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Teff growth and yield response to blended fertilizer type and rate in Debub Ari and Bena Tsemay Districts, Southwestern Ethiopia

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ABSTRACT

Depleting of soil fertility, soil organic matter, macro-and micro-nutrients and crop nutrient imbalances are among the primary biophysical limitations that reduce the production of teff. The experiment was conducted to evaluate teff response to blended fertilizer types and rates in Debub Ari and Bena Tsemay districts. Control, Recommended NP, 3 dosages of NPS and NPSB blended fertilizer rates each were used that is laid out in RCBD following three replication. The full dose of blended and P fertilizers was applied at planting and urea was applied in two splits. The result was revealed that application of 200 kg ha^{-1} NPSB + 127 kg ha^{-1} Urea resulted in the highest grain yield of 2299.5 kg ha^{-1} in Debub Ari and 200 kg ha^{-1} NPS + 117 kg ha^{-1} Urea gives 1809.2 kg ha^{-1} in Bena Tsemay, while the lowest grain yield was recorded from the nil in both districts. However, the highest economic return was obtained in response to the application of 64 kg ha^{-1} N + 20 kg ha^{-1} P in both districts. Application of 64 kg ha^{-1} N + 20 kg ha^{-1} P gives 57.24% and 14.42% yield increment in Debub Ari and Bena Tsemay, respectively; also 54.47% and 7.57% increment in economic return in Debub Ari and Bena Tsemay in the same order over the control. Application of 64 kg ha^{-1} N + 20 kg ha^{-1} P was recommended for the production of teff on the study area and similar agro-ecologies, as it was optimum for improving teff production. Further investigation should be done on plant nutrient uptake and using efficiency and grain quality.

Keywords: Blended Fertilizer, Economic Return, Productivity, Soil fertility

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Introduction

Teff [*Eragrostis tef* (Zuccagni) *Trotter*] is one of the most essential cereal crops in Ethiopia, occupying about 23.85% of the cultivated land from the total area of cereals (80.71%) with accounting for 17.26% of grain production (CSA, 2018). It is widely grown from sea level up to 2800 meters above sea level under various rainfall, temperature and soil conditions (Seyfu, 1997). It is commonly used in Ethiopia in the form of fermented flatbread called injera (Zhu, 2018). Crymes (2015) described this traditional flatbread as a soft, thin pancake with a sour taste. Additionally, teff is utilized as a local alcoholic beverage (Abraham, 2015). It is relatively rich in protein, ranging from 8.4-19.4% of dry matter, depending on the cultivar, location and year (Descheemaeker *et al.*, 2009). Its straw is an important source of feed for animals and it is also a resilient crop adapted to diverse agro-ecologies with reasonable tolerance to both low (especially terminal drought) and high (waterlogging) moisture stresses (Solomon *et al.*, 2017).

Depletion of soil organic matter, depletion of macro-and micronutrients, poor soil health, and crop nutrient imbalances; thus low soil fertility are among the primary biophysical limitations that decrease agricultural production in Ethiopia (Gete *et al.*, 2010; Tarekegn, 2010; CSA, 2018). Additionally, lack of local specific fertilizer recommendation per commodity and limited guidance to farmers on the possible integration of fertilizer with other soil and water management practices, removal of topsoil by erosion and change of soil physical properties are core constraints that hinder agricultural productivity in Ethiopian (Gete *et al.*, 2010). Despite its versatility in adapting to extreme environmental conditions, the productivity of teff in the country including the study area is very low up to 1.748 t ha^{-1} (CSA, 2016; CSA, 2018) as compared to the crop potential of 2.53 t ha^{-1} (Solomon *et al.*, 2017).

Soil fertility management through balanced crop nutrition that takes account of site-specific deficiencies in macronutrients and micronutrients and considers the use of manure and other organic soil amendments with fertilizer experiments for yield gap assessment and provides data and information relevant to developing strategies and identifying possible solutions is needed to achieve optimum crop yields in the country (Tamene *et al.*, 2017). Moreover, improving the nutrient concentration of cereal crops particularly teff in micronutrient deficient soil using a mixture of all essential plant nutrients in an adequate and balanced form of fertilizer enhances the total nutrient (N, P, K and Zn) uptake because of that crop productivity is increased (Fayera *et al.*, 2014). Application of blended fertilizer enhances the growth, grain yield and straw yield of teff (Berhe *et al.*, 2020). Application of Nitrogen, Phosphorus, and Sulphur with appropriate sowing method is promising for growing up of teff and improving productivity (Wakjira, 2018). Blended fertilizer greatly benefits farmers where deficiencies of micronutrients in the soil significantly reduce the productivity of the crops and are also important for teff production (Fayera *et al.*, 2014). The combined application of 100 kg ha^{-1} NPSZnB blended fertilizer supplemented with 92 kg ha^{-1} N enhances grain yield by 83.35% and economic return by 77.80% over absolute control (Teshome *et al.*, 2019).

According to ATA (2016) deficiencies in nutrients such as nitrogen, phosphorus, sulfur and boron are widespread in soils of the study area. The experiment was conducted to evaluate the effect of blended fertilizer types and rates on improving the production of teff [*Eragrostis tef (*Zuccagni) Trotter in Debub Ari and Bena Tsemay districts, southwestern Ethiopia.

Materials and Methods

Study area description

The study was conducted in 2019-2020 and 2020-2021 during the meher season in Debub Ari and Bena Tsemay districts, southwestern Ethiopia. The study site of Bena Tsemay district was located at a latitude of N05°39', the longitude of E036°40', and an altitude/elevation of 1352 meters above sea level. The study site of Debub Ari district was located at a latitude of N05°43', the longitude of E036°38', and an altitude/elevation of 1535 meters above sea level.

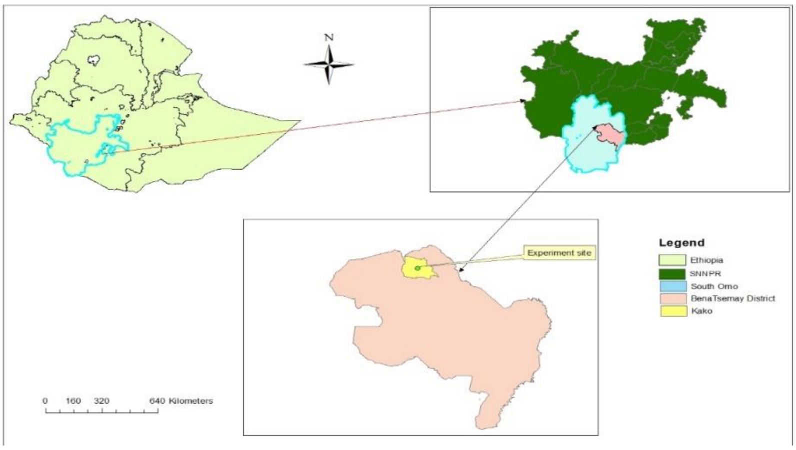

Fig. 1. Map of the study area (Bena Tsemay District)

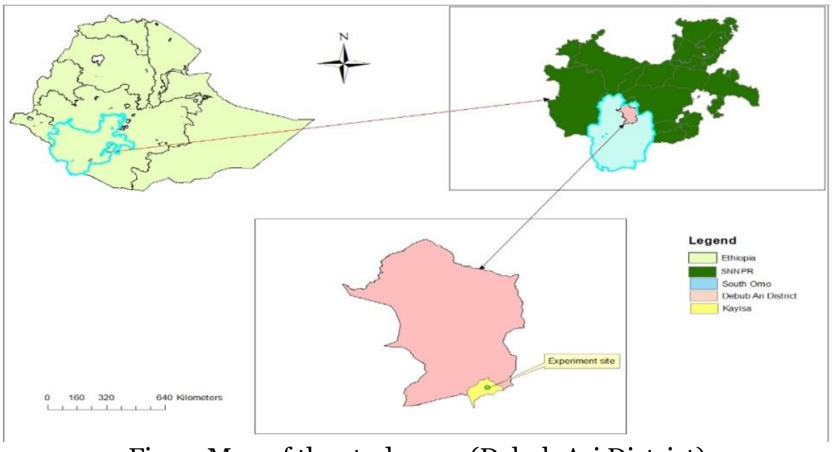

Fig. 2. Map of the study area (Debub Ari District)

Experimental design and treatments

The experiment was laid out in Randomized Complete Block Design (RCBD) following three replication. The experimental site was plowed and harrowed before sowing. The improved teff variety Dagim was used for the experiment. Improved teff variety Dagim was used due to its high yielding potential with grain yield advantage over other varieties like 7.31% and 8.14% over Quncho and local check, respectively, and stable performance, very white caryopsis color, and good straw yield (Solomon *et al.,* 2017). Furrow rows were made manually in the spacing of 20cm apart and teff seed was drilled manually and thinned appropriately following management recommendations for teff.

The experiment consisting of eight treatments:

T_1: Control (no fertilizer)
T_2: Recommended NP (64 kg ha^{-1} N, 20 kg ha^{-1} P)
T_3: 100 kg ha^{-1} NPS + 58 kg ha^{-1} Urea (46, 38, 7)
T_4: 150 kg ha^{-1} NPS + 88 kg ha^{-1} Urea (69, 57, 10)
T_5: 200 kg ha^{-1} NPS + 117 kg ha^{-1} Urea (92, 76, 13)
T_6: 100 kg ha^{-1} NPSB + 61 kg ha^{-1} Urea (46, 37.7, 6.7, 0.1)
T_7: 150 kg ha^{-1} NPSB + 91 kg ha^{-1} Urea (69, 56.5, 10, 0.15)
T_8: 200 kg ha^{-1} NPSB + 127 kg ha^{-1} Urea (92, 75.4,13, 0.2)

Urea and TSP were used as sources of N and P respectively and blended NPS and NPSB fertilizers were used as sources of other nutrients. All the recommended rates of P, S, and B nutrients, according to the different treatments will be applied at planting time whereas N will be applied in two splits: half at planting and the remaining half at the growth stage of 35 days after planting.

Data collection and analysis

Composite soil samples from a depth of 0-20 cm will be collected before planting and analysed for organic carbon (OC), texture, pH, TN, available P, S, and B. Plant height, the number of tillers per plant, panicle length, above-ground biomass, straw yield, and grain yield data were collected for evaluation of blended NPS and NPSB fertilizer rates effect on teff. Analysis of variance was performed using the GLM procedure of SAS Statistical Software Version 9.1. Treatment effects were considered significant in all statistical calculations if the P-values were < 0.05. Treatment means were separated using the Least Significant Difference (LSD) test.

Economic analysis

The economic evaluation comprising partial budget analysis with dominance and marginal analysis was carried out. To estimate economic parameters, the grain yield was valued based on the average market price of teff collected from the local markets during two consecutive years of production. The average cost of urea, TSP, NPS, and NPSB was 15.46, 15.85, 16.17 and 16.27 birr per kilogram was respectively for Bena Tsemay; and the average cost of urea, TSP, NPS, and NPSB for Debub Ari district was 15.51, 15.85, 16.22 and 13.62 birr per kilogram in the same order. A wage rate of 50 birrs a man per day and a teff grain value of 33 birrs per kilogram were considered.

The dominance analysis was also done, which was used to select potentially profitable treatments and it was carried out by first listing the treatments in order of increasing costs that vary. Any treatment that has net benefits that are less than or equal to those of treatment with lower costs that vary is dominated. The selected treatments by using this technique were referred to as undominated treatments. For each pair of ranked undominated treatments, a percentage marginal rate of return (% MRR) was calculated. The percent MRR between any pair of undominated treatments denoted the return per unit of investment in crop management practices. The MRR (%) was calculated as the Marginal rate of return (MRR) was calculated as the ratio of differences between net benefits of successive treatments to the difference between total variable costs of successive treatments (CIMMYT, 1988). For a treatment to be considered a worthwhile option to farmers, the marginal rate of return (MRR) needed to be at least 100%. Some of the concepts used in the partial budget analysis are gross field benefit (GFB), total variable cost (TVC), and net benefit (NB).

Gross margin (ETB ha^{-1}) = Total revenue (ETB ha^{-1}) – Total variable cost (ETB ha^{-1})

NR Net return (ETB ha^{-1}) = Gross margin (ETB ha^{-1}) – Total fixed cost (ETB ha^{-1})

Total production cost (ETB ha^{-1}) = Total variable cost (ETB ha^{-1}) + Total fixed cost (ETB ha^{-1})

Benefit-cost ratio = Net Return/Total Cost Production (CIMMYT, 1988).

Results and Discussion

Soil analysis

Table 1. Some physical and chemical properties of the soil from Debub Ari district before the test.

Soil Properties	Composition
Sand (%)	50
Silt (%)	11
Clay (%)	39
Textural class	Sandy clay
pH (H_2O)(1:2.5)	6.58
OC (%)	0.94
TN (%)	0.08
Available P (ppm)	8.45
B (ppm)	0.987
S (ppm) as SO_4	5.486

Table 2. Some physical and chemical properties of the soil from Bena Tsemay district before the experiment.

Soil Properties	Composition
Sand (%)	58
Silt (%)	11
Clay (%)	31
Textural class	Sandy clay
pH (H_2O) (1:2.5)	6.66
OC (%)	1.66
TN (%)	0.11
Available P (ppm)	31.93
B (ppm)	0.998
S (ppm) as SO_4	5.625

Analysis of soil sample collected before the experiment was done at the soil laboratory of Jinka Agricultural Research Centre. The soil of the Debub Ari district experimental site has a proportion of 50% sand, 11% silt, and 39% clay; which was classified as sandy clay; the soil of the Bena Tsemay district experimental site has a proportion of 58% sand, 11% silt and 31% clay; which was classified as sandy clay based on the soil textural triangle. The organic carbon of the experimental site of Debub Ari and Bena Tsemay districts was 0.94% and 1.66%, respectively which was done by Walkely Blacky methods Black (1965), which was rated as low for Debub Ari and medium for Bena Tsemay district (Tekalign *et al.,* 1991). The pH (H_2O) of the Debub Ari and Bena Tsemay district experimental site was 6.58 and 6.66 in the same order, which was implied that the soil of the experimental site was slightly acidic according to Tekalign *et al.* (1991).

The soil of the experimental site has total nitrogen of 0.084% for Debub Ari and 0.112% for Bena Tsemay by Keljdal digestion and distillation followed by titration method, which showed that both experimental sites have a low level of total nitrogen according to Tekalign *et al.* (1991). The experimental soil has available phosphorus of 8.45ppm for Debub Ari and 31.93 ppm for Bena Tsemay district analysed by Olsen methods which were effective for both alkaline and acidic soil and extracted by 1M $NaHCO_3$, which was rated as a medium for Debub Ari and high for Bena Tsemay district according to Olsen *et al.* (1954). The soil of the experimental site has available boron of 0.987 ppm for Debub Ari and 0.998 ppm for Bena Tsemay district done by dilute HCl methods in which most effective and efficient, most applicable for acidic, neutral, and alkaline soil and more economical than that of hot water methods (only for alkaline soil), which was categorized under medium-level according to Horneck *et al.* (2011); 5.49 ppm of sulfur for Debub Ari and 5.63 ppm sulfur for Bena Tsemay district exist in the soil in sulfate (SO_4^{2-}-S) form which was done by turbidymetric methods of analysis (acidic and non-calcareous soil) and its extractant was calcium chloride dehydrate as sulfate, which showed that the soil has a medium level of sulfur according to Marx *et al.* (1999).

Table 3. Plant height, tiller number per plant and panicle length of teff as influenced by blended fertilizer type and rate in Debub Ari and Bena Tsemay woreda.

Treatments	Plant Height (cm)		Tiller Number		Panicle Length (cm)	
	Debub Ari	Bena Tsemay	Debub Ari	Bena Tsemay	Debub Ari	Bena Tsemay
Control	61.31[d]	91.185	1.86[b]	2.15[b]	24.44[d]	30.35
64 kg ha^{-1} N + 20 kg ha^{-1} P	94.43[ab]	91.737	2.61[a]	2.47[ab]	33.27[a]	32.52
100 kg ha^{-1} NPS + 58 kg ha^{-1} Urea	92.61[b]	91.163	2.35[a]	2.5[ab]	31.22[abc]	31.14
150 kg ha^{-1} NPS + 88 kg ha^{-1} Urea	95.69[a]	93.845	2.33[a]	2.61[ab]	31.29[abc]	32.17
200 kg ha^{-1} NPS + 117 kg ha^{-1} Urea	96.33[a]	91.990	2.58[a]	2.62[ab]	31.07[bc]	32.06
100 kg ha^{-1} NPSB + 61 kg ha^{-1} Urea	94.55[ab]	92.322	2.64[a]	2.39[ab]	32.96[ab]	31.13
150 kg ha^{-1} NPSB + 91 kg ha^{-1} Urea	87.19[c]	94.888	2.33[a]	2.74[a]	29.86[c]	32.57
200 kg ha^{-1} NPSB + 127 kg ha^{-1} Urea	97.31[a]	95.382	2.49[a]	2.75[a]	32.69[ab]	31.89
$LSD_{0.05}$	2.9654	NS	0.3998	0.5489	2.0878	NS
CV	1.88	4.75	9.52	12.39	3.86	5.49

Treatments that carry the same letters are statistically not significantly different at 0.05. CV= Coefficient of Variation; LSD= Least Significant Difference; UTD= Urea Top Dressed; cm= centimeter; kg ha^{-1} = kilogram per hectare

Plant height

Analysis of variance revealed that plant height of teff was significantly affected by blended fertilizer type and rates in Debub Ari woreda. Blended fertilizer types and the rate did not significantly influence plant height of teff in Bena Tsemay woreda (Table 3). The highest plant height of 97.307 cm was recorded from 200 kg ha^{-1} NPSB + 127 kg ha^{-1} Urea followed by 200 kg ha^{-1} NPS + 117 kg ha^{-1} Urea of which both were in statistical parity with the rest of all treatments except 150 kg ha^{-1} NPSB + 91 kg ha^{-1} Urea and absolute control treatments, while the lowest plant height of 61.313 cm was recorded from the nil one in Debub Ari district.

The result of this study become agreed with the highest plant height obtained at the higher blended fertilizer levels and increases with enhancing the amount of blended fertilizer rate which might be because of the vital role of N applied for elongation and vegetative growth (Berhe *et al.*, 2020; Okubay *et al.*, 2014; Haftamu *et al.*, 2009). Blended fertilizer types and rates had no significant effect on plant height of teff in Bena Tsemay district and this result was in the line of agreement with increasing levels of N fertilizer application did not significantly enhance plant height of teff (Temesgen, 2001).

Tiller number per plant

Analysis of variance revealed that the total tiller number per plant of teff was significantly influenced by blended fertilizer types and rates in Debub Ari and Bena Tsemay district. There was statistical parity in between all treatments except absolute control treatments in both Debub Ari and Bena Tsemay districts. The lowest total tiller number per plant of 1.86 and 2.15 in Debub Ari and Bena Tsemay district respectively was recorded from unfertilized treatment. Similarly, Berhe *et al.* (2020) reported that there was no significant difference except with the control plot on both the total number of tillers and productive/effective tillers. The current result agrees with total and fertile tiller increased consistently and significantly in response to increasing the rate of NPS fertilizer from nil up to 120 kg ha^{-1}NPS (Wakjira, 2018); increasing N levels from 0 to 138 kg ha^{-1} N resulted in linear and consistent increment of tiller number while, the main effect of blended fertilizer did not affect tiller number of teff (Teshome *et al.*, 2019).

Panicle length

Analysis of variance revealed that panicle length of teff was significantly influenced by blended fertilizer types and rates in Debub Ari, but showed no significant difference in the Bena Tsemay district. The highest panicle length of 33.27 cm was recorded from 64 kg ha^{-1} N + 20 kg ha^{-1} P which was in statistical parity with rest treatments other than control, 200 kg ha^{-1} NPS + 117 kg ha^{-1} Urea and 150 kg ha^{-1} NPSB + 91 kg ha^{-1} Urea, while the lowest panicle length of 24.44 cm was measured from the absolute control treatment. The result of this study is in line of agreement with increasing application of N to 92 kg ha^{-1} N significantly increased panicle length, but further increasing N fertilizer did not consistently increase panicle length (Teshome *et al.*, 2019); teff panicle length increased in response to an increasing rate of nitrogen application (Okubay *et al.*, 2014).

Teff plants with higher panicle length were found by applying a high amount of N fertilizer due to high nitrogen usually favors vegetative growth of teff, which results in relatively greater panicle length (Haftamu *et al.*, 2009). Blended fertilizer types and rates had no significant effect on panicle length of teff in Bena Tsemay woreda and this result was in the line of agreement with panicle length of teff did not influence by blended fertilizer rather than by N application (Teshome *et al.*, 2019).

Table 4. Biomass, grain and straw yield of teff as influenced by blended fertilizer types and rates in Bena Tsemay and Debub Ari district.

Treatments	Biomass (kg ha^{-1})		Grain yield (kg ha^{-1})		Straw yield (kg ha^{-1})	
	Debub Ari	Bena Tsemay	Debub Ari	Bena Tsemay	Debub Ari	Bena Tsemay
Control	3437^{c}	5125^{c}	886.4^{c}	1450.6^{c}	2551^{c}	3674^{c}
64 kg ha^{-1} N + 20 kg ha^{-1} P	10496^{ab}	9028^{ab}	2072.8^{ab}	1695.1^{ab}	8423^{ab}	7333^{ab}
100 kg ha^{-1} NPS + 58 kg ha^{-1} Urea	9607^{b}	8440^{abc}	1917.3^{b}	1546.4^{bc}	7690^{b}	6893^{abc}
150 kg ha^{-1} NPS + 88 kg ha^{-1} Urea	11096^{ab}	9907^{ab}	1934.2^{b}	1600.1^{abc}	9162^{ab}	8307^{ab}
200 kg ha^{-1} NPS + 117 kg ha^{-1} Urea	10956^{ab}	10616^{a}	1856.1^{b}	1809.2^{a}	9099^{ab}	8807^{a}
100 kg ha^{-1} NPSB + 61 kg ha^{-1} Urea	9459^{b}	6662^{bc}	1812.6^{b}	1639.7^{abc}	7647^{b}	5022^{bc}
150 kg ha^{-1} NPSB + 91 kg ha^{-1} Urea	10430^{ab}	8556^{ab}	1865.4^{b}	1593.5^{abc}	8564^{ab}	6962^{abc}
200 kg ha^{-1} NPSB + 127 kg ha^{-1} Urea	12859^{a}	9023^{ab}	2299.5^{a}	1774.8^{a}	10560^{a}	7248^{ab}
$LSD_{0.05}$	2690.8	3397.5	269.68	217.36	2511.6	3311.6
CV	15.69	23.04	8.41	7.57	18.01	27.89

Treatments carries the same letters are statistically not significantly different at 0.05. CV= Coefficient of Variation; LSD= Least Significant Difference; UTD= Urea Top Dressed; cm= centimeter; kg ha^{-1} = kilogram per hectare.

Biomass

Analysis of variance revealed that the above-ground biomass of teff was significantly influenced by blended fertilizer types and rates in both Debub Ari and Bena Tsemay districts. The highest above-ground biomass of 12859 kg ha^{-1} was recorded from the application of 200 kg ha^{-1} NPSB + 127 kg ha^{-1} Urea which was in statistical parity with rest treatments except 100 kg ha^{-1} NPS + 58 kg ha^{-1} Urea, 100 kg ha^{-1} NPSB + 61 kg ha^{-1} Urea and unfertilized treatment, while the lowest above-ground biomass of 3437 kg ha^{-1} was recorded from unfertilized treatment in Debub Ari district. The highest above-ground biomass of 10616 kg ha^{-1} was recorded from the application of 200 kg ha^{-1} NPS + 117 kg ha^{-1} Urea which was in statistical parity with rest treatments except 100 kg ha^{-1} NPSB + 61 kg ha^{-1} Urea and unfertilized treatment, whereas the lowest above-ground biomass of 5125 kg ha^{-1} was recorded from unfertilized treatment in Bena Tsemay district (Table 4). The result of this study agreed with increasing the rate of NP from 0/0 to 64/46 N/P_2O_5, the dry above-ground biomass yield was also increased by 134.82% over the control which may be attributed due to the proportional vegetative growth (especially the plant height) as a result of NP (Assefa *et al.*, 2016). Similarly, Teshome *et al.* (2019), Fayera *et al.* (2014) and Wakjira (2018) suggested that aboveground dry biomass yield was significantly increased by enhancing the application of blended fertilizer because of better crop nutrition via applied blended micronutrients with macronutrients, which is result in nicely enhancing crop's vegetative growth.

Grain yield

Analysis of variance revealed that grain yield of teff was significantly influenced by blended fertilizer types and rates in both Debub Ari and Bena Tsemay districts. The highest grain yield of 2299.5 kg ha^{-1} was recorded from the application of 200 kg ha^{-1} NPSB + 127 kg ha^{-1} Urea which was in statistical parity with treatments that get 64 kg ha^{-1} N + 20 kg ha^{-1} P, while the lowest grain yield of 886.4 kg ha^{-1} was recorded from unfertilized treatment in Debub Ari district. The highest grain yield of 1809.2 kg ha^{-1} was recorded from the application of 200 kg ha^{-1} NPS + 117 kg ha^{-1} Urea which was in statistical parity with rest treatments except 100 kg ha^{-1} NPS + 58 kg ha^{-1} Urea and unfertilized treatment, whereas the lowest grain yield of 1450.6 kg ha^{-1} was recorded from unfertilized treatment which was in statistical parity with the rest treatments except 64 kg ha^{-1} N + 20 kg ha^{-1} P, 200 kg ha^{-1} NPS + 117 kg ha^{-1} Urea and 200 kg ha^{-1} NPSB + 127 kg ha^{-1} Urea treatments in Bena Tsemay district (Table 4). This result was agree with the maximum obtained from the application of 250 kg ha^{-1} of NPSB yield has 62.5% yield increment over control; the response of teff for blended fertilizer rates did not show consistent variation among treatments but it indicated the importance of the macro and micronutrients (Berhe *et al*..2020); the increased grain yield might be due to effect of balanced nutrients on improving crops agronomic performance thereby enhancing nutrient use efficiency (Fayera *et al.*, 2014) and the grain yield increment from plot treated with N and blended fertilizer might be due to the contribution of balanced nutrient (macro and micronutrient) present in fertilizers which increased yield attributes through more uptakes of all the nutrients and increased translocation of photosynthetic materials from source to sink (Teshome *et al.*, 2019). Consistent with this result Wakjira (2018) reported that grain yield increased consistently and significantly in response to increasing the rate of NPS fertilizer from nil up to 120 kg NPS ha^{-1} with transplanting. The result becomes agreed with the magnitude of increase in grain yield due to the application of 46 kg ha^{-1} N and 10 kg ha^{-1} P was higher by 137 % than the control (Getahun *et al.*, 2018).

Straw yield

The straw yield of teff was significantly affected by blended fertilizer types and rates. The highest straw yield of 10560 kg ha^{-1} was recorded in response to the application of 200 kg ha^{-1} NPSB + 127 kg ha^{-1} Urea which was statistically at par with rest treatments except 100 kg ha^{-1} NPS + 58 kg ha^{-1} Urea, 100 kg ha^{-1} NPSB + 61 kg ha^{-1} Urea and nil treatments, while the lowest straw yield of 2551 kg ha^{-1} was recorded from the control in Debub Ari district. The highest straw yield of 8807 kg ha^{-1} was recorded in response to application of 200 kg ha^{-1} NPS + 117 kg ha^{-1} Urea which was statistically at par with rest treatments except 100 kg ha^{-1} NPSB + 61 kg ha^{-1} Urea and nil treatments, while the lowest straw yield of 3674 kg ha^{-1} was recorded from the control which was in statistical parity with 100 kg ha^{-1} NPS + 58 kg ha^{-1} Urea, 100 kg ha^{-1} NPSB + 61 kg ha^{-1} Urea and 150 kg ha^{-1} NPSB + 91 kg ha^{-1} Urea treatments in Bena Tsemay district (Table 4). The result becomes agreed with increasing level of N up to 69 kg ha^{-1} N significantly increased straw yield, which may be attributed to the vigorous vegetative growth-enhancing property of nitrogen (Getachew, 2017). Combined application of N and P with the rate of 46 kg ha^{-1} N and 10 kg ha^{-1} P increase straw yield in resulted in 129% compared to the control (Getahun *et al.*, 2018). Application of NPS fertilizer on the transplanted plant up to 120 kg ha^{-1} increased straw yield 61% which could be attributed due to the availability of macronutrients and some secondary nutrients formulated with the blended fertilizer, which could increase the vegetative consequently (Wakjira, 2018).

Economic analysis

Table 5. Partial budget analysis of blended fertilizer type and rate effect experiment on teff production in Debub Ari district.

Treatments	Variables				
	Average Yield kg ha^{-1}	10% Adjusted Yield kg ha^{-1}	Total Return (ETB ha^{-1})	Total variable cost (TVC) (ETB ha^{-1})	Net benefit (ETB ha^{-1})
Control	886.4	797.76	26326.08	0	26326.08
100 kg ha^{-1} NPS + 58 kg ha^{-1} Urea	1917.3	1725.57	56943.81	3577.61	53366.20
100 kg ha^{-1} NPSB + 61 kg ha^{-1} Urea	1812.6	1631.34	53834.22	3688.72	50145.50
64 kg ha^{-1} N + 20 kg ha^{-1} P	2072.8	1865.52	61562.16	3742.52	57819.64
150 kg ha^{-1} NPS + 88 kg ha^{-1} Urea	1934.2	1740.78	57445.74	5400.00	52045.74
150 kg ha^{-1} NPSB + 91 kg ha^{-1} Urea	1865.4	1678.86	55402.38	5516.26	49886.12
200 kg ha^{-1} NPS + 17 kg ha^{-1} Urea	1856.1	1670.49	55126.17	7370.97	47755.20
200 kg ha^{-1} NPSB + 127 kg ha^{-1} Urea	2299.5	2069.55	68295.15	7546.00	60749.15

10%Adj. Yield= Marketable Yield Adjusted to 10% downward; ETB= Ethiopian Birr

Table 6. Partial budget analysis of blended fertilizer type and rate effect experiment on teff production in Bena Tsemay District.

Treatments	Variables				
	Average Yield kg ha^{-1}	10% Adjusted Yield kg ha^{-1}	Total Return (ETB ha^{-1})	Total variable cost (TVC) (ETB ha^{-1})	Net benefit (ETB ha^{-1})
Control	1450.6	1305.54	43082.82	0	43082.82
64 kg ha^{-1} N + 20 kg ha^{-1} P	1695.1	1525.59	50344.47	3735.56	46608.91
100 kg ha^{-1} NPS + 58 kg ha^{-1} Urea	1546.4	1391.76	45928.08	3566.11	42361.97
150 kg ha^{-1} NPS + 88 kg ha^{-1} Urea	1600.1	1440.09	47522.97	5382.64	42140.33
200 kg ha^{-1} NPS + 117 kg ha^{-1} Urea	1809.2	1628.28	53733.24	7165.78	46567.46
100 kg ha^{-1} NPSB + 61 kg ha^{-1} Urea	1639.7	1475.73	48699.09	3676.90	45022.19
150 kg ha^{-1} NPSB + 91 kg ha^{-1} Urea	1593.5	1434.15	47326.95	5498.57	41828.38
200 kg ha^{-1} NPSB + 127 kg ha^{-1} Urea	1774.8	1597.32	52711.56	7746.56	44965.00

10% Adj. Yield= Marketable Yield Adjusted to 10% downward; ETB= Ethiopian Birr.

Partial budget analysis of blended fertilizer type and rate effect on teff production experiment in Debub Ari district was revealed that the highest net return 60749.15 ETB ha^{-1} was obtained in response to application of 200 kg ha^{-1} NPSB + 127 kg ha^{-1} Urea which showed 56.66% higher return over the nil one 26326.08 ETB ha^{-1}; followed by treatment with recommended NP of net return 57819.64 ETB ha^{-1}, while the lowest net return of 26326.08 ETB ha^{-1} was obtained from unfertilized treatment (nil treatment) (Table 5).
Partial budget analysis of blended fertilizer type and rate effect on teff production experiment in Bena Tsemay district was revealed that the highest net return of 46608.90 ETB ha^{-1} was obtained in response to application of recommended NP (64 kg ha^{-1} N + 20 kg ha^{-1} P) which showed 10.26% increment in net return over the lower net return of 41828.38 ETB ha^{-1} followed by treatment which receives 200 kg ha^{-1} NPS + 117 kg ha^{-1} Urea of net return 46567.46 ETB ha^{-1}, while the lowest net return of 41828.38 ETB ha^{-1} was recorded in response to application of 150 kg ha^{-1} NPSB + 91 kg ha^{-1} Urea (Table 6).

Dominance and Marginal (MRR) analysis

Dominance analysis of the result in Debub Ari district was revealed that among the treatments 100 kg ha^{-1} NPS + 58 kg ha^{-1} Urea, 64 kg ha^{-1} N + 20 kg ha^{-1} P and 200 kg ha^{-1} NPSB + 127 kg ha^{-1} Urea were un-dominated (Table 7). This indicated that an increase in the total cost of these treatments increases the net benefit proportionally which means benefits were greater than the lower total costs. Treatments that get 64 kg ha^{-1} N + 20 kg ha^{-1} P with MRR of 2700.53% and 100 kg ha^{-1} NPS + 58 kg ha^{-1} Urea treatment with MRR of 755.82% were both accepted according to CIMMYT (1988) as the minimum acceptable required rate of return is in between 50% and 100%.

Dominance analysis of the result in Bena Tsemay district was revealed that among the treatments only 100 kg ha^{-1} NPSB + 61 kg ha^{-1} Urea and 64 kg ha^{-1} N + 20 kg ha^{-1} P were un-dominated (Table 8). This indicated that an increase in the total cost of 100 kg ha^{-1} NPSB + 61 kg ha^{-1} Urea and 64 kg ha^{-1} N + 20 kg ha^{-1} P treatments increases the net benefit proportionally which means benefits were greater than the lower total costs. Treatments that receives 64 kg ha^{-1} N + 20 kg ha^{-1} P with MRR of 2704.94% and 100 kg ha^{-1} NPSB + 61 kg ha^{-1} Urea with MRR of 52.75% were both accepted according to CIMMYT (1988) as the minimum acceptable required rate of return which is in between 50% and 100%.

Table 7. Dominance and marginal analysis, teff yield improvement by blended fertilizer type and rate experiment in Debub Ari.

Treatments	Variables				
	10% Adjusted Yield kg ha^{-1}	TVC (ETB ha^{-1})	Net Benefit (ETB ha^{-1})	Dominance Analysis	MRR (%)
Control	797.76	0	26326.08	-	-
100 kg ha^{-1} NPS + 58 kg ha^{-1} Urea	1725.57	3577.61	53366.20	ND	755.82%
100 kg ha^{-1} NPSB + 61 kg ha^{-1} Urea	1631.34	3688.72	50145.50	D	-
64 kg ha^{-1} N + 20 kg ha^{-1} P	1865.52	3742.52	57819.64	ND	2700.53%
150 kg ha^{-1} NPS + 88 kg ha^{-1} Urea	1740.78	5400.00	52045.74	D	-
150 kg ha^{-1} NPSB + 91 kg ha^{-1} Urea	1678.86	5516.26	49886.12	D	-
200 kg ha^{-1} NPS + 117 kg ha^{-1} Urea	1670.49	7370.97	47755.20	D	-
200 kg ha^{-1} NPSB + 127 kg ha^{-1} Urea	2069.55	7546.00	60749.15	ND	77.02%

Treatments that carries D = Dominated and ND= Non dominated

Table 8. Dominance and marginal analysis, teff yield improvement by blended fertilizer type and rate experiment in Bena Tsemay.

Treatments	Variables				
	10% Adjusted Yield kg ha^{-1}	TVC (ETB ha^{-1})	Net Benefit (ETB ha^{-1})	Dominance Analysis	MRR (%)
Control	1305.54	0	43082.82	-	-
100 kg ha^{-1} NPS + 58 kg ha^{-1} Urea	1391.76	3566.11	42361.97	D	-
100 kg ha^{-1} NPSB + 61 kg ha^{-1} Urea	1475.73	3676.90	45022.19	ND	52.75%
64 kg ha^{-1} N + 20 kg ha^{-1} P	1525.59	3735.56	46608.91	ND	2704.94%
150 kg ha^{-1} NPS + 88 kg ha^{-1} Urea	1440.09	5382.64	42140.33	D	-
150 kg ha^{-1} NPSB + 91 kg ha^{-1} Urea	1434.15	5498.57	41828.38	D	-
200 kg ha^{-1} NPS + 117 kg ha^{-1} Urea	1628.28	7165.78	46567.46	D	-
200 kg ha^{-1} NPSB + 127 kg ha^{-1} Urea	1597.32	7746.56	44965.00	D	-

Treatments that carries D = Dominated and ND= Non dominated.

Conclusion and Recommendation

The experiment was carried out to investigate the role of different blended fertilizer types and rates on improving the production of teff in Debub Ari and Bena Tsemay Districts, Southwestern Ethiopia; due to the low productivity of teff in the study area specifically and in the region as compared to the crop potential and even the national average yield which is related with depleting soil fertility, inappropriate and imbalanced application of fertilizers including blended fertilizer (which is among one of the main constraints of teff production). The result of the study has revealed that teff has responded well to the application N, P, S, and B than the unfertilized one. Application of 200 kg ha^{-1} NPSB + 127 kg ha^{-1} Urea resulted in the highest grain yield of 2299.5 kg ha^{-1} in Debub Ari and application of 200 kg ha^{-1} NPS+117 kg ha^{-1} Urea gives a higher grain yield of 1809.2 kg ha^{-1} in Bena Tsemay District, while the lowest grain yield of 886.4 kg ha^{-1} from Debub Ari and 1450.6 kg ha^{-1} from Bena Tsemay District was recorded from the nil. However, the highest economic returns/marginal rate of return of 2700.53% in Debub Ari and 2704.94% in Bena Tsemay District was recorded in response to the application of 64 kg ha^{-1} N + 20 kg ha^{-1} P. Application of 64 kg ha^{-1} N + 20 kg ha^{-1} P gives 57.24% and 14.42% yield increment in Debub Ari and Bena Tsemay district respectively; also 54.47% and 7.57% increment in economic return in Debub Ari and Bena Tsemay in the same order over the control. Therefore, we recommend the application of 64 kg ha^{-1} N+20 kg ha^{-1} P for farmers and investors to produce teff on the study area and similar agro-ecologies, as it was optimum for improving teff production. Further studies and investigation should be done on plant nutrient uptake, nutrient use efficiency, optimization and grain quality.

Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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