

Full Length Research Paper

Optimization of fertilizer recommendation for bread wheat production at Adiyo District of Kaffa Zone, Southwestern Ethiopia

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Received 21 September, 2019; Accepted 30 December, 2019

An experiment was conducted on farmer's fields during the main cropping season of 2016/2017 in Adiyo district, Southwestern Ethiopia to optimize fertilizer rate recommendation for major cereal production systems by using bread wheat (*Triticum aestivum* L.) as test crop. Experiment was laid out in a randomized complete block design (RCBD) with three replications for sixteen treatments. The grain yield and yield components were all elevated remarkably by applying different rates and types of fertilizers; five levels of N (0, 23, 46, 69 and 92 kg ha⁻¹); four levels of P (0, 10, 20 and 30 kg ha⁻¹); and four levels of K (0, 10, 20 and 30 kg ha⁻¹). In addition, the last three diagnostic treatment foliar applications 45 days after planting and compared with control (absolute zero) treatment was done. Yield and yield components were measured using the SAS statistical package program version 9.3. The least significant difference (LSD) at 5% probability level was used to establish the difference among the means. To investigate the economic feasibility of the fertilizers, partial budget, dominance analysis and marginal rate of return were used. There was significant difference in grain yield and yield components of bread wheat (danda'a variety) among the treatments. As the results showed high biological yield response recorded under 92N20P20K kg ha⁻¹ (5.62 t ha⁻¹) and the lower yield response was under control treatment (4.09 t ha⁻¹); but high economic yield response recorded under 23N20P kg ha⁻¹ (5.20 t ha⁻¹). In conclusion, the fertilizers containing nutrient rate of 23N20P (kg ha⁻¹) had brought the higher economic net benefit (27409.99 ETB/ha) with MRR (92.61%) and showed efficient use of fertilizer. Therefore, based on the biological yield response and economic net benefit, it is recommended to apply 23N20P (kg ha⁻¹) fertilizers at Adiyo district, Southwestern Ethiopia and areas with the same soil conditions and agro-ecology.

Key words: Economic analysis, foliar application, wheat yield, nutrient type, rate.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the most important cereal crop in the world and is the staple food for humans. Ethiopia is one of the largest wheat producers in sub-Saharan Africa (Minot et al., 2014). Bread wheat is

one of the most important cereals cultivated in Ethiopia. It ranks fourth after teff (*Eragrostis tef*), maize (*Zea mays*) and sorghum (*Sorghum bicolor*) in area coverage and third in total production (CSA, 2014). Mean wheat yields

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Table 1. List of treatments.

Treatment	Nutrients rate (kg ha ⁻¹)						
	N	P	K	S	Zn	Mg	B
T1 = Control	0	0	0	0	0	0	0
T2 = 23N	23	0	0	0	0	0	0
T3 = 46N	46	0	0	0	0	0	0
T4 = 69N	69	0	0	0	0	0	0
T5 = 92N	92	0	0	0	0	0	0
T6 = 20P	0	20	0	0	0	0	0
T7 = 23N20P	23	20	0	0	0	0	0
T8 = 46N20P	46	20	0	0	0	0	0
T9 = 69N20P	69	20	0	0	0	0	0
T10 = 92N20P	92	20	0	0	0	0	0
T11 = 92N10P	92	10	0	0	0	0	0
T12 = 92N20P20K	92	20	20	0	0	0	0
T13 = 92N30P	92	30	0	0	0	0	0
T14 = 92N20P10K2.5S0.5Zn2.5Mg0.5B	92	20	10	2.5	0.5	2.5	0.5
T15 = 92N20P20K5S0.5Zn2.5Mg1B	92	20	20	5	0.5	2.5	1
T16 = 92N20P30K7.5S0.75Zn3.75Mg1.5B	92	20	30	7.5	0.75	3.75	1.5

N= Nitrogen, P= phosphorus, K= potassium, S = sulfur, Zn = zinc, Mg = magnesium, B= Boron, nutrient rate was in kg per hectare.

increased from 1.3 tons ha⁻¹ in 1994 (Central Statistical Authority (CSA, 1995) to 2.54 t ha⁻¹ in 2015 (CSA, 2016), well below experimental yields of over 5 tons ha⁻¹ (Gete et al., 2010; Mann and Warner, 2015). The low yield is primarily allied with the depletion of soil fertility due to continuous nutrient uptake of crops, low fertilizer use and insufficient organic matter application (Balesh, 2005; Kidane, 2015). Low availability of nitrogen and phosphorus has been reported to be a major constraint to wheat production in Ethiopia (Minale et al., 2006). Many researches showed that nitrogen and phosphorus application increased grain yield of wheat (Haile et al., 2012; Assefa, 2014; Assefa, 2014; Bereket, 2014). Amsal et al. (2000) also revealed that nitrogen and phosphorus are the two most essential plant nutrients often limiting the yield and growth of wheat crop. Many researches proved that wheat responses to inorganic fertilizer applications with recommended rates showed high yield and economically effective (Abdo et al., 2012; Abreha et al., 2013; Adamu, 2013; Assefa et al., 2015). Reduction of applied nitrogen fertilizer rate to an optimized level can reduce soil nitrate leaching (Power et al., 2000). Therefore, ideal nitrogen management optimizes yield, farm profit and nitrogen use efficiency while minimizing the potential for leaching of nitrogen beyond the crop rooting zone (Rahmati, 2009). Under most field conditions, the amounts of nutrients are insufficient to meet the crop requirement. Also determination of optimum nitrogen and phosphorus fertilizer rates is critical for economic production and productivity of wheat crop Hence, determination of optimum rates and

evaluating different source fertilizers and thereby improving the yield of bread wheat and maximizing the economic yields are of paramount importance. Therefore, the present investigation was undertaken for the following objectives; to optimize fertilizer recommendations for bread wheat and determine yield with different levels for each nutrient of interest and to obtain the information needed to determine robust nutrient response functions in the study area.

MATERIALS AND METHODS

Description of the study area

The study was conducted in Southwestern Ethiopia, Kaffa Zone of Adiyo district at farmer's field during 2016/2017 main cropping season. The geographical coordinates of the site is b/n 07°15.488' N latitude and 36°25.140' E longitudes at an elevation of 2536 m above sea level. The rainfall is bimodal and receives 600 to 1800 mm of rain throughout the year. Temperature ranges from 15 to 20°C. Topographically, the area consists of gently undulating plain with average slope gradient of 6%. Crop production in the study area is characterized by cereal, pulses and tubers cropping system. Wheat is extensively grown followed by faba bean. Some highland tubers (enset and potato), field pea and barley are also grown in the study area (Adiyo Woreda Agricultural and Natural Resource Development Office (AWANRDO), 2017).

Experimental design and treatment application

Experiment was laid out in a randomized complete block design (RCBD) in three replications that contained 16 treatments of different plant nutrient combinations (Table 1). The last three

Table 2. Effect of fertilizer (s) types and rates on wheat grain yield and yield components in Adiyo district in 2016/2017.

Treatment	PH (cm)	SL (cm)	S/S	BM (t ha ⁻¹)	GY (t ha ⁻¹)
Control	87.93 ^{cd}	8.13 ^b	50.13 ^{ab}	8.46 ^e	4.09 ^f
23N	87.07 ^d	8.57 ^{abc}	48.47 ^{ab}	8.74 ^{de}	4.39 ^{def}
46N	89.73 ^{bcd}	8.63 ^{abc}	50.33 ^{ab}	9.79 ^{bcd}	4.48 ^{def}
69N	89.33 ^{bcd}	7.97 ^c	48.00 ^{ab}	8.98 ^{de}	4.24 ^{ef}
92N	94.27 ^{abc}	8.97 ^{ab}	44.80 ^{ab}	9.11 ^{de}	4.47 ^{def}
20P	97.00 ^a	9.10 ^a	44.13 ^b	8.57 ^{de}	4.25 ^{ef}
23N20P	96.27 ^{ab}	9.47 ^a	49.27 ^{ab}	10.76 ^{abc}	5.20 ^{abc}
46N20P	94.00 ^{abcd}	8.97 ^{ab}	45.13 ^{ab}	9.72 ^{cde}	4.65 ^{cdef}
69N20P	94.53 ^{abc}	9.00 ^{ab}	46.20 ^{ab}	10.48 ^{abc}	4.99 ^{bcd}
92N20P	95.13 ^{ab}	9.43 ^a	43.00 ^b	10.72 ^{abc}	4.81 ^{bcd}
92N10P	89.93 ^{bcd}	9.17 ^a	48.60 ^{ab}	10.44 ^{abc}	4.89 ^{bcd}
92N20P20K	97.67 ^a	9.27 ^a	49.33 ^{ab}	11.2 ^a	5.62 ^a
92N30P	92.13 ^{abcd}	9.13 ^a	47.40 ^{ab}	10.85 ^{abc}	5.29 ^{ab}
92N20P10K2.5S0.5Zn2.5Mg0.5B	91.80 ^{abcd}	9.07 ^a	54.67 ^a	10.93 ^{abc}	5.20 ^{abc}
92N20P20K5S0.5Zn2.5Mg1B	91.73 ^{abcd}	9.23 ^a	44.80 ^{ab}	11.0 ^{ab}	5.35 ^{ab}
92N20P30K7.5S0.75Zn3.75Mg1.5B	95.20 ^{ab}	9.13 ^a	48.67 ^{ab}	11.07 ^a	5.11 ^{abc}
CV%	4.49	6.15	12.64	7.59	7.82
LSD (0.05)	6.944	0.9187	10.051	1.2729	0.628

PH=Plant height, SL=spike length, S/S=seed number per spike, BM=biomass, GY=grain yield, nutrient rate was in kg ha⁻¹.

treatments (14, 15 and 16) were diagnostic treatments containing micro nutrients; sulfur (S), zinc (Zn), magnesium (Mg), and boron (B) were used from fertilizer source CaSO₄.2H₂O, ZnSO₄, MgSO₄.7H₂O and borax, respectively. Phosphorus (P), potassium (K) and half dose of nitrogen (N) nutrients from sources of TSP, KCl and urea, respectively were applied at planting from conventional fertilizers. The remaining half dose of nitrogen was applied at knee height, while other nutrients S, Zn, Mg and B were applied by foliar application from different formulations later-on 45 days after germination. All treatments were applied on specified plot size, plant spacing using bread wheat (*danda'a* variety) as test crop. Each treatment was applied on a plot size of 3 m × 3 m (9 m²) with 1 m distance between blocks and within plots. Seed rate used was 150 kg ha⁻¹ and planted by drilling in each row at spacing of 20 cm.

Data collection and statistical analysis

Grain yield data was collected and adjusted at 11.5% moisture content. It was subjected to analysis of variance (ANOVA) using the GLM procedure of SAS statistical package version 9.3 (SAS Institute, 2011). The List Significant Difference using Fisher's LSD test at 5% level of significance was used to identify differences among the means.

Economic analysis

Economic analysis was performed to investigate the economic feasibility of the optimum fertilizers for wheat production. The partial budget, dominance and marginal rate of return were calculated. The average yield was adjusted downwards by 10%, assuming that farmers would get 10% less yield than is achieved on an experimental field. Field price of wheat was assumed to be 6.50 ETB/kg. Assuming cost of triple super phosphate (TSP) at planting was 2460.08 ETB, Urea was 1099.86 ETB and that of potassium chloride was 1932 ETB, the cost of the nutrients would be 23.91

ETB/kg N, 53.48 ETB/kg P₂O₅ and 32.2 ETB/kg K₂O. The cost of other production practices like seed purchasing, field preparation, weeding and harvesting were assumed to remain the same or insignificant among the treatments. For a treatment to be considered a worthwhile option for farmers, the minimum acceptable marginal rate of return should be over 50% (International Maize and Wheat Improvement Center [CIMMYT], 1988).

RESULTS AND DISCUSSION

Effect of different nutrient types and rates on yield and yield component of bread wheat

The application of different nutrient types and rates showed a significant ($p \leq 0.05$) positive influence on the growth, yield attributes and yield of wheat (Table 2). Bread wheat (*danda'a* variety) response showed a significant differences for different nutrient types and rates of fertilizers applied. From the result, application of nitrogen with phosphorus, especially phosphorus amount of 20 P ha⁻¹ with different levels of nitrogen increased plant height rather than the application of different levels of nitrogen alone. According to spike length, the result recorded was better with application of nitrogen; also nitrogen is combined with phosphorus rather than control. The wheat yield revealed a significant differences among the treatment and the high yield response (5.62 t ha⁻¹) recorded under N-P-K (92-20-20 kg ha⁻¹) and followed by yield (5.35 t ha⁻¹) advantage under N-P-K-S-Zn-Mg-B (92-20-20-5-0.5-2.5-1 kg ha⁻¹), respectively. The least yield response was recorded (4.09 t ha⁻¹) under untreated plot. The results of an experiment

Table 3. Economic (partial budget and dominance) analysis of fertilizers on wheat at Adiyo district

Treatment	Av. yield (kg ha ⁻¹)	Adj. yield (kg ha ⁻¹)	GB (ETB/ha)	TCTV (ETB/ha)	NB (ETB/ha)	MRR (%)
1. Control	4090	3681	23926.5	0	23926.5	-
2. 23N	4390	3951	25681.5	549.93	25131.57	-
3. 46N	4480	4032	26208	1099.86	25108.14	D
4. 69N	4240	3816	24804	1649.79	23154.21	D
5. 92N	4470	4023	26149.5	2199.72	23949.78	D
6. 46P ₂ O ₅	4250	3825	24862.5	2460.08	22402.42	D
7. 23N46P ₂ O ₅	5200	4680	30420	3010.01	27409.99	-
8. 92N23P ₂ O ₅	4890	4401	28606.5	3429.76	25176.74	D
9. 46N46P ₂ O ₅	4650	4185	27202.5	3559.94	23642.56	D
10. 69N46P ₂ O ₅	4990	4491	29191.5	4109.87	25081.63	D
11. 92N46P ₂ O ₅	4810	4329	28138.5	4659.8	23478.7	D
12. 92N46P ₂ O ₅ 24K ₂ O	5620	5058	32877	5432.6	27444.4	-
13. 92N69P ₂ O ₅	5290	4761	30946.5	5889.84	25056.66	D

Yield adjustment=10%, ETB=Ethiopian Birr, field price of wheat=6.5 ETB/kg, official price for N=23.91 ETB/kg, official price for P₂O₅=53.48 ETB/kg and official price for K₂O=32.2 ETB/kg, Av. yield=average yield, Adj. yield=adjusted yield, GB=gross benefit, TCTV=total costs that varies, NB=net benefit, D indicates dominated treatments that are rejected, MRR=marginal rate of return.

showed that the application of nitrogen, phosphorus and potassium caused enormous increase in the biomass and grain yield of wheat; but the least values of both biomass and yield were obtained in the treatment with omission of fertilizers. These results are supported by the findings of Mojid et al. (2011). Bereket (2014) and Fekremariam et al. (2015) also reported that grain yield was increased with higher NP levels. The research results indicated that application of nitrogen fertilizer is one of the most important measures that increases grain yield of wheat. In agreement with this, the experiment conducted in Sinana Ethiopia involving five nitrogen rates indicated that application of different rates of nitrogen fertilizer had significantly affected most of the yield and yield components of wheat (Tilahun et al., 2017). Also, researches indicated that application of different levels of nitrogen and phosphorus in different regions of Ethiopia had significantly increased biomass and grain yields of wheat (Dawit et al., 2014; Assefa, 2014; Bereket, 2014; Fekremariam et al., 2015).

The result indicated that the sole nitrogen and phosphorus application was not effective on bread wheat grain yield. Application of the other nutrients; sulfur, zinc, magnesium and boron used in these experiments were effective on grain yield of bread wheat as compared to the control (no fertilizer) and sole (nitrogen or phosphorus) but economically not feasible. Also the result indicated that the foliar application (for micronutrients) of 92N-20P-20K-5S-0.5Zn-2.5Mg-1B was better by grain yield as compared to other diagnostic treatments. However, the significant yields of diagnostic treatments were not economically feasible as compared to other treatment as well as the control. Therefore, treatments

containing these diagnostic nutrients were not considered in further analysis.

Economic analysis

Diagnostic treatments (14, 15 and 16) were rejected because the yield recorded from these treatments was low when compared with NPK fertilizers applied field. Based on the dominance analysis treatments 1, 2, 7 and 12 were potential options (Table 3) and other treatments were dominated by the treatments with lower variable cost and higher net benefit. Therefore, other treatments were eliminated from further economic analysis and only the dominant treatments were considered further in the partial budget analysis (Table 4). Based on the partial budget analysis (Table 4), the treatment with the higher net benefit was treatment 12 (27444.4 ETB/ha) as compared to treatments 2 and 7; but the MRR (%) value (1.42%) was below the minimum acceptable marginal rate of return (50%). However, the marginal rates of return for treatments 2 (25131.57 ETB/ha) and 7 (27409.99 ETB/ha) were 219.13 and 92.61%, respectively. Therefore treatment 7 (27409.99 ETB/ha) with MRR (92.61%) can give an acceptable marginal rate of return for the extra investment.

Conclusions

Reducing the degradation of natural resources, improving soil fertility and health management is imperative to enhance and sustain agricultural productivity. To increase the wheat productivity improved and available soil fertility

Table 4. Economic (partial budget and marginal rate of return) analysis of fertilizers on wheat at Adiyo district.

Treatment	Av. yield (kg ha ⁻¹)	Adj. yield (kg ha ⁻¹)	GB (ETB/ha)	TCTV (ETB/ha)	NB (ETB/ha)	MRR (%)
1. Control	4090	3681	23926.5	0	23926.5	-
2. 23N	4390	3951	25681.5	549.93	25131.57	219.13
7. 23N46P ₂ O ₅	5200	4680	30420	3010.01	27409.99	92.61
12. 92N46P ₂ O ₅ 24K ₂ O	5620	5058	32877	5432.6	27444.4	1.42

Yield adjustment=10%, ETB=Ethiopian Birr, field price of wheat=6.5 Ethiopian Birr/kg, official price for N=23.91 ETB/kg, official price for P₂O₅=53.48 ETB/kg and official price for K₂O=32.2 ETB/kg, Av. yield=average yield, Adj. yield=adjusted yield, GB=gross benefit, TCTV=total costs that varies, NB= net benefit, D indicates dominated treatments that are rejected, MRR=marginal rate of return.

management practice is necessary. The current study revealed that the application of different fertilizer types and rates containing different fertilizer sources were significantly ($P \leq 0.05$) influenced the bread wheat characters such as plant height, seed number per spike, spike length, biomass and grain yield. The maximum biological yield obtained with application of rate of 92N20P20K kg ha⁻¹ showed the great biological yield advantage (5.62 t ha⁻¹) with net benefit of 27444.4 ETB ha⁻¹ and MRR of 1.42%. But in terms of economic feasibility application of 23N20P kg ha⁻¹ gave yield advantage (5.2 t ha⁻¹) accrued the net benefit of 27409.99 ETB ha⁻¹ with MRR of 92.61% and is advisable for farmers to maximize bread wheat grain yield and economic return. Therefore, on the basis of the result of the present study, it is indicative that better economic yield advantage obtained at Adiyo district and farmers can benefit more by application of 23N20P kg ha⁻¹ which is economically feasible. As a conclusive remark, the result of the current study provides basic information for further research and development efforts in soil fertility management for sustainable utilization of the soil resources in the study area.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

The authors thank Alliance for Green Revolution in Africa, Soil Health Program (AGRA SHP) for financial support. They also thank the South Agricultural Research Institute (SARI), Natural Resources Management Research Directorate and Bonga Agricultural Research Center (BARC) both for valuable collaboration work by evaluation and monitoring of the activity on the field through.

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