. 2017). The effect of fertilizer formulation on plant height at maturity and number of spikelet at maturity is shown on Table 3 with a similar trend like yield and biomass. Number of tillers per plant (Table 3), days to emergence (Fig. 4) and days to maturity were not statistically different among the fertilizer formulations, a similar observation was made by Miko et al 2006.

Table 1. Physical and Chemical properties of Soils across the study area.

Soil Parameter	BUK	Bagwai	Bunkure	Danbatta	Garko	Garun Malam	Kura	Takai	Warawa
Sand (%)	40.04	73.21	28.84	67.83	44.94	64.37	75.28	34.57	52.35
Silt (%)	36.39	15.26	26.99	16.94	17.56	23.85	15.52	34.26	37.99
Clay (%)	23.57	11.53	44.17	15.23	37.50	11.78	9.20	31.17	9.66
pH (1:1)	5.92	5.99	5.99	6.00	5.86	6.12	6.44	6.14	6.12
EC Us/cm	95.85	132.95	137.65	135.36	117.84	111.79	130.38	82.52	109.49
O.C (%)	0.59	0.65	0.55	0.59	0.76	0.58	0.58	0.64	0.59
N (%)	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06
P (mg/kg)	3.48	5.51	5.87	3.60	4.62	5.79	4.60	4.58	6.59
Ca (cmol/kg)	1.99	2.29	2.23	2.58	2.22	2.19	2.02	2.87	2.37
Mg (cmol/kg)	0.65	0.77	0.68	0.71	0.69	0.64	0.77	0.67	0.85
K (cmol/kg)	0.17	0.23	0.23	0.19	0.20	0.20	0.23	0.22	0.17
Na (cmol/kg)	0.08	0.08	0.10	0.09	0.09	0.09	0.08	0.10	0.09
EA (cmol/kg)	0.12	0.33	0.27	0.25	0.29	0.20	0.16	0.17	0.40
ECEC (cmol/kg)	3.00	3.70	3.44	3.80	3.40	3.27	3.19	4.02	3.85
Zn (mg/kg)	14.09	11.48	7.13	7.24	9.75	8.25	15.15	7.17	11.94
Cu (mg/kg)	2.01	2.05	2.27	2.60	2.35	2.21	2.56	2.11	1.82
Mn (mg/kg)	29.17	21.11	19.29	19.70	20.26	19.03	28.26	18.72	17.87
Fe (mg/kg)	176.05	170.90	193.81	167.71	180.66	230.42	187.39	218.87	195.28
S (mg/kg)	9.04	10.41	8.44	9.48	10.28	9.63	10.58	8.96	9.53
B (mg/kg)	0.63	0.67	0.76	0.59	0.70	0.71	0.72	0.70	0.58

Table 2. Effect of Fertilizer formulation and location on grain yield and total biomass of wheat in Kano.

Parameter	Grain Yield kg ha^{-1}	Total Biomass kg ha^{-1}
Fertilizer Formulation		
Absolute Control (AC)	1608b	4712b
Local Control (LC)	3442a	9430a
OCP 1	3462a	10026a
OCP 2	3787a	10092a
SED	175.1	552.6
F Prob.	<0.001	<0.001
Community		
Bagwai	2589c	6159c
BUK	3172bc	7834bc
Bunkure	3841ab	9949ab
Danbatta	3562ab	10228ab
Garko	3984a	10388ab
Garun Malam	2709c	8334bc
Kura	1103d	3347d
Takai	3700ab	12247a
Warawa	3012bc	8600bc
SED	262.7	828.9
F. Prob.	<0.001	<0.001
Interaction		
Fert Formulation x Community	NS	NS
SED	525.4	1657.8
F prob.	0.245	0.524

Table 3. Effect of fertilizer formulation and location on plant height, number of tillers and number of spikelet of wheat in Kano.

Parameter	Plant Height at Maturity cm	Number of Tillers m^{-2}	Number of Spikelet m^{-2}
Fertilizer Formulation			
Absolute Control (AC)	61.42b	377	315.1b
Local Control (LC)	83.58a	370	342.8ab
OCP 1	86.81a	487	367.6a
OCP 2	85.97a	389	364.9a
SED	1.661	71.6	18.56
F Prob.	<0.001	0.327	0.019
Community			
Bagwai	84.62ab	351	315.8bc
BUK	77.88b	381	354.2ab
Bunkure	85.56ab	425	391.4ab
Danbatta	84.94ab	439	405.1a
Garko	82.88ab	471	353.6ab
Garun Malam	69.12c	578	330.9ab
Kura	57.88c	310	241.1c
Takai	87.19a	371	341.4ab
Warawa	84.94ab	426	395.1ab
SED	2.492	107.4	27.85
F. Prob.	<0.001	0.427	<0.001
Interaction			
Fert Formulation x Community	NS	NS	NS
SED	4.984	214.7	55.69
F prob.	0.096	0.310	0.755

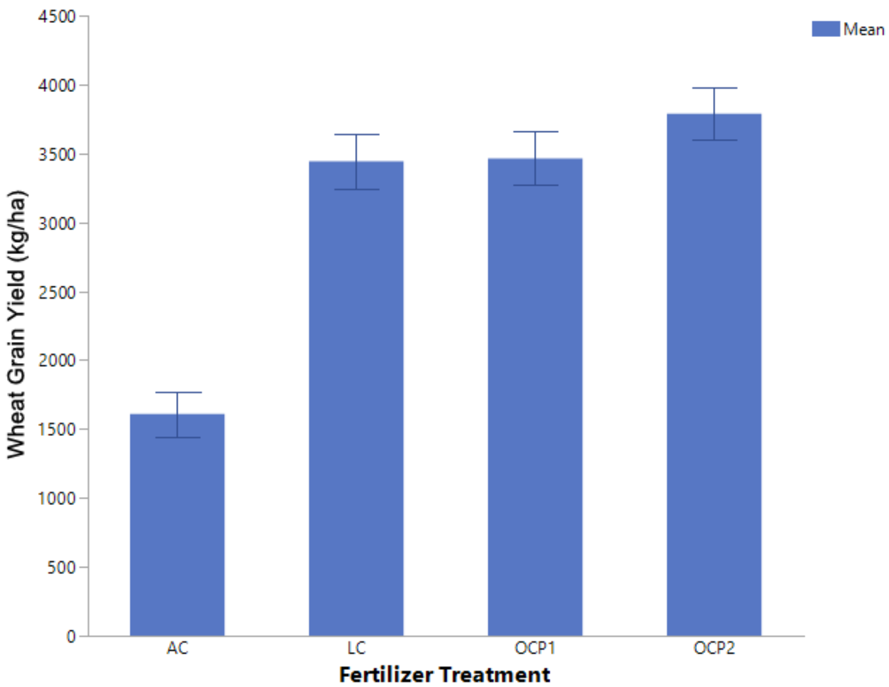

Fig. 2. Effect of Different Fertilizer Formulation on Wheat Grain Yield.

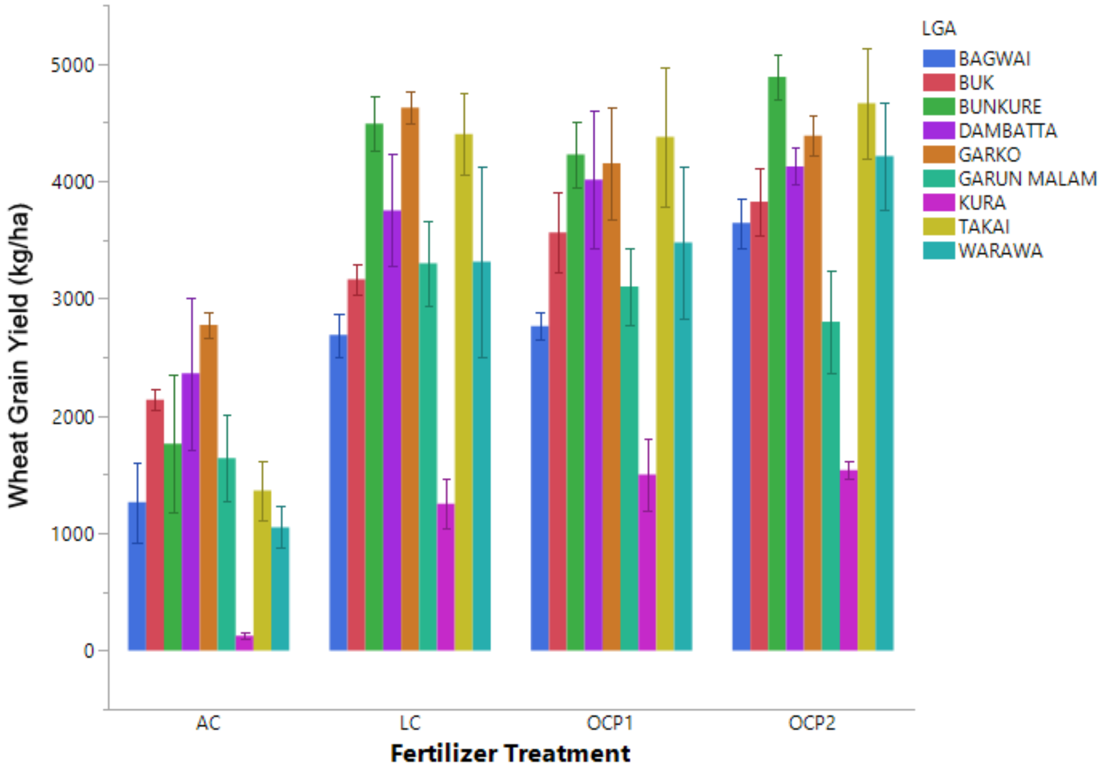

Fig. 3. Effect of Different Fertilizer Formulation on Wheat Grain Yield Across the different Local Government Areas.

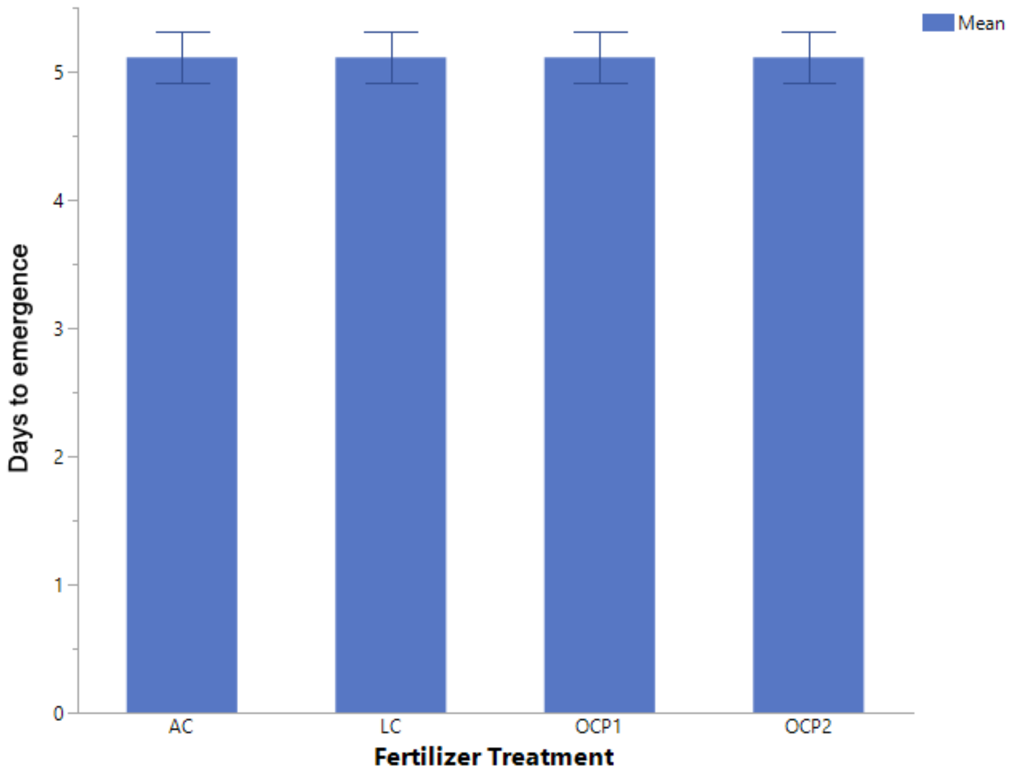

Fig. 4. Effect of Different Fertilizer Formulation on Number of Days to Emergence.

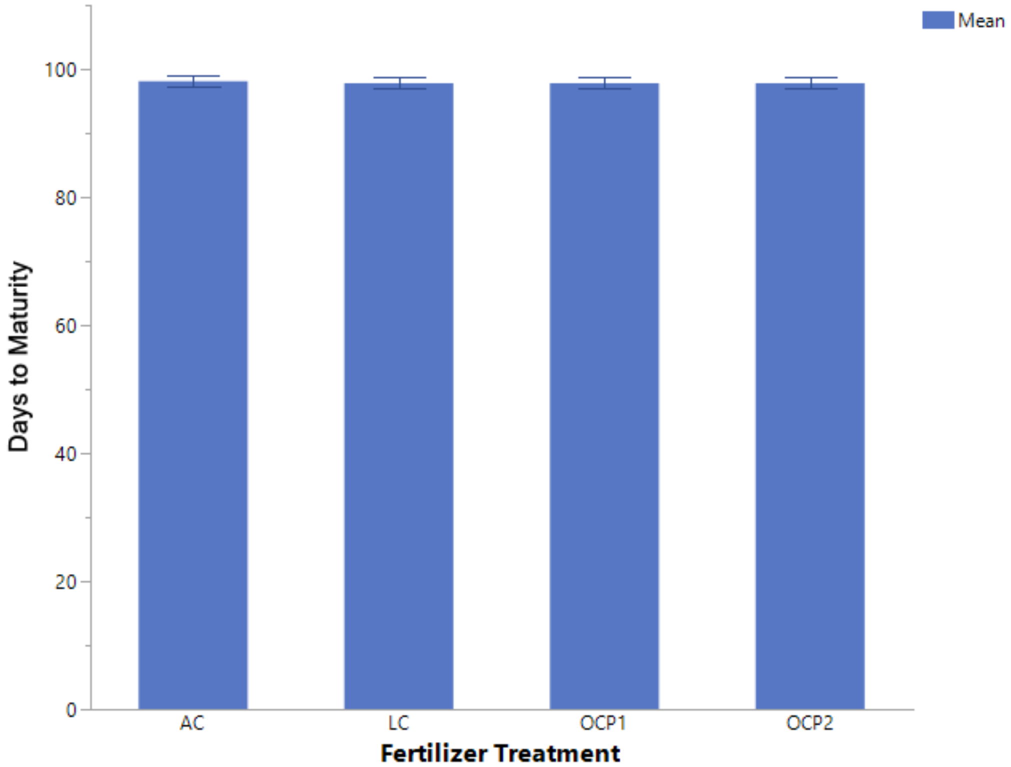

Fig. 5. Effect of Different Fertilizer Formulation on Number of days to maturity.

CONCLUSION AND RECOMMENDATIONS

The wheat grain yield due to indigenous nutrient supply (about 1600 kg/ha) is an indication of some amount of nutrients in soils of the Nigerian dry Savanna. However, balanced N, P K fertilizer application is likely to be highly profitable for wheat production in the Savanna soils of Nigeria if the crop yield is not much constrained by factors other than nutrient deficiency. If typical yields are about 1600 kg with no fertilizer applied and the yield doubles with addition of N, P and K alone (Fig. 2), a further addition of Mg and S and with another addition of micronutrients (Zn, B and Mo), the probability of profitable yield response to a more balance application of this nutrients is high. Application of N, P, K with other macro and micronutrients has good profit potential in Nigeria since a reduced amount of the N (100kg) less than the generic recommendation (120kg N) gives higher yield due to the introduction of other nutrients (Mg, S, Zn, B and Mo).

Additional information is needed to determine which deficiencies of Mg, S, Zn, B and Mo are most important. Wheat grain yield responses to applied nutrients tended to be greater in soils with medium to high clay content. Apart from soil nutrient deficiency, the synergistic effect of some macro and micronutrients with N, P and K will greatly influence yield of wheat.

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