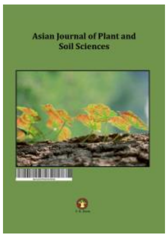

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Efficacy of Various Combinations of NPK Fertilizer Sources on Economics and Yield Quality of Spring Wheat (*Triticum aestivum* L.) under Rainfed Condition on Obudu Highlands, Cross River State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Optimum NPK fertilization from the right sources is the most important production factors for higher grain yield of wheat. Study to investigate the effect of NPK fertilizer sources on grain yield, gluten contents and economic benefit of rainfed Wheat production at two different locations (Obudu Cattle Ranch East and West). The field experiment consists of twelve (12) treatment combinations from

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three (3) different sources of NPK fertilizers (100 kg N ha$^{-1,}$ 40 kg P ha^{-1} as SSP, T_4, 60 kg K ha$^{-1,}$N + P (100:40) kg ha^{-1}, N + k (100:60) kg ha$^{-1,}$ K + P (60:40) kg ha^{-1} , NPK (50:20:30) kg ha-^{1}, NPK (75:30:45) kg h, NPK (100:40:60) kg ha-^{1}, NPK (125: 50:75) kg ha-^{1}, NPK (150:60:90) kg ha-^{1} ,NPK (175:70:105) kg ha-^{1})and one control (without any fertilizer application). The field experiment was laid down in a randomized complete block design with three replications. Economic analysis was determined by the use of enterprise analysis and profitability measures and ratio. Results indicate that: N, P, and K, fertilizers applied at the rate of 125:50:75 kg ha $^{-1}$ significantly influenced grain yield and quality of spring wheat. The lowest grain yield (t/ha) of spring wheat at Obudu Cattle was 0.63 t/ha while the highest was 3.12 t/ha indicating high production potentials. Profitability Index (PI**)** analysis show that the highest PI values (1.86 and 1.87) were obtained from TNPK 125:50:75 kg ha $^{-1}$ for both OCR East and West. The least PI values (0.98 and 0.82) were obtained from the Control plots. With PI of 1 and above implies that plant Wheat at OCR is a viable investment, Highest net revenue returns of #633,000 and #639,000 was obtained at 125: 50: 75 kg/ha from OCR- East and OCR-West experimental sites respectively. Cultivation of spring wheat at Obudu Cattle Ranch under rain - fed is hereby, recommended due to its potentials while N, P, and K fertilization at rates of 125 kg N; 50 kg P; 75kg K ha-1 is recommended for sustainable spring wheat production both in terms of grain yield and quality.

Keywords: Growth; yield; spring wheat; fertilizer; sources; rain-fed.

1. INTRODUCTION

Wheat (*Triticum aestivum* L.) is a staple food of the world and belong to family (Gramineae). It is a C3 plant primarily grown in temperate regions and also at higher altitude under tropical climatic areas in winter season. Wheat provided nearly 55% of the carbohydrate and 20 % of food calories which is consumed by two billion people (36% of world population) as staple food. It is said that as a food, wheat is more nutritive as compared to the other cereals.

"Nigeria needs 4 million metric tonnes of wheat annually and local production vis-a-vis consumption falls below the national requirement" (Olabanji, 2015). "The continuous mining of nutrients from soils coupled with inadequate and imbalanced fertilizer use has resulted in decrease in wheat productivity. An annual depletion of 36 million tons of nutrients (NPK) from soil, has been estimated while the replacement through fertilizer is only 28 million tonnes leaving a net annual deficit of 8 million tonnes which keeps accumulating year after year depleting the soil fertility" [1].

"Wheat is a heavy nutrient feeder and leads to large withdrawal of plant nutrients from soil. This depletion will result in decline in yield of the crop. In intensive cropping without balanced fertilization had led to depletion of major as well as micro nutrients from the soil" [2]. This has deteriorated soil health and has lead to a decrease in crop productivity in several regions of the country. Balanced fertilization results in the supply of nutrients in a well balanced ratio, leading to their efficient utilization. Among various nutrients, NPK play crucial roles in wheat production.

The inadequacy of local wheat production could be curbed with the application of right agronomic technologies practices. Fertilizer use rate and management is of critical importance in wheat production to achieve high yields [3].

An estimated 80,000 hectares of land with temperate temperature and adequate rainfall suitable for rainfed wheat cultivation around the Mambilla Plateau, Obudu Highlands and Jos exist in Nigeria and are left uncultivated. Rain-fed wheat cultivation would require minimal inputs compared to the irrigated wheat cultivation [4]. The objective of this research is to evaluate the economic benefits and yield productivity of Spring Wheat (*Triticum aestivum* L**.**) to different sources of NPK fertilizers combination rates at Obudu Cattle Ranch.

2. MATERIALS AND METHODS

2.1 Description of Experimental Sites

This study was conducted in 2015 and 2016 main cropping seasons at East and West areas of Obudu Cattle Ranch (OCR) (Fig. 1) Cross River State, Nigeria. The study areas receives a bimodal rainfall pattern with the wet season extending from May to October and the dry season which extends from November to April.

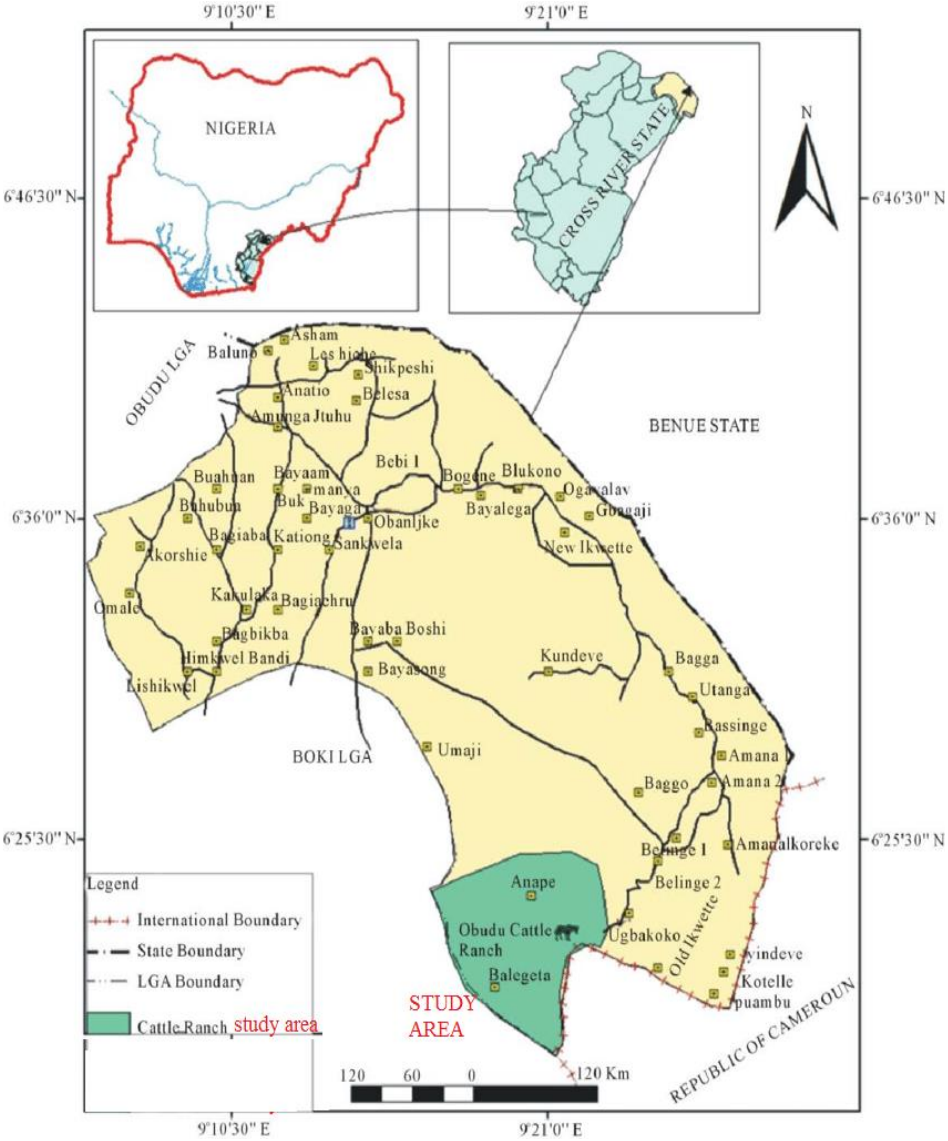

Fig. 1. Map of Cross River State showing study sites

The areas are characterized by heavy and erratic rainfall distribution. The sites are located at an elevation of 1595 metres above sea level. Temperature ranges between 16" to 32°C in June to September. Annual rainfall is between 2000-2500/mm. Mono cropping of cereals, mainly bread wheat (*Triticum aestivum* L.), Barley (*Hordium vulgare* L.) and pulses is a common practice in these areas. Wheat is the predominant staple food crop for the rural population in these districts.

2.2 Experimental Materials, Procedures and Design

The field experiment consists of twelve (12) treatment combinations from three (3) different sources of NPK fertilizers (100kg N ha$^{-1,}$ 40kg P ha^{-1} as SSP, T_4, 60kg K ha$^{-1,}$N + P (100:40) kg ha^{-1}, N +k (100:60) kg ha$^{-1,}$ K + P (60:40) kg ha^{-1}, NPK (50:20:30) kg ha-^{1}, NPK (75:30:45) kg h, NPK (100:40:60) kg ha-^{1}, NPK (125: 50:75) kg ha-^{1}, NPK (150:60:90) kg ha-^{1}, NPK (175:70:105) kg ha-^{1})and one control (without any fertilizer application). The field experiment was laid down in a randomized complete block design with three replications. All experimental unites were treated with their appropriate rates of P2O5 ha-1 in the form of triple super phosphate (TSP), K2O ha-1 from Muriate of potash (KCl) and Nitrogen from Urea. The plot size was 6 m × 6 m (36 m2), and 1,404 m2 net size. The middle ten rows were used for agronomic data collection and the outside rows rows served as border. The spacing between plants, rows, plots, and blocks were 5, 20, 50 and 150 cm, respectively. An improved bread wheat variety known Attila/13/ Hui was sown by drilling in rows using manual row maker at recommended seed rate of 150 kg ha-1 and row spacing of 20 cm and was used as test crop. Plots were kept free of weeds by hand weeding. No insecticide or fungicide was applied since there was no outbreak of insects or diseases. Harvesting was done manually using hand sickle.

2.3 Data Collection

2.3.1 Grain yield

Grain yield (kg/plot) was taken from each plots by excluding the border rows and adjusting to 12.5% moisture level and then converted to hectare basis. Gluten content was assess after harvest

2.4 Economic Analysis

This was determined by the use of enterprise analysis and profitability measures and ratio [5]. The following profitability measures were calculated:

i) Returns to management, labour, capital or net income (RMLC) given as RMlC = Total value of product (TVP) less total fixed cost (TFC) less total variable cost (TVC).
ii) Rate of return to investment (RRTI) is given by RRTI = (RMLC/TC) x 100.
iii) Return on fixed cost of production (RFC) or Gross Margin (GM) is given by `RFC = Gross Revenue (GR) minus total variable cost (TVC).
iv) Rate of return on fixed cost (RRFC) is given by RRTC = RFC/TFC x 100.
v) Rate of return of variable cost (RRVC) is given by RRVC = GR – TFC/TVC x 100.
vi) Profitability index Gross Revenue(GR) divided by Total cost of production(TCP)

2.5 Soil Sampling, Sample Preparation and Analysis

Prior to start of experiment, eight (8) composite surface soil samples were collected using standard Auger from surface soil samples (0-20cm) each at OCR- East and West location and bulked to form one composite sample for initial soil fertility evaluation of the experimental fields. The soil samples were air dried and past through 2mm sieve for laboratory studies. The soil samples were determined using the procedure according to Anderson and Ingram [6].

2.6 Data Analysis

After verifying the homogeneity of error variances, the Analysis of Variance (ANOVA) for the studied grain yield variable was computed using the GLM procedure of SAS software version 9.4 [7] following the standard procedures of ANOVA for RCB design [8]. The differences in fertilizers rates and types were considered significant if the p-values were ≤ 0.05. Least significance difference test (LSD) was used to compare among treatments at 5% probability level. T- test was used to test the yield performance between the two locations OCR East and OCR West for 2015 and 2016 planting seasons respectively.

3. RESULTS AND DISCUSSION

3.1 Soil Properties of the Experimental Sites before Planting

The results of the physical and chemical properties of the soil before planting at OCR-East and west experimental sites are presented in Table 1. Results of the analysis at the East location show that the soil was moderately acidic with pH of 5.81%, N value of 0.07 was high and organic matter content of 2.57 was very adequate under tropical condition. Available P of 3.02 ppm was adequate. Exchangeable cations Ca^{2+} 2.83 cmol/kg was moderate, K^+ and Mg $^{2+}$ values (0.30 and 2.09 cmol/kg) were moderate. Na^+ value 0.11 cmol/kg was low. The CEC value of 6.83 cmol/kg was moderate while BS of 91 percent was very high. The particles size distribution shows that the soil was sandy loam. The results of the analysis at the West site indicate pH of 5.88 which indicated moderate acidity. Percentage N value of 0.81 percent was high and organic matter at 2.78 percent was sufficient. Available P of 3.10 ppm was adequate. Exchangeable cations Ca^{2+} 2.78 cmol/kg was moderate while k^+ and Mg^{2+} values of 0.32 and 2.11 cmol/kg were sufficient, Na^+ 0.10 cmol/kg was low while the CEC value of 6.91 cmol/kg was moderate. Base saturation of 94 percent was high and particle size distribution analysis of the soil revealed that the soil is sandy loam.

Table 1. Soil physico-chemical properties of the study sites

	OCR East	OCR West
Sand (%)	89.20	87.7
Silt (%)	2.80	3.2
Clay (%)	8.00	9.1
Textural class	SL	SL
pH(H_20)	5.81	5.88
O.C (%)	1.50	1.62
O M (%)	2.57	2.78
N (%)	0.70	0.81
Av. P (ppm)	3.02	3.10
K (cmol/kg)	0.30	0.32
Ca (cmol)	2.83	2.78
Mg (cmol)	2.09	2.11
Na (cmol)	0.11	0.10
E. A (Meg/100g)	0.50	0.54
CEC (cmol/kg)	6.83	6.91
Bs (%	91.00	94

3.2 Effect of N, P and K Fertilizer Rates on Yield of Wheat and Gluten Content

The mean effects of rates of NPK fertilizers on grain Yield (t ha^{-1}) and gluten Content (g/100 g seed wt) of Spring Wheat are presented in Table 2. The grain yield and gluten content were significantly influenced by the rates of NPK fertilizers applied. The highest grain yield of 3.13 and 2.98 (t/ha) and gluten contents of 28.96 and 28.67 were obtained under NPK (125:50:90) kg ha-^{1} plots in 2015 and 2016 planting season respectively. The lowest grain yield and gluten content were obtained from control treatment plots.

The results of the study showed that NPK fertilization rates improved seed grain yield. This may be attributed to adequate increase of Nitrogen rates in right proportions with Phosphorus and Potassium. This findings agreed with Zahang et al. [9] who reported that nitrogen is the most often indicative among the nutrients which affected grain weight and quality. Grain yield increased with increased nitrogen rates. The report of Zahang, et al. [9] confirmed that under high nitrogen supply conditions, wheat grain weight and number increased. However, increase in NPK fertilizer rates prolonged duration of grain filling by 7 to 10 percent relative to unfertilized control treatment. Jacson (1998) observed increase in N rates result in increased yield but, the differences were not significant. Highest gluten content was obtained from plots with high N application (T_{11}, T_{12}, T_{13}, T_{10}, T_9 and T_8). This result agrees with the finding of Wood et al. [10], who found out that higher N rates results in higher grain yield and gluten content, although technological parameters of such yields still raise controversies, that high rates of N can cause worse quality gluten by increasing the shape of low-molecular gluten. While Jackson [11] in his study noted that nitrogen required for acceptable protein may exceed that required to maximize yield.

Phosphorus and Potassium had no influence on gluten content and wheat grains yield. However, complimentary role of both nutrients help assist the plant to be less vulnerable to water deficiency and further shape N management in high yield of protein and gluten. This is confirmed by the work of Ma, et al. [12] who reported that adequate supply of potassium and phosphorus plants are less vulnerable to water stress, low temperature, and pathogen attack, therefore, shape N management to achieve high yield.

3.3 Economic analysis of Spring Wheat Production

Table 3 show the results of the analysis of the cost and returns that would accrue to an average farmer to grow wheat at Obudu Cattle Ranch under rain fed condition. The results indicated that total variable cost of N633.00 was 60.22% of the cost of cultivation, while Total Fixed cost of N345,000.00 represented 39.78% of total production cost. Estimated net income for both OCR East and OCR West (N633,000.00, N623,000.00) and profitability index of 1.88 and 1.86. Estimated yield of 3.13 t h^{a-1} from (125kg N;50 kg P;75 kg) h^{a-1}.

Table 2. Mean Effect of N, P and K Fertilizers on Grain Yield (t/ha) and Gluten Content (g/100g) of Spring Wheat in OCR East and OCR West

		Grain Yield (t/ha)		Gluten yield (g/100g)	
Treatment		**East**	**West**	**East**	**West**
T_1	Control	0.71^{fg}	0.63^{f}	13.52^{m}	12.20^{n}
T_2	N (100) kg ha-^{1}	0.95^{f}	0.86^{ef}	16.31^{l}	15.60^{m}
T_3	P (40) kg ha-^{1}	0.87^{f}	0.84^{ef}	14.79^{k}	15.60^{jk}
T_4	K (60) kg ha-^{1}	0.78^{f}	0.77^{f}	14.98^{j}	15.09^{j}
T_5	N+P (100:40) kg ha-^{1}	1.41^{e}	0.97^{ef}	14.90^{g}	17.01^{h}
T_6	N+K (100+60) kg ha-^{1}	1.87^{e}	0.99^{ef}	17.45^{h}	16.54^{l}
T_7	K+P (60:40) kg ha-^{1}	1.74^{e}	1.07^{def}	17.90^{l}	17.84^{g}
T_8	N P K (50:20:30) kg ha-^{1}	1.85^{d}	1.56^{bcd}	22.57^{f}	21.34^{f}
T_9	N P K (75:30:45) kg ha-^{1}	2.41^{c}	2.21^{ab}	23.43^{e}	22.62^{e}
T_{10}	N P K (100:40:60) kg ha-^{1}	2.64^{bc}	2.37^{a}	27.72^{d}	27.47^{d}
T_{11}	N P K (125:50:90) kg ha-^{1}	3.13^{a}	2.98^{a}	28.96^{a}	28.67^{a}
T_{12}	N P K (150:60:90) kg ha-^{1}	3.02^{a}	2.81^{a}	28.34^{b}	28.03^{b}
T_{13}	N P K (175:70:105) kg ha-^{1}	2.85^{ab}	2.47^{a}	28.04^{c}	27.23^{c}

Within each column, means with the same letters are not significantly different according to Duncan Multiple Range Test (DMRT)

Table 3. Profitability analysis OCR –East

	Treatment Value												
Profitability Measures/ratio	**T_1**	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**	**T_7**	**T_8**	**T_9**	**T_{10}**	**T_{11}**	**T_{12}**	**T_{13}**
Return to management, labour and capital	38,000	40,000	-39,000	16,000	-78,000	116,000	6,000	464,000	455,000	442,000	633,000	514,000	126,000
Rate of return to investment(%)	14.07	10.28	8.53	4.47	-14.44	25.43	100.00	81.18	68.76	86.59	86.59	63.77	14.39
Return on fixed cost of production (#)	108,000	110,200	31.000	86,000	-8,000	186,000	76,000	554,000	530,400	447,400	708,000	589,000	201,200
Rate of return on fixed cost (%)	154,28	157,43	4.43	122,86	-11,43	265,71	108,57	791,43	707,20	596,65	944,00	785.33	268.27
Rate of return on variable cost (%)	119.00	109.34	89.92	105.56	83.40	130.05	101.33	116.24	193.70	177.79	196.49	170.31	115.74
profitability index	0.98	1.10	1.04	1.04	0.85	1.25	1.01	1.88	1.82	1.69	1.86	1.64	1.26

Table 4. Profitability analysis OCR –East

	Treatment Value												
Profitability Measures/ratio	**T_1**	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**	**T_7**	**T_8**	**T_9**	**T_{10}**	**T_{11}**	**T_{12}**	**T_{13}**
Return to management, labour aid capital(#)	16,000	101.000	-83,000	-23,600	-117,600	-11,600	-178,800	286,800	435,600	429,600	639,000	522,800	377,000
Rate of return to investment(%)	5.93	25.93	-18.16	-6.59	-21.78	-2.54	-34.25	59.09	77.65	66.71	87.41	64.86	42.98
Return on fixed cost of production (#)	86,000	101,400	50,400	46,400	-47,600	58,400	-108.80	286,000	510,600	504,600	714,000	597,800	452,000
Rate of return on fixed cost (%)	122,86	144.86	72.00	66.29	-68.00	83.43	-155.42	70.79	680.80	672.80	952.00	797.7	602.67
Rate of return on variable cost (%)	108.00	109.78	78.55	91.81	74.97	96.98	60.44	143.60	189.62	175.50	197.41	171.52	147.01
profitability index	0.82	1.08	1.01	0.93	0.78	0.97	0.66	1.59	1.78	1.67	1.87	1.65	1.43

Profitability Index (PI**)** analysis as presented in Table 4 show the highest PI values (1.86 and 1.87) were obtained from T_{11} NPK (125:50:75) kg ha $^{-1}$ for both OCR East and West. The least PI values (0.98 and 0.82) were obtained from the Control plots . With PI of 1 and above implies that plant Wheat at OCR is a viable investment, This is confirmed by the work of Emenyomu *et al.,* 2007 on enterprise analysis and profitability measures that any enterprise with estimated PI (1) one and above is viable business.

Highest net revenue returns of #633,000 and #639,000 was obtained at T $_{11}$ (125: 50: 75) kg/ha from OCR- East and OCR-West experimental sites respectively in 2016 planting season. Net return figures #514,000, # 522,800 and 126,000, #377,000 for both T $_{12}$ and T $_{13}$ at OCR- East and West decreased with increased N, P and K fertilizer rates. The lowest rates to returns were obtained from control T 2, T 3, T 4 and T 5 respectively. This agree with Zhang *et al.,* 2007 who reported that increase in NPK rates prolonged duration in grain wheat filling. The profitability ratio obtained at T 11 was highest at both locations.

4. CONCLUSION

Several factors limiting crop yields have been reported by many workers and the current study showed that application of NPK fertilizer sources and rate were significantly (P ≤ 0.05) influenced grain yield and gluten content both at Obudu East and West Cattle Ranch . Significantly higher grain yields with higher net benefit were obtained from application of 125: 50: 75 kg/ha. The present research revealed that different levels of NPK fertilizers had a significant effect on grain yield and gluten content and of spring wheat components. The seed yield (t/ha) of spring wheat at Obudu Cattle Ranch ranged between 0.63 to 3.12 indicating high production potentials. Profitability Index (PI**)** analysis show that the highest PI values (1.86 and 1.87) were obtained from $_{NPK}$ 125:50:75) kg ha $^{-1}$ for both OCR East and West. With PI of 1 and above implies that plant Wheat at OCR is a viable investment, Highest net revenue returns of #633,000 and #639,000 was obtained at 125: 50: 75) kg/ha NP and K from OCR- East and OCR-West experimental sites respectively. N, P and K, fertilizers applied at the rate of 125:50:75 kg ha $^{-1}$ significantly influenced grain yield and quality of spring wheat. Cultivation of spring wheat at Obudu Cattle Ranch under rainfed is therefore, recommended.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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