



Response of Bread Wheat (*Triticum aestivum* L.) Varieties to Blended Fertilizer Rates on Quality Attributes and Economic Advantages

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Abstract

Bread wheat (*Triticum aestivum* L.) quality is an important component of the crop productivity as it improves both food security and income sources for farmers. However, its grain quality and economic yields are mainly constrained by poor soil fertility and lack of site specific fertilizer recommendation in the study area for specific variety. Therefore, a field experiment was conducted in Tiyo district of Arsi Zone, Ethiopia, on farmer's field in 2018 main cropping season in response of bread wheat varieties to blended fertilizer rates on quality attributes and its economic advantages. Factorial combination of two improved bread wheat varieties (Wane and Kingbird) and seven fertilizer treatments [Control, Recommended NP (150 kg ha⁻¹ TSP (69%P₂O₅) + 158.7 kg ha⁻¹ Urea (73 N)), 100 kg NPSB + recommended urea (46 kg N), 150 kg NPSB + recommended urea, 200 kg NPSB + recommended urea, 250 kg NPSB + recommended urea, 300 kg NPSB + recommended urea.] were laid out in randomized complete block design with three replications. Results revealed that grain protein content and hectoliter weight were significantly affected by the main effect of varieties and fertilizer rates with highest grain quality obtained from Wane variety at 200 kg NPSB + 100 kg Urea ha⁻¹, and recommended NP fertilizer application. The partial budget analysis results revealed that the application of 200 kg NPSB ha⁻¹ + 100 kg Urea ha⁻¹ on Wane and Kingbird varieties gave maximum marginal rates of return of 992.8% and 546.3% with highest net benefits respectively. Therefore, application of NPSB at the rate of 200 kg NPSB ha⁻¹ + 100 kg Urea ha⁻¹ in the production of Wane and Kingbird varieties produced better bread wheat quality and economic advantages for the experimental area of wheat production.

Keywords: Blended fertilizers; Economic benefit; Yield; Wheat; Main effect; Grain quality

Introduction

Wheat (*Triticum aestivum*) is the most important and the second widely cultivated crop, after corn, which played a fundamental role in combating hunger and improving the global food security [1]. The grains of wheat provide about 20% of all calories and proteins to humans [2] and produce good flour for making bread, cakes, sweet yeast goods, cookies, and crackers as well as the use in blended mixes. In recent years, demand for wheat grains has significantly

increased due to the global population growth, and thus wheat industry is facing a competitiveness crisis [1].

Wheat grows under a broad range of latitudes and altitudes; it is not only the most widely cultivated crop but also the most consumed food crop all over the world [3]. Wheat is one of the most important cereals cultivated in Ethiopia. Ethiopia is the largest producer of wheat in sub-Saharan Africa (SSA), over 1.8 million hectares annually [4]. It ranks fourth after maize, tef and sorghum both in area coverage and

production [5]. Wheat production in the country is adversely affected by low soil fertility and suboptimal use of mineral fertilizers in addition to diseases, weeds, erratic rainfall distribution in lower altitude zones, and water-logging in the Vertisols areas Amanuel G & Stewart WM [6,7] Reported that 50 to 60% of the increase in crop yields worldwide was due to application of chemical fertilizers. They also stated that during the 21st century, the essential plant nutrients would be one of the factors limiting crop yields, especially in developing countries; the main factors responsible for low yield are more or less plant population and inadequate crop nutrition. Nutritionally, bread wheat grain is high in carbohydrates: whole grain wheat flour contains roughly 70% carbohydrate, 11.5% protein (varying from 8-15%), 2% fat, 2% fibre, 1.5% ash, and 13% water [8].

Declining of soil fertility in agricultural soils exacerbated by improper land use, yield and water productivity in the rain fed systems in many Sub-Saharan Africa countries is decreasing or stagnating [9]. About 97% of agricultural land in Sub-Saharan Africa is under rain fed system Bai Z & Mosisa W [9,10] described nutrient depletion as a major biophysical factor limiting small-scale production in Africa. Inappropriate cropping systems, mono cropping, nutrient mining, unbalanced nutrient application, removal of crop residues from the fields and inadequate re-supplies of nutrients have contributed to decline in crop yields [11]. Low soil fertility due to monoculture cereal production systems is recognized as one of the major causes for declining per capita food production. Declining soil fertility is also an important bottleneck for smallholder cereal growers in central western parts of Ethiopia [12]. Continuous monocultures of cereals also result in reduction of yields and soil nutrients [13,14]. Declining yield and soil fertility as a result of continuous mono-cropping have also been reported for finger millet [15,16].

Grain quality is expressed through a complex of indices including its physical properties, chemical composition and bio-chemical and technological characteristics, which are variety-specific [17]. Gluten proteins, consisting of gliadins and glutenins, play an important role in the bread-making quality of wheat flour as gliadins mainly contribute to

dough viscosity and extensibility, while glutenins to dough strength and elasticity [18]. Wheat quality can be assessed using a variety of approaches that range from the physical measurement of the dough characteristics to chemical fractionation of the protein [19]. Protein content is a character determining the water absorbing ability, stability, resistance and elasticity of flour. The protein content in flour is the main quality criterion for wheat, especially for bread making [20]. Wheat grain protein content is frequently used as the main measurement of grain quality [21] and indicators for milling and baking [22]. Protein content in cereals is one of the most important quality parameters for marketing. Many studies have attempted to relate wheat proteins to breadmaking quality [23-27]. The positive effects may be attributed mainly to the N rate effect since the fertilizer N use efficiency can be enhanced by split N application under appropriate environmental conditions, which resulted in higher plant N uptake [28,29]. Szentpetery [30] demonstrated that intensified wheat fertilization with N resulted in better milling and baking quality through increased hectoliter weight, grain protein content and bread volume.

Materials and Methods

Description of the Study Area

The experiment was conducted at Tiyo district around Kulumsa Agricultural Research Center (KARC) on farmer field located at about 167 km South East of Addis Ababa (Arsi Zone, Oromia-Ethiopia). Its geographical location is 8° 02' N latitude and 39° 10' E longitude, representing a medium altitude at 2200m above sea level with moderate rainfall of 848 mm per annum. Tiyo wereda was potential area for cereals and highland pulses, the area is dominated by continuous monoculture of cereals especially wheat which exhaust the same kind of nutrients season to season. It has a unimodal rainfall pattern with extended rainy season from March to September. However, the peak season is from July to August. The mean annual maximum and minimum temperature is 23.1°C and 9.9°C respectively. During the months of July to September, the rain fall is higher than the full potential evapotranspiration [31].

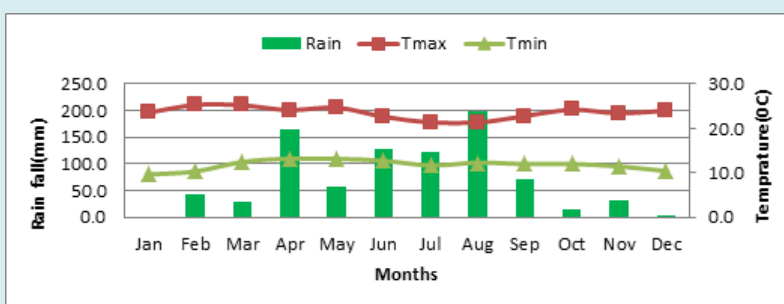


Figure 1: Mean monthly rain fall, maximum and minimum temperature of the study area in the year 2018.

Experimental Materials

Planting materials: Wane and Kingbird bread wheat varieties were used as planting materials. The appropriate application of NPSB blended fertilizer rate in the experimental

area, these varieties were selected based on their adaptability to agro-ecological zone of the area, productivity and resistant for disease (Table 1).

No	Bread Wheat Varieties	Agro-ecology	Year of release	Altitude(m)	Rainfall	Maturity days	On station productivity
					(mm)		(q ha ⁻¹)
1	Kingbird	Midland	2015	2000-2200	800-1000	133	40 - 50
2	Wane	Midland	2016	2000-2300	750-1500	120	50 - 65

Source: Kulumsa Agricultural Research Center (KARC), Wheat breeding program (2017).

Table 1: Descriptions of the Bread wheat varieties to be used in the experiment.

Fertilizer Materials: TSP (69% P2O5) and Urea (73% N) for recommended rate of NP and Urea (46% N) were used as the supplementary fertilizers for making NPSB optimum amount for the crop productivity. The blended NPSB fertilizer rates (18.1% of N, 36.1% of P2O5, 6.7% of S and 0.71% of B) in 100 kg bags as shown in AACC [32]. Farmers and other bread wheat producers use Urea (100 kg) and DAP (150 kg) for recommended NP (73% N and 69% P2O5). But in this time DAP was out of the market. For this research it used TSP instead of DAP fertilizer. 150 kg of DAP have (69% P2O5 + 27% N) but 150 kg TSP have only 69% of P2O5. To

compensate the remaining 27% of N and fulfill the 73% N, add the Urea fertilizer until the recommended fertilizer was balanced.

Treatments and Experimental Design

The experimental design used for this experiment was Randomized Complete Block Design (RCBD) with factorial arrangement of two varieties (Wane and Kingbird) and seven fertilizer rates with three replications which comprised a total of 14 treatment combinations (Table 2).

Fertilizer rates	N	P ₂ O ₅	S	B
Control	0.00	0.00	0.00	0.00
150 kg TSP + 158.7 kg Urea h ⁻¹	73.00	69.00	0.00	0.00
100 kg NPSB + 100 kg Urea ha ⁻¹	64.10	36.10	6.70	0.71
150 kg NPSB + 100 kg Urea ha ⁻¹	73.15	54.15	10.05	1.07
200 kg NPSB + 100 kg Urea ha ⁻¹	82.20	72.20	13.40	1.42
250 kg NPSB + 100 kg Urea ha ⁻¹	91.25	90.25	16.75	1.78
300 kg NPSB + 100 kg Urea ha ⁻¹ 100.30	108.30	108.30	20.10	2.13

N, Nitrogen; P2O5, di phosphorus pento Oxide; S, Sulfur; B, Boron; TSP, Triple Super Phosphate; and NPSB, Nitrogen Phosphorus Sulfur and Boron

Table 2: Detail treatment of fertilizer rates used for the experiment and their nutrient contents.

Experimental Procedures and Management

The gross experimental area was 42.9m x 14m (600.6m²), Gross Plot size of 4m x 2.6m (10.4m²) and net plot size of 3m x 2m (6m²). The spacing between rows, plots and blocks were 0.20m, 0.5m and 1 m, respectively. By excluding the two outer rows from both sides of a plot and a 0.25m row length on both ends of each plant, row of each plot to avoid border effects resulting in to a net plot size.

The land was ploughed two times including land clearing or removing unwanted materials from the field. Then, a field

layout was made and each treatment was assigned randomly to the experimental units within a block. Seed of bread wheat varieties were sown at the recommended seed rate of 125 kg ha⁻¹ in rows of 20 cm spacing and sown in row of 3-4cm depth by using mechanical row marker and the seed was drilled manually in the rows at June 29, 2018. NPSB blended fertilizer rates are applied at sowing time for all plots except control. Supplementary nitrogen fertilizer in the form of Urea was applied in the experiment splits two times to maintain the N requirement of the crop. The whole amount of blended (NPSB) fertilizer and 1/3 of recommended

Urea were applied at sowing and the rest of 2/3 of Urea was applied at booting time by top-dressing. Weeding was done two times and Rexido fungicide was applied when the disease occurred. The crop was finally harvested on the basis of crop maturity stage of each variety from the net plot area and threshed manually.

Data Collection

Quality assessment: Wheat samples were uniformly divided through Boerner Divider and analyzed for quality characteristics such as hectoliter weight and protein content according to standard procedures as described in AACCC [33].

- **Hectoliter weight:** Grain weight of one liter volume (random sample) was estimate for each experimental unit by following standard procedure AACCC [33].
- **Protein Content:** Protein content in grain was determined by Near Infra-Red Spectroscopy [33].

Economic Analysis

The economic analysis was performed whenever significant difference was observed for mean grain yields with respect to the applied blended fertilizer rates as per the procedures of GenStat [34]. Accordingly, those factors with significant effect were considered for partial budget analysis, dominance and marginal analysis.

The net benefit (NB) was calculated as the difference between the gross field benefit and the total variable (TVC) using the formula: $NB = GFB - TVC$

Where, GFB = Gross Field Benefit, TVC = Total Variable Cost

Actual yield was adjusted downward by 10% to reflect the difference between the experimental yield and the yield farmers could expect from the same size field. Any treatment that has higher TVC but net benefits that are less than or equal to the preceding treatment (with lower TVC but higher net benefits) is dominated treatment (marked as "D"). The dominance analysis illustrates that to improve farmers' income, it is important to pay attention to net benefits rather than yields, because higher yields do not necessarily mean high net benefits. The discarded and selected treatments using this technique were referred to as dominated and un dominated treatments, respectively. For each pair of ranked treatments, % marginal rate of return (MRR) was calculated using the formula:

$$MRR (\%) = \frac{\text{Change in NB (NBb-NBa)}}{\text{Change in TVC (TCVb-TCVa)}} \times 100$$

Where, NBa = the immediate lower NB, NBb = the next higher

NB, TVCa = the immediate lower TVC and TVCb = the next highest TVC.

The % MRR between any pair of undominated treatments was the return per unit of investment in fertilizer. To obtain an estimate of these returns, the % MRR was calculated as changes in NB (raised benefit) divided by changes in cost (raised cost). Thus, a MRR of 100% implied a return of one Birr on every Birr spent on the given variable input.

Then, gross yield benefit was obtained by multiplying the adjusted yield by the price of grain (12.5 birr kg^{-1}) for Tiyo districts. The mean market price of wheat was obtained by assessing the market price during 2018 cropping season. Net benefit or net revenue was calculated, by subtracting labor cost (assuming 75 ETB per person) from gross yield. Total variable cost (TVC) equals to fertilizer cost Birr ha^{-1} plus fertilizer application and transport cost in Birr. Net revenue (NR) was obtained by subtracting TVC from total revenue (TR). The average open market price (9 birr kg^{-1}) for wheat crop and the official prices of DAP (7.98 birr kg^{-1}), Urea (10.66 birr kg^{-1}), NPSB (11.40 birr kg^{-1}), Finally, marginal rate of return (MRR) in percentage was calculated as the change in net revenue (NR) divided by the change in total variable cost (TVC) multiplied by hundred. This enables' to make farmer recommendations from marginal analysis.

Data Analysis

All data collected were subjected to analysis of variance (ANOVA) procedure using GenStat (17th Edition) software [34,35]. The comparisons among treatments means with significant difference for measured characters was done by LSD test at 5% level of significance.

Results and Discussion

Quality Parameters

Grain protein content: Grain protein content of the experiment showed highly significant ($P < 0.01$) difference in the main effect of blended fertilizer rates and varieties. But the interaction between the two factors was non-significant (Table 3). Wane variety gave the highest grain protein content of 11.5% whereas variety Kingbird gave significantly lower grain protein content of 10.8%. The highest grain protein content (12.1%) was observed at recommended rate of NP. The lowest was at control (9.22%). Above 200 Kg ha^{-1} NPSB fertilizer treatments was statistically not significantly different from the recommended NP (Table 3). Gooding [36] reported the protein content in wheat grains ranged from 9.23% to 15.11%. There was a shortage of water in a cropping season after anthesis (Figure 1). Labuschagne & Bencze [37,38], demonstrated that both N fertilization and

post-anthesis water stress slightly increased grain protein concentration. Adequate nitrogen supply improves protein content of vegetative organs as well as storage tissues and manufactures protein from carbohydrates Tisdale [39]. Sadowska [40] findings that the grain quality and physical properties of the different wheat varieties examined were strongly influenced by the cultivars. The protein content in flour increases significantly with bread wheat as the result of the heat stress Bekalu & Labuschagne [41,42]. SH Park [43] stated that both quantity and quality of proteins affected bread making properties such as mixing time, tolerance, dough handling properties, water absorption, oxidation requirements, loaf volume, and crumb grain.

Varieties	Grain Protein content (%)
Wane	11.46 ^a
Kingbird	10.75 ^b
LSD (%)	0.20
Fertilizer rates (kg ha ⁻¹)	
0 kg F ha ⁻¹	9.22 ^c
150 kg TSP + 158.7 kg Urea h ⁻¹	12.08 ^a
100 kg NPSB + 100 kg Urea ha ⁻¹	11.58 ^b
150 kg NPSB + 100 kg Urea ha ⁻¹	11.82 ^{ab}
200 kg NPSB + 100 kg Urea ha ⁻¹	11.98 ^{ab}
250 kg NPSB + 100 kg Urea ha ⁻¹	11.85 ^{ab}
300 kg NPSB + 100 kg Urea ha ⁻¹	12.00 ^{ab}
LSD (5%)	0.42
P Value	<.0001
CV (%)	3.17

TSP, Triple Super Phosphate; NPSB, Nitrogen Phosphorus Sulfur and Boron; LSD, Least Significant Difference; CV, Critical Value. Means followed by the same letter(s) within a column are not significantly different from each other at 5% level of significance, ns: Not significant.

Table 3: Main effect of variety and blended fertilizer rates on grain protein content.

Hectoliter weight: Hectoliter weight content of the experiment showed highly significant ($P < 0.01$) difference in the main effect of blended fertilizer rates and varieties. But the interaction between the two factors was non-significant (Table 4). Wane variety gave the highest hectoliter weight content of 73.03 kg hl⁻¹ whereas variety Kingbird gave significantly lower hectoliter weight content of 70.97 kg hl⁻¹. The highest hectoliter weight content (72.93 kg hl⁻¹) was observed at recommended rate of NP. The lowest was at control (71.22 kg hl⁻¹). Above 200 Kg ha⁻¹ NPSB fertilizer treatments was statistically not significantly different from

the recommended NP (Table 4). This could be related to difference in variety with respect to applied fertilizer. Atwell [44] reported that, HLW may range from about 57.9 kg hL⁻¹ for poor wheat to 82.4 kg hL⁻¹ for sound wheat. The result of the study affirmed that the value of HLW for both varieties from the highest value of Wane (74.5 kg hl⁻¹) to the lowest value of Kingbird (70.0 kg hl⁻¹) of the tested bread wheat varieties was as a medium range. Significantly higher HLW with the application of blended NPSB rate might be due to the role of balanced nutrients on quality of wheat such as flour yield [45,46]. The amount of powder of wheat was important for millers just as grain yield is important to wheat producer. Gooding [36] reported slight increase in HLW in response to N application under more favorable growing conditions. Tahir [47] report showed that HLW of the varieties significantly influenced by genotype.

Varieties	Hectoliter Weight (kg hl ⁻¹)
Wane	73.03 ^a
Kingbird	70.97 ^b
LSD (%)	0.67
Fertilizer rates (kg ha ⁻¹)	
0 kg F ha ⁻¹	71.22 ^{bc}
150 kg TSP + 158.7 kg Urea h ⁻¹	72.93 ^{ab}
100 kg NPSB + 100 kg Urea ha ⁻¹	72.43 ^{ab}
150 kg NPSB + 100 kg Urea ha ⁻¹	72.18 ^{abc}
200 kg NPSB + 100 kg Urea ha ⁻¹	72.52 ^a
250 kg NPSB + 100 kg Urea ha ⁻¹	71.78 ^{abc}
300 kg NPSB + 100 kg Urea ha ⁻¹	71.82 ^{abc}
LSD (5%)	1.34
P Value	<.0001
CV (%)	1.59

TSP, Triple Super Phosphate; NPSB, Nitrogen Phosphorus Sulfur and Boron; LSD, Least Significant Difference; CV, Critical Value; Means followed by the same letter(s) within a column are not significantly different from each other at 5% level of significance, ns: Not significant.

Table 4: Interaction effect of blended fertilizer rates on hectoliter weight of bread wheat varieties.

Partial Budget Analysis

Partial budget analysis is important to identify experimental treatments with an optimum return to the farmer's investment and to develop recommendation for the agronomic data. Experimental yields are often higher than the yields that farmers could expect using the same treatments; hence in economic calculations, yields of farmers are adjusted by

10% less than that of the research results AACC [32]. As indicated in Table 10, the partial budget analysis showed that highest net benefit of (50536) Birr ha⁻¹ was obtained for variety Wane that received 300 kg NPSB ha⁻¹. However, the lowest net benefits of (26496) Birr ha⁻¹ were obtained from the unfertilized treatment with the variety Kingbird. In this study, Wane varieties gave economic benefit of (48540 birr ha⁻¹) with marginal rate of return (992.8 %) at 200 kg NPSB ha⁻¹ fertilizer rate with supplementary urea but economic benefit of (50536 birr ha⁻¹) birr was obtained for the variety

Wane at 300 kg NPSB ha⁻¹ with about a (1996 birr ha⁻¹) net benefit increment (Table 5). whereas, in case of Kingbird variety at 200 kg NPSB ha⁻¹ fertilizer rate gave the maximum economic benefit (46551 ha⁻¹) with marginal rate of return (546.3 %). According to AACC [32] suggestion, the minimum acceptable marginal rate of return should be more than 100 %. Therefore, Wane variety at 300 kg NPSB ha⁻¹ and for Kingbird variety at 200 kg NPSB ha⁻¹ were economical and recommended for production of bread wheat in the study area and other areas with similar agro ecological condition.

Treatment		GY	SY	Income (ETB ha-1)		GFB	TVC	NB	MRR
Var	Fer	(kg ha ⁻¹)	(kg ha ⁻¹)	Yield	Straw	(ETB ha ⁻¹)	(ETB ha ⁻¹)	(ETB ha ⁻¹)	%
W	0	2165	3137	28140	627	28768	0	28768	-
W	100	3425	5324	44524	1065	45589	3390	42409	538.3
W	150	3489	6416	45351	1283	46634	3600	42804	188.1
W	NP	3561	6020	46299	1204	47503	4266	43437	95.1
W	200	3966	7315	51557	1463	53020	4780	48540	992.8
W	250	4107	8285	53369	1657	55046	5130	49916	393.1
W	300	4236	9816	55072	1963	57036	6500	50536	45.3
KB	0	1991	3062	25884	612	26496	0	26496	-
KB	100	3252	4856	42279	971	43250	3390	40070	341.4
KB	150	3375	5317	43871	1063	44939	3600	41109	494.8
KB	NP	3647	6520	47405	1304	47709	4266	43743	395.5
KB	200	3737	7761	48579	1552	50131	4780	46551	546.3
KB	250	3499	7827	45481	1565	47046	5130	41916	D
KB	300	3682	8327	47861	1665	49527	6500	43027	81.1

Where, W, Wane; KB, Kingbird; Var, variety; Fer, fertilizer; GY, grain yield; SY, straw yield; GFB, gross field benefit; TVC, total variable costs; NB, net benefit; MRR, marginal rate of return; ETB ha⁻¹, Ethiopian Birr per hectare; D, dominated treatments.

Table 5: Summary of economic analysis of the effects of blended fertilizer (NPSB) rates on bread wheat varieties.

Conclusion

Bread wheat qualities are depends on the total grain protein content. The amount of hectoliter weight of wheat is higher, the flour of yield also higher. The highest protein content and hectoliter weight of bread wheat were recorded from wane variety (11.46%, 73.03kg hl⁻¹) and due to fertilizer treatments, recommended NP (12.08% , 72.93 kg hl⁻¹) and 200 kg ha⁻¹NPSB with supplementary urea (11.98%, 72.52 kg hl⁻¹) respectively, were the best records from other treatment; along the maximum marginal rates of return of 992.8% even though a net benefit of 50,536 Birr ha⁻¹ was obtained from the same variety at 300 kg NPSB ha⁻¹ + 100 kg Urea ha⁻¹ fertilizer application about a 1996 net benefit increment. Therefore, application of NPSB at the rate of 200 kg NPSB ha⁻¹+100 kg Urea ha⁻¹ in the production of Wane and Kingbird varieties was economically beneficial and has more

quality recommended for around Kulumsa area and similar growing areas. Since the study was conducted in one location for one season, it should be repeated in more location and season for further recommendation in similar agro ecologies.

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