academicresearchJournals

Vol. 8(4), pp. 361-377, May 2020
DOI: 10.14662/ARJASR2020.018

ISSN: 2360-7874
http://www.academicresearchjournals.org/ARJASR/Index.htm

Academic Research Journal of Agricultural Science and Research

Research paper

Effect of Blended NPS and Nitrogen Fertilizers rates on Yield Components and Yield of Tef [*Eragrostis tef (*Zucc.) Trotter] at Adola District, Southern Ethiopia

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Accepted 28 May 2020

Field experiment was carried out at Adola District during the 2018 main cropping season to investigate the effect of blended NPS and N fertilizers rates on yield components and yield of teff and to identify the economically feasible rates of blended NPS and N fertilizers for high yield of teff production in the study area. The treatments consisted of factorial combinations of four levels of blended NPS (0, 50, 100 and 150 kg NPS ha^{-1}) and four levels of nitrogen (0, 23, 46 and 69 kg N ha^{-1}) fertilizer rates. The experiment was laid out as a randomized complete block design with three replications. Analysis of the results revealed that total tillers (TT), productive tillers (PT), thousand kernels weight (TKW) and lodging index (LI) were highly significant (P<0.01) for the main effect of NPS as well as the main effect of N; while aboveground dry biomass yield (BMY), grain yield (GY) and straw yield (SY) were highly significant (P<0.01) only by the main effect of NPS. The maximum TT (1291 plant m^{-2}), PT (1192 plant m^{-2}), BMY (10038 kg ha^{-1}) GY (2162 kg ha^{-1}), TKW (0.3549 g), SY (7876 kg ha^{-1}) and LI (70.83%) were recorded at the highest rate of blended NPS (150 kg NPS ha^{-1}). Similarly, the maximum TT (1232 plant m^{-2}), PT (1138 plant m^{-2}), TKW (0.3446 g) and LI (66.67%) were recorded at the highest rate of N (69 kg N ha^{-1}). The interaction of the two fertilizers were also highly significant (P<0.01) for days to 90% maturity (DM) and panicle length (PL) and significantly (P<0.05) affected by days to 50% panicle emergency (DPE) and plant height (PH).The highest DPE (49 days) and DM (86.33 days) were obtained from unfertilized (control) treatments. Maximum PH (105.72cm) and PL (43.33 cm) were recorded at combined application of 150 kg NPS with 69 kg N ha$^{- 1}$, respectively. Economic analysis result showed that combined application of 150 kg NPS and 46 kg N ha^{-1}had gave highest economic benefit of 61315.41 Birr ha^{-1} with the marginal rate of return of 852.50%. Therefore, use of 150 kg NPS and 46 kg N ha^{-1} was recommended for production of teff in the study area.

Keywords: Blended Fertilizer, Teff, Yield and Partial budget Analysis

Cite this article as: Yared T., Yibekal A., Kiya A (2020). Effect of Blended NPS and Nitrogen Fertilizers rates on Yield Components and Yield of Tef [*Eragrostis tef (Zucc.)* Trotter] at Adola District, Southern Ethiopia. Acad. Res. J. Agri. Sci. Res. 8(4): 361-377

INTRODUCTION

Teff [*Eragrostis tef* (Zucc.) Trotter] is a small cereal grain indigenous to Ethiopia. It has been recognized that Ethiopia is the center of origin and diversity of teff (Vavilov, 1951). It belongs to the grass family Poaceae and genus *Eragrostis* (Seyfu, 1993).

Teff is the most important cereal grain of Ethiopia most probably domesticated thousands of years ago before the birth of Christ (Seyfu, 1997). As a result of this, it is a part of the society's culture, tradition and food security. Teff has got both cultural and economic value for Ethiopian farmers with more than six million households' life depending on the production of teff (Tareke *et al*., 2011). It is a daily staple food for about 57.20 million people of Ethiopia, and this accounts for more than 64% of the total population of the country (ATA, 2013).

Teff covers the largest agricultural area of the country than any other types of grain, but its productivity is low (Tareke *et al.,* 2011). Currently, in Ethiopia teff is cultivated on area of about 3.02 million hectares. Teff and maize taking up about 24% and 17% of the total grain crop area, respectively (CSA, 2018). This makes teff the first among cereals in the country in area coverage. However, out of the total cereal grain produced, maize and teff accounted for 27% (8.39 million tons) and 17% (5.28 million tons), respectively (CSA, 2018), and the average national yield of teff is only 1.74 tons ha^{-1} in 2017/18 cropping season (CSA, 2018) which is very low as compared with teff yield produced at research station 2.53 to 3.2 tons ha^{-1} and its yield potential (Solomon *et al*., 2017).

The Oromia Regional State is suitable for teff production in Ethiopia. In the region, among the total land area of 4,797,159 hectares planted by cereals, teff covered 1,447,848 hectares, which is 30.2% of the production area covered by all cereals grown in the region. Among all the crops grown in the region, teff is the first major crop in area coverage (CSA, 2018). In Guji Zone, teff is one of the major cereal crops produced for the purpose of both home consumption and market. In the Zone, out of the total land size of 87,667.59 hectares planted by cereals, teff covered 19,649.60 hectares, which is 22% of the production area covered by all cereals in 2017/18 cropping season (CSA, 2018). However, out of the total cereal grain production (1,809,904.64 tons), teff accounted for 14% (257,258.43 tons), and the average yield of teff in 2017/18 cropping season was only 1.78 t ha^{-1} which is also very low as compared with the yield potential of teff. Even if the average yield is above the national average yield, the fertilizer types used are only N and P fertilizers in the study area, farmers never use balanced fertilizers both macro with micro nutrients (Yared *et al*., 2018).

The low productivity of teff could be due to a complex interaction among the environments, lack of appropriate management practices, biotic and abiotic stresses. Of these, soil fertility problem is one of the major causes of temporal and spatial yield variability (Melesse, 2007; Brhan, 2012).

The major problems affecting food production in Africa, including Ethiopia is rapid depletion of nutrients in smallholder farms (Achieng *et al.,* 2010). Low availability of nitrogen and phosphorus has been demonstrated to be a major constraint to cereal production. As summarized by Tekalign *et al*. (2001), nitrogen is deficient in almost all soils and phosphorus (P) is deficient in about 70% of the soils in Ethiopia. This low nutrient content is due to erosion and absence of nutrient recycling. On the contrary, most of the areas used for production of grains, especially teff, wheat and barley fall under the low fertile soils. Soils in the highlands of Ethiopia usually have low levels of essential plant nutrients and organic matter content (Hailu *et al.,* 2015). In Ethiopia, smallholder farmers generally apply low amounts of mineral fertilizers to crops (Morris *et al.,* 2007; Haregeweyn *et al*., 2008; Bekunda *et al*., 2010).

In Ethiopia, di-ammonium phosphate (DAP) and urea have been the only chemical fertilizers used for crop production. Earlier studies recognized that nitrogen and phosphorus are the major limiting nutrients of Ethiopian soils (Bekabil and Hassan, 2006). However, plant growth and crop production require adequate supply and balanced amounts of all nutrients, but the use of only urea and DAP have totally neglected the use of micronutrients (Mengel and Kirkby, 1996). Since deficiency of micronutrients is reported in tropical soils thereby necessitating the application of nutrient sources that reduce such deficiencies (Hassan *et al.,* 2010). This can only be achieved if the nutrient content of the fertilizer fits to the needs of the crops.

Most research work so far focused on Nitrogen and Phosphorus (NP) requirements of crops and, hence, limited information is available on various sources of fertilizers like S, Zn, B and other micronutrients. Therefore, application of other sources of nutrients beyond urea and DAP, especially those containing S, Zn, B and other micro-nutrients could increase crop productivity (CSA, 2018). Application of balanced fertilizers could be the basis to produce more crop output from existing land under cultivation through satisfying the nutrient needs of crops according to their physiological requirements and expected yields (Ryan, 2008). Ethiopian soil map indicates the fact that most Ethiopian soils suffer from deficiency of one or more of S, K, B, Zn, Mn, Cu, etc (Ethio-SIS, 2014).

It is important to increase the productivity of crops along with desirable attributes through production management practices and application of other sources of nutrients beyond the blanket recommendation of urea and DAP, especially those that contain potassium, sulfur and other micro nutrients (Ethio-SIS, 2014). Therefore, soil test based fertilizer recommendations could be designed for reducing such production constraints.

Farmers in most parts of the country in general and Adola district in particular have limited information on the impact of different types and rates of fertilizers except blanket recommendation of nitrogen (64 kg N ha^{-1}) and phosphorus (46 kg P_2O_5 ha^{-1}) that is100 kg urea and 100 kg DAP ha^{-1} (MoARD, 2008). The soil fertility mapping project in Ethiopia reported the deficiency of K, S, Zn, B and Cu in addition to N and P in major Ethiopian soils and N, P, S particularly in the study area (Ethio-SIS, 2014).

Except the blanket recommendation of nitrogen and phosphorus, the effect of other fertilizers on yield components, yield, and overall performance of teff are unknown, even though new blended fertilizers such as NPS (19% N, 38% P_2O_5, and 7% S) are currently being used by the farmers in the study area. Blended fertilizer is customized to specific type of soils and crops as well. This helps to feed crops that Urea and DAP have not managed to nourish. In addition to this, the amount of N in the blended NPS is small as compared to the requirement of teff. Thus, there is a need to supplement with nitrogenous fertilizer in the form of urea. Thus, there is a need to develop site specific recommendation on the fertilizer rates to increase production and productivity of teff. Therefore, this study was undertaken with the following objectives

To investigate the effects of blended NPS and N fertilizers rates on growth, yield components and yield of teff; and

To identifying the economically feasible rates of blended NPS and N fertilizers for high yield of teff.

MATERIALS AND METHODS

Description of Experimental Site

The experiment was conducted in Adola District on sub site of Bore agricultural research center field during the 2018 main cropping season. Adola is located 463 km away from Addis Ababa on the way to Negale Borena in the southern direction. The site of the experiment is located at latitude of 55°36'31"N, longitude of 38°58'91"E (Figure 1) and at an altitude of 1721 meters above sea level (m.a.s.l) in Guji Zone of Oromia Region.

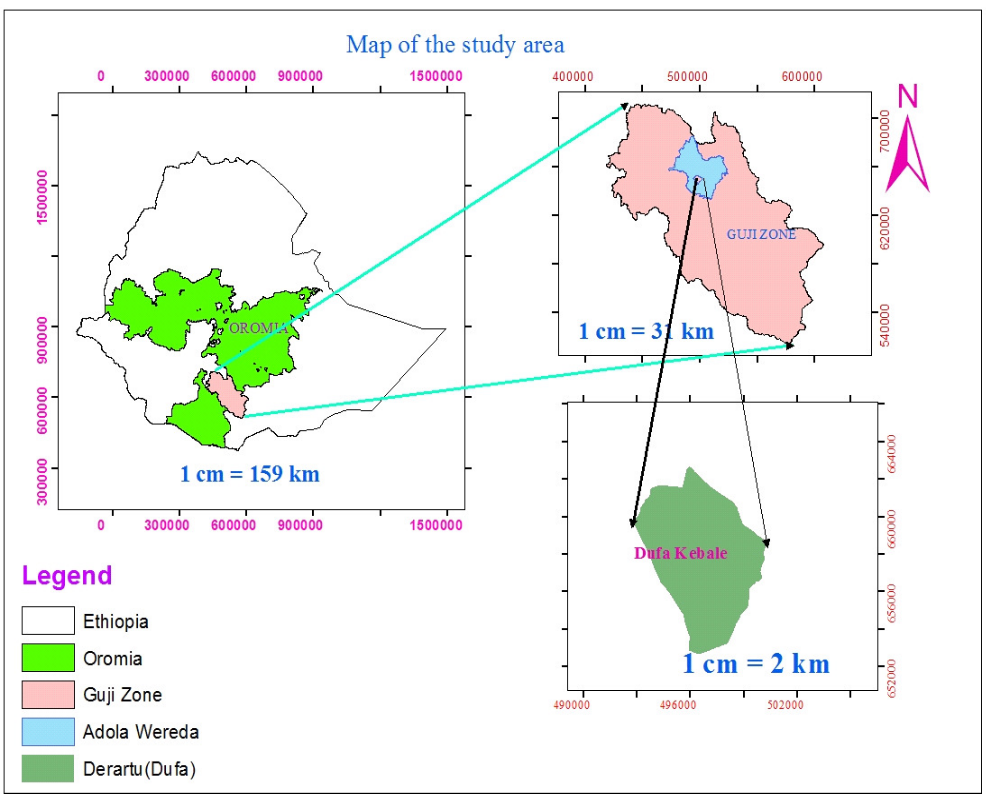

Figure 1. Map of the Study area

The climatic condition of the area is a humid moist condition mid land, with a relatively shorter main growing season (August to December). The area receives annual rainfall of 1132 mm with a bimodal pattern extending from April to November. The first rainy season (*belg*) is from April up to July and the second (main) season starts in late August and ends at the beginning of November. According to the weather record from Adola Meteorology Station, the average annual rainfall and annual mean minimum and maximum temperatures of the area based on the last 10 years (2009-2018) records were 1132 mm, and 13.5^{o}C and 26.6^{o}C, respectively. The total rainfall of the study area during the growing season was 554.9 mm which was suitable for teff production throughout the growth stages and the minimum and maximum mean temperatures were 13.5^{o}C and 25.54^{o}C, respectively.

The major soil type of the study area is red basaltic *Nitisols* and *Orthic Aerosols* soil (Yazachew and Kasahun, 2011). The treatments consisted of factorial combinations of four levels of blended NPS (0, 50, 100 and 150 kg ha^{-1}) and four levels of nitrogen (0, 23, 46 and 69 kg ha^{-1}) fertilizer rates. The experiment was laid out in randomized complete block design (RCBD) with three replications. The size of each experimental plot was 2.5 m x 2.4 m (6.0 m^2). The blocks were separated by 1.5 m wide open spaces, whereas the plots within a block were 0.5 m apart from each other. The outermost two rows from each side of a plot and 0.2 m on both ends of each rows were considered as border and were not included for recording the data. Thus, the net plot size was 2 m x 2.1 m (4.2 m^2). The entire blended NPS fertilizer was applied as per the treatments at a full dose at sowing, whereas N was applied in two splits (½ at sowing and ½ at tillering about 30 days after sowing) in the form of urea. Urea (46% N) and blended NPS (19% N, 38% P_2O_5, and 7% S) were used as a source of plants nutrient. The teff variety named 'Dagim' (DZ-Cr-438 (RIL No. 91A)) was used for the experiment. All other cultural practices were uniformly applied to each of the plots as per the recommendations

Soil Sampling and Analysis

Soil samples (0-30 cm) were collected randomly by Auger in a zigzag pattern before sowing the crop from the entire experimental field and composited into one sample. From this composite sample, a sample weighing 1.0 kg was taken. Air dried soil sample was ground with a pestle and mortar under shading. The sample was sieved through a 2 mm sieve mesh. The soil analysis was done for soil textural class, soil pH, organic carbon, total N, available P, cation exchange capacity (CEC) and, available S. The soil analyses were done at the Soils Laboratory of Horticoop Ethiopia Soil and Water Analysis Laboratory which was found at Debre Zeit town.

Soil textural Class was determined by Bouyoucos Hydrometer Method (Bouyoucos, 1962). Soil pH was determined in 1:2.5 soil: water ratio using a glass electrode attached to a digital pH meter (Page, 1982). Organic carbon was estimated by the wet digestion method (Walkley and Black, 1934) after air-dried soil was ground to pass a 0.2 mm sieve.

To determine the cation exchange capacity (cmol kg^{-1} soil), the soil sample first was leached using 1 M ammonium acetate, washed with ethanol and the adsorbed ammonium was replaced by sodium (Na). Then, the CEC was determined titrimetrically by distillation of ammonia that was displaced by Na (Sahlemedhin and Taye, 2000). Total nitrogen (%) was determined using the Kjeldhal method (Jackson, 1973). Available phosphorus (ppm) was determined by Olsen method (Olsen *et al*., 1954). Available sulfur (S) was determined by mono-calcium phosphate extraction method (Hoeft *et al.,* 1973).

Data Collected

Effect of blended NPS and N fertilizers rate were investigated by measuring data on phenology, growth, and yield component, and yield parameters. Data on phonological parameters were measured through visual observation as the number of days from sowing to when 50% of plants in a net plot had reached head emergency/flowering and 90% physiological maturity. Data on growth and yield component parameters were taken in each plot from ten randomly selected plants and count plants per m^2 at physiological maturity and at harvest time, respectively. For above ground biomass yield, straw yield, and grain yield the whole plant from the net plot area was harvested and the yield per hectare was determined by converting the yield per plot (kg per plot) into kg per hectare.

Lodging index (%): The degree of lodging was assessed just before the time of harvest by visual observation based on the scales of 1-5 where 1 (0-15^o) indicates no lodging, 2 (15-30^o) indicate 25% lodging, 3 (30-45^o) 50% indicate lodging, 4 (45-60^o) indicate 75% lodging and 5 (60-90^o) indicate 100% lodging (Donald, 2004). The scales were determined by the angle of inclination of the main stem from the vertical line to the base of the stem by visual observation. Each plot was divided based on the displacement of the aerial stem in to all scales by visual observation. Each scale was multiplied by the corresponding percent given for each scale and average of the scales represents the lodging percentage of that plot.

Data Analysis

The collected Data were subjected to analysis of variance

(ANOVA) using GenStat release 18th ed. software (GenStat, 2014). The result interpretations were made following the procedure of Gomez and Gomez (1984). Mean separation were done using the Fishers' protected Least Significant Difference (LSD) test at 5% level of significance.

Economic Analysis

An economic analysis was done using partial budget procedure described by CIMMYT (1988). Labour costs involved for application of blended NPS and N fertilizer rates were recorded and used for analysis. The current (November to December, 2018) price of grain and straw yield of tef were valued at an average open market price at Adola town which were 24 birr kg^{-1} and 1.5 birr kg^{-1}, respectively. The net returns (benefits) and other economic analysis were based on the formula developed by CIMMYT (1988) and given as follows:

RESULTS AND DISCUSSION

Soil Physico-Chemical Properties

The results of the pre-sowing laboratory analyses indicated that the soil of experimental site was 51% clay, 22% silt and 27% sand (Table 1). Thus, the texture class of the soil was clay according to Bouyoucos (1962) classification. The texture properties of the soil influence water holding capacity, water intake rates, aeration, and root penetration. Thus, the soil texture is suitable for teff production as it is well adapted to a wide range of soil types and ability to perform well in heavy soil (ATA, 2013). So in clay soil high rain fall/heavy irrigation/accumulation of water in the field causes yield reduction in most crops.

The pH of the soil was 6.10 (Table 3) which was slightly acid (Tekalign, 1991). This value falls in the pH range that is very conducive for teff production since an optimum soil pH for teff production is from 6 to 7.5 (Seyfu, 1993).

Cation exchange capacity (CEC) is an important parameter of soil, because it gives an indication of the type of clay mineral present in the soil and its capacity to retain nutrients against leaching. The CEC of the soil was 40.92 meq /100g (Table 1) soil which was very high in its capacity to retain cations (Landon, 1991). According to Landon (1991), CEC of the soils greater than 40 cmol (+)/kg rated as very high, 25-40 cmol (+)/kg as high, and CEC of soil from 15-25, 5-15 and < 5 cmol (+)/kg of soil are classified as medium, low, and very low, respectively.

The organic carbon (OC) analysis indicated that the experimental field had 2.13% organic carbon and 3.67 organic matters (Table 1) both of them were in medium range as per Booker (1991).

Tekalign (1991), has classified soil total N content of < 0.05% as very low, 0.05-0.12% as poor, 0.12-0.25% as moderate and > 0.25% as high. The total nitrogen of experimental soil was 0.14% (Table 3) which was medium according to the classification of Tekalign (1991). Olsen *et al.* (1954), classified soil P availability of <3 ppm as very low, 4-7 ppm as low, 8-11 ppm as medium, 12-20 ppm as high, and >20 ppm as very high. Therefore, the experimental site soil has medium P content of 10.71 ppm (Table 1).

The analysis for available sulfur indicated that the experimental soil had value of 6.18 ppm of available sulfur which is rated under very low according to Ethio-SIS (2014). Ethio-SIS (2014), rating soil which is < 9 mg kg^{-1} (very low), 10-20 mg kg^{-1} (low), 20-80 mg kg^{-1}(medium), 80-100 mg kg^{-1} (high) and >100 $mgkg^{-1}$of soil very high. Thus, the soil of the experimental site was considered as very low in available sulfur content, which is unsatisfactory for optimum teff growth and yield. Thus, it is important to apply sulfur sources fertilizer for good crop growth and yield (FAO, 2008).

Table 1. Soil physical and chemical properties of the experimental site before planting

Soil properties	Values	Ratings
A. Physical properties		
Clay (%)	51	-
Silt (%)	22	-
Sand (%)	27	-
Textural class	Clay	
B. Chemical Properties		
pH (1:2.5 H_2O)	6.10	Moderately acid
Organic carbon (%)	2.13	Medium
Organic matter	3.67	Medium
Total nitrogen (%)	0.14	Medium
Available P (ppm)	10.71	Medium
CEC (meq/100 g soil)	40.92	Very high
Available sulfur (ppm)	6.18	Very low

Phenological Traits

Days to panicle emergence

The analysis of variance showed that the main effects of blended NPS and N fertilizer rates were highly significant ($P<0.01$), and the interaction effect was significant ($P<0.05$) on days to panicle emergence of teff. The highest days to 50% panicle emergence (49 days) was recorded for the control plots, while the lowest (37 days) was recorded for the highest rates of 150 kg blended NPS ha^{-1} combined with 69 kg N ha^{-1} fertilizers (Table 2). On the other hand, the second lowest days to panicle emergence (39 days) was recorded with the combination of 150 kg blended NPS ha^{-1} and 46 kg N ha^{-1}.

Application of N and blended NPS fertilizer hastened the days to Panicle emergence because the teff plants were able to take up sufficient nutrients from the soil which encouraged early establishment, rapid growth and development of crop. Assefa (2016), also indicated that as the rate of NP increased, the number of days elapsed to heading was shortened. Hence, the longest days to Panicle emergence was recorded in the control plots. Similar result was reported by Seifu (2018), in which the highest days to 50% panicle emergence (73 days) was recorded from the control plot, while the lowest (50 days) was recorded from the combined application of 69 kg N with 150 kg blended (NPSB) ha^{-1} fertilizers. Similarly, Teshome (2018), reported that combined application of 200 kg ha^{-1} NPS with 138 kg ha^{-1} N fertilizer reduced days to panicle emergency compared to unfertilized plot in teff. Wakjira (2018), reported that application of NPS significantly shortened days to heading of teff than control. In line with the current finding, application of N fertilizer reduced days to heading compared to unfertilized treatment in teff (Temesegen, 2012; Shiferaw, 2012).

This result is in contrast with Legesse (2004), who reported that N fertilization at the rate of 46 kg N ha^{-1} significantly delayed the heading stage of teff by five days as compared to the control. Similarly, Abraha (2013), reported that the application of N at the rate of 46 kg ha^{-1} delayed days to heading of teff over the control. This may be due to longer time required to establish, grow and complete the vegetative growth.

Table 2. Mean number of days to 50% panicle emergence of teff as affected by the interaction of blended NPS and N fertilizer rates

Blended NPS (kg ha^{-1}) fertilizer rates	N (kg ha^{-1}) fertilizer rates			
	0	23	46	69
0	49.00^{a}	46.00^{b}	45.00^{b}	42.33^{c}
50	40.67^{cde}	42.00^{cd}	40.33^{cd}	39.00^{e}
100	40.33^{de}	40.33^{de}	39.33^{e}	39.67^{e}
150	39.00^{e}	40.00^{e}	39.00^{e}	37.00^{f}
LSD (0.05)	1.86			
CV (%)	2.7			

Where, LSD= Least Significant Difference at 5% level; CV= Coefficient of Variation.
Means in column and row followed by the same letter(s) are not significantly different at 5% level of significance.

Days to physiological maturity

The analysis of variance showed that main effects of blended NPS and N fertilizer rates as well as the interaction of the two factors were highly significant ($P<0.01$) on days to physiological maturity of teff.

Similar to that of the days to 50% panicle emergence, the highest value for days to 90% physiological maturity (86.33 days) was recorded from the unfertilized (control) plots while the lowest physiological maturity (71 days) were recorded from the highest rate of 150/69 and 150/46, blended NPS combined with N kg ha^{-1} fertilizer rates respectively (Table 3).

The enhanced maturity with the application of blended fertilizer could be due to the presence of balanced fertilizer in the blended fertilizer. Normally, crops treated with N show better vegetative growth and that treated with P fertilizer exhibit good root development to reach physiological maturity in time. Brady and Weil (2002), described that phosphorus application could possibly shorten maturity date since it promotes rapid cell division. Onasanya *et al.* (2009), showed that phosphorus plays an important role in many physiological processes that occur within a developing and maturing plants. It is involved in enzymatic reactions in the plant and hastens the maturity of plants. However, the delay of physiological maturity in unfertilized plots may be due to insufficient amount of essential elements.

Consistent with this result, Seifu (2018), reported that the shortest days (95) to physiological maturity of teff were obtained from the application of 150 kg NPSB ha^{-1} and 69 kg N ha^{-1} and the longest days (106) from the control. In line with the result, Tilahun *et al.* (2013), reported that increasing of P_2O_5 from 50 kg ha^{-1} to 100 kg ha^{-1} with increasing compost rate from 0 to 7.5 t ha^{-1} showed reduction in days to maturity and increased grain yield of rice. Similarly, Getahun *et al.* (2018), reported that the shortest days (91) to physiological maturity of teff were obtained from the application of 69 kg N ha^{-1} and 30 kg P_2O_5 ha^{-1} and the longest days (97) from the control.

The result of present study is contrary with the result of Abraha (2013) reported that as the rate of N increased from 0 to 69 kg N ha^{-1}, days to maturity of teff was significantly delayed. In the same way Teshome (2018), reported that physiological maturity of teff was not significantly affected by the main effects blended NPS and N fertilizers rate and by their interaction.

Table 3. Mean days to maturity of teff as affected by the interaction of blended NPS and N fertilizer rates

	N (kg ha^{-1}) fertilizer rates			
Blended NPS (kg ha^{-1}) fertilizer rates	0	23	46	69
0	86.33^{a}	80.33^{b}	76.67^{d}	76.67^{d}
50	80.67^{b}	80.67^{b}	78.00^{cd}	77.67^{cd}
100	78.33^{c}	76.67^{d}	77.67^{cd}	77.33^{cd}
150	78.67^{c}	73.67^{e}	72.00^{f}	71.00^{f}
LSD (0.05)	2.41			
CV (%)	1.1			

Where, LSD= Least Significant Difference at 5% level; CV= Coefficient of Variation.
Means in column and row followed by the same letter(s) are not significantly different at 5% level of significance.

Growth Parameters

Plant height

The result of analysis of variance indicated that the main effect of N was highly significant (P< 0.01), blended fertilizer as well as their interactions were significantly (P< 0.05) influenced plant height of teff.

The tallest plant height (105.72 cm) was obtained at the rate of 150 kg blended NPS ha^{-1} combined with 69 kg ha^{-1} of N which was statistically at par with the rate of 150 kg blended NPS ha^{-1} with 46 kg ha^{-1} N. However, the shortest plant height (77.95 cm) was obtained from the control plot, but other treatment combinations were statistically at par with each other (Table 4). This significant increment may be attributed to the fact that N usually favors vegetative growth of teff, resulting in higher stature of plants while P is main element involved in energy transfer for cellular metabolism in addition to its structural role and sulphur enhanced the formation of chlorophyll and encouraged vegetative growth (Halvin *et al.*, 2003). A similar result was reported by Teshome (2018) where application of 200 kg ha^{-1} blended fertilizer (NPSZnB) combined with 138 kg N ha^{-1} significantly increased plant height of teff. Sate (2012), also reported that plant height of teff was significantly affected by application of P and N with blended fertilizer. Conformity with the results of Bakala (2018) reported application of blended fertilizer under balanced N increased plant height of maize. Generally, increased combined application of N and blended fertilizer showed consistent increment in plant height.

In contrast to this finding, Esayas, 2015; and Adera, 2016 reported that plant height of teff was not significantly affected by the rate and type of different blended fertilizers. The lack of significance among the blended fertilizer treatments might be due to the constant amount of nitrogen they uses (64 kg N ha^{-1}) for all rate and types of treatments in which the increase in nitrogen rate increases the plant height. Bizuwork (2018), also reported non-significant main and interaction effect of blended fertilizer rate on plant height of durum wheat. Similarly, Usman (2018), also reported that NPSB rate at 0-200 kg ha^{-1} had non-significant effect on plant height in bread wheat.

Table 4. Mean plant height (cm) of teff as affected by the interaction of blended NPS and N fertilizer rates

Blended NPS (kg ha^{-1}) fertilizer rates	N (kg ha^{-1}) fertilizer rates			
	0	23	46	69
0	77.95^{d}	95.05^{c}	103.72^{abc}	103.07^{abc}
50	95.83^{bc}	97.35^{abc}	99.28^{abc}	102.00^{abc}
100	101.61^{abc}	99.72^{abc}	102.56^{abc}	103.12^{abc}
150	100.22^{abc}	104.11^{ab}	105.05^{a}	105.72^{a}
LSD (0.05)	8.7			
CV (%)	5.2			

Where, LSD= Least Significant Difference at 5% level; CV= Coefficient of Variation.
Means in column and row followed by the same letter(s) are not significantly different at 5% level of significance

Panicle length

The main effect of blended NPS and N fertilizer rate highly significant (P<0.01) effect on panicle length and the interaction effect of the two factors were also highly significant.

Similar to plant height, panicle length also increased with increasing combined application of blended NPS with N fertilizer rate. The highest panicle length of 43.66 cm was recorded at the highest rate of blended NPS 150 kg ha^{-1} combined with 69 kg N ha^{-1} while the shortest mean panicle length of 28.5 cm was recorded from the unfertilized plot (Table 6). This highest panicle length is due to efficient blended NPS with nitrogen plays critical role in the structure of chlorophyll and other proteins which favor vegetative growth of teff which results in taller teff plants having relatively greater panicle length.

In many studies, the effect of high N and P application on teff yield was attributed to the major role played by panicle length on grain yield (Mulugeta, 2003; Legesse, 2004; Mitiku, 2008; Haftamu *et al*., 2009). Longer panicles bear more number of spikeletes that contain higher number of grains, higher total biomass and straw yield. This result is consistent with the findings of Mulugeta (2003); Legesse (2004); Mitiku (2008) and Haftamu *et al*. (2009), who reported that panicle length exhibited positive and highly significant correlation with plant height and grain yield.

In line with this result, Adera (2016), reported that the application 150 kg ha^{-1} of blended NPSKZnB) fertilizer combined with that contained 64 kg^{-1} resulted into higher panicle length. Wakjira (2018), reported that increasing the application of blended fertilizer rate from 0 to 120 kg ha^{-1} markedly increased the panicle length of the teff by about 61.6%. In accord with result, Fayera *et al.* (2014), reported that the longest panicle length (45.60 cm) was obtained from the application of 150 kg ha^{-1} blended NPKSZnB with 23 kg N ha^{-1} while the shortest (30.17 cm) was recorded from the control. Thus, increasing N from 0 to 64 kg N ha^{-1} with 200 kg ha^{-1} blended fertilizer was increased panicle length by 40%, compared to the control (Molla, 2016)

Table 5. Mean panicle length (cm) of teff as affected by the interaction of blended NPS and N fertilizer rates.

Blended NPS (kg ha^{-1}) fertilizer rates	N (kg ha^{-1}) fertilizer rates			
	0	23	46	69
0	28.50^{k}	34.00^{j}	35.00^{h}	37.11^{f}
50	34.00^{j}	37.18^{f}	37.22^{f}	37.87^{d}
100	35.33^{g}	37.55^{e}	37.61^{e}	38.00^{d}
150	34.67^{i}	38.95^{c}	40.67^{b}	43.33^{a}
LSD (0.05)	0.26			
CV (%)	0.4			

Where, LSD= Least Significant Difference at 5% level; CV= Coefficient of Variation.
Means in column and row followed by the same letter(s) are not significantly different at 5% level of significance.

Yield Components and Yield

Number of total tillers

Analysis of variance showed that main effect of blended NPS and N fertilizer rates were highly significant (P<0.01) on the number of total tillers of teff. However, the interaction effect of the two factors was not significant.

The highest number of total tillers (1291plants m^{-2}) was obtained with the application of blended fertilizer 150 kg NPS ha^{-1}, while the lowest number of total tillers (897 plant m^{-2}) was obtained from the unfertilized plots (Table 6). The highest number of tillers at the highest rates of NPS might be due to the rapid conversion of synthesized carbohydrates into protein and consequently increased the number and size of growing cells, ultimately resulting in increased number of tillers. The improvement in total number of tillers with NPS application might be due to the role of P found in NPS in developing radical and seminal roots during seedling establishment (Cook and Veseth, 1991).

This result is in agreement with that of Brhan (2012), who reported that application of blended fertilizer (69 kg N ha^{-1} + 46 kg P_2O_5 + 22 kg S ha^{-1} + 0.3 kg Zn ha^{-1}) brought significant increase in total tillers (15 tillers per plant) of teff as compared to 5 tillers per plant of unfertilized plot. In agreement with the result, Wakjira (2018), reported total number of tillers increased consistently and significantly in response to increasing the rate of blended NPS fertilizer from nil to 120 kg ha^{-1}. Seifu (2018), reported that highest total number of tillers of teff was obtained from the application of the highest rate 150 kgha^{-1} blended (NPSB) fertilizer whereas the lowest number of tillers was from the control plot.

This result is in contrary to the finding of Teshome (2018), who reported non-significant difference on total number of tiller in teff as the rate of blended fertilizer (NPSZnB) increased from zero to 250 kg ha^{-1}. Adera (2016), also reported that total tiller of teff was not significantly affected by the rate and type of different blended fertilizers. In line with the result, Esayas (2015), reported non-significant differences in the numbers of total tillers per plant among different blended fertilizers in durum wheat.

Similarly, the highest number of total tillers (1232 plants m^{-2}) was obtained with the application of 69 kg N ha^{-1} while, the lowest number (928 plants m^{-2}) was obtained from the control plot. The increase in the number of total tillers with increased rate of nitrogen might be due to the increased availability of N that played a positive role in cytokinin synthesis which is a key plant hormone for cell division. Consistent with this result, Seifu (2018); Teshome (2018) and Haftamu *et al.* (2009), reported significantly higher number of total tillers in response to the application of high N rate on teff. The current result is also in agreement with that of Okubay *et al.* (2014), who reported significantly increased number of total tillers with increasing levels of N from 0 to 69 kg ha^{-1} in teff. Furthermore, Melesse (2007) reported that as the N fertilizer rate increased from 0 to 69 kg ha^{-1}, the total number of tillers of bread wheat was increased from 4 to 7 per plant.

Number of productive tillers

The main effects of both blended NPS and N fertilizer rates were highly significant (P<0.01) on number of productive tillers of teff. However, the interaction effect of the two factors was not significant.

The highest number of productive tillers (1192 plants m^{-2}) was obtained with the application of blended fertilizer at the rate of 150 kg NPS ha^{-1}, while the lowest number of productive tillers (753 plants m^{-2}) was obtained from the control plots (Table 6). The highest number of productive tillers might be due to sufficient amount of growth and development of plants owing to the essential elements under blended NPS fertilizer condition.

In agreement with the results of this study, Fayera *et al.* (2014), found the highest productive tillers of teff (26 tillers per plant) under the application of 200 kg $ha^{-1}$of NPKSZnB blended fertilizer (14N, 21P_2O_5, 15K_2O, 6.5S, 1.3Zn and 0.5B) combined with 23 kg N ha^{-1} fertilizer. This result is also supported by the findings of Wakjira (2018), where productive tiller number of teff was increase from 8.62 to 15.17 under the application blended NPS fertilizer rates at zero and 120 kg ha^{-1} respectively. Similarly, Seifu (2018), reported that highest number of productive tillers of teff was obtained from the application of the 150 kg ha^{-1} blended (NPSB) fertilizer rate while the lowest number of productive tillers obtained from the control plot.

The number of productive tillers was significantly increased in response to increasing application rate of nitrogen. The maximum number of productive tillers (1138 plant m^{-2}) was recorded in response to nitrogen applied at the rate of 69 kg N ha^{-1}, whereas the lowest number of productive tillers (839 plant m^{-2}) was recorded from the control. The maximum number of productive tillers may be due to nitrogen promotes activities essential for carbohydrate utilization and its most important function in plant promotion of rapid growth through increasing productive number of tillers. Maqsood *et al.* (1999), reported that the increase in the number of fertile tillers with increasing nitrogen levels could be attributed to the well-accepted role of nitrogen in accelerating vegetative growth of plants.

The present result is in agreement with the study by Adugna (2017), who reported that the number of productive tillers of teff was affected significantly by N fertilizer application. He indicated that the maximum number of productive tillers was recorded with 111 kg N

ha^{-1} fertilizer rate, while the lowest number of productive tillers recorded at lower rates of N (42 kg N ha^{-1}). Similarly, Haftom *et al.* (2009), reported higher number of productive tillers of teff with application of 69 kg N ha^{-1}. Additionally, Okubay *et al.* (2014), reported that highest fertile tillers (23 per plant) of teff from the application of the highest rate (69 kg N ha^{-1}), whereas the lowest number of fertile tillers per plant was obtained from the control plot.

Table 6. Mean numbers of total and productive tillers of teff as influenced by the main effects of blended NPS and N fertilizer rates

Treatment Blended NPS rate (kg ha^{-1})	Total tillers per m^2	Productive tillers per m^2
0	897^{c}	753^{c}
50	1022^{b}	956^{b}
100	1105^{ab}	1035^{ab}
150	1291^{a}	1192^{a}
LSD (5%)	186.7	180.1
N Rate (kg ha^{-1})		
0	928^{b}	839^{b}
23	1093^{ab}	977^{ab}
46	1153^{ab}	1011^{ab}
69	1232^{ab}	1138^{a}
LSD (5%)	186.7	180.1
CV (%)	15.4	17.3

Where, LSD (0.05) = Least Significant Difference at 5% level; CV= coefficient of variation. Means in column followed by the same letter(s) are not significantly different at 5% level of significance.

Grain yield

Analysis of variance revealed that main effects of blended NPS fertilizer rates were highly significant (P<0.01) on grain yield of teff while the main effects of N and interaction effect of the two factors was not significant.

As the application rate of blended NPS fertilizer increased from 0 to 150 kg ha^{-1}, there was increasing trend in mean grain yield though all increases are not statistically significant (Table 7). The highest grain yield (2162 kg ha^{-1}) of teff was obtained at the highest rate of blended (150 kg NPS ha^{-1}) fertilizer application, while the lowest grain yield of 1045 kg ha^{-1} was recorded from control (unfertilized) plot. However, the highest grain yield recorded at blended 150 kg NPS ha^{-1} fertilizer rate was at par with the yield obtained from 100 kg blended NPS ha^{-1} fertilizer (Table 7).

The highest grain yield at the highest NPS rates might have resulted from improved canopy and root growth resulting in increased photosynthetic product and increased uptake of nutrients favoring increased growth which enhanced yield components and yield. The application of P is reported to be of secondary importance in many soils and is recommended at minimum levels of application except in highly weathered soils that fix considerable amount of applied P (Tekalign *et al.,* 2002). However, the present study showed that P tended to increase yields of teff (Table 7).

In conformity with this finding, Seifu (2018) reported the highest grain yield (3228 kg ha^{-1}) at 150 kg blended NPSB ha^{-1} while the lowest grain (2503 kg ha^{-1}) was obtained from control (unfertilized) plot. The present result is in agreement with the study conducted by Teshome (2018) who reported that application of 100 kg NPSZnB ha^{-1} produced the maximum grain yield (1386.5 kg ha^{-1}) of teff, while the lowest grain yield (1085.8 kg ha^{-1}) was obtained under the control treatment. Brhan (2012) reported that treatments that received blended fertilizers (69 kg N ha^{-1} + 46 kg P_2O_5 + 22 kg S ha^{-1} + 0.3 kg Zn ha^{-1}) under row planting of teff given 4155 kg ha^{-1} grain yield which showed an increase of 30% and 378% over treatments that receive 100 kg ha^{-1} urea and DAP under row planting and control plots, respectively. Additionally, Wakjira (2018) reported that increasing NPS rate from 0 to 120 kg ha^{-1} increased grain yield of teff by 28.3% in transplanting sowing methods. Adera (2016), also reported the highest grain yield of teff (1301 kg ha^{-1}) at 200 kg blended NPKSZnB ha^{-1} fertilizer application over the recommended NP (64 N and 46 P kg ha^{-1}) treated plot. Similarly, Jarvan *et al.* (2012), reported that the addition of 100 kg N ha^{-1} with 10 kg S ha^{-1} to winter wheat gave yield of 5.88 t ha^{-1} while it gave 5.73 t ha^{-1} when 100 kg N ha^{-1} with 6 kg ha^{-1} S.

Aboveground biomass yield

The analysis of variance showed highly significantly (P<0.01) different in above ground dry biomass yields due to the main effect of blended NPS fertilizer while main effects of N fertilizer, and their interactions were non-significant (Appendix 5).

The highest aboveground biomass yield (10,038 kg ha^{-1}) was recorded at the highest rate of blended NPS (150 kg ha^{-1}) which is statistically at par with 100 kg NPS ha^{-1} with mean aboveground biomass yields of (9421 kg ha^{-1}), the lowest dry biomass yield (5,222 kg ha^{-1}) was obtained from the control plot (Table 9). Increase in aboveground biomass of teff due to high nutrients particularly NPS might be due to increased leaf area index and protein synthesis that enable the plants capture ample solar radiation, which may result in the corresponding increment of photosynthetic rate (Hurder *et al*., 2007). Furthermore, increase in aboveground dry biomass at the highest rates of NPS might have resulted from improved root growth and increased uptake of nutrients favoring better growth of the crop due to synergetic effect of the three nutrients (NPS) (Fageria *et al.,*2011).

The result was in conformity with the findings of (Bereket *et al.,* 2014; Adera, 2016; Seifu, 2018) they showed that above ground dry biomass yield was significantly affected by application of blended fertilizer. Similarly, Wakjira (2018), reported that application of blended NPS fertilizer show significant increment in aboveground biomass yield of teff from 841 to 1009 kg ha^{-1} at 0 and 120 kg blended NPS ha^{-1}.

Thousand Kernel weight

Analysis of variance revealed that, thousand kernel weights was highly significantly (P < 0.01) affected due to the main effects of NPS and significantly (P<0.05) influenced by N fertilizer applications, but the interaction effect of the two factors were not significant (Table 7).

The highest thousand kernels weight (0.345 g) was recorded at application of 69 kg N ha^{-1} while, the lowest thousand kernels weight (0.333 g) was observed at control (0 kg N ha^{-1}). Increasing the supply of nitrogen fertilizer from nil to 69 kg ha^{-1} increased thousand kernels weight by 3.4%. Nitrogen application increased from 0 to 69 kg ha^{-1} on teff showed consistent increment in thousand kernel weight. Thousand kernels weight recorded from the 69 kg N ha^{-1} fertilized plot exceed thousand kernels weight obtained from the other N treated plot, but not significantly different.

Mengel and Kirkby (1996), reported that N is an indispensable element and an integral component of many essential plant compounds such as amino acids that are a building blocks of all proteins including enzymes and chlorophyll (Brady and Weil, 2002). In accord with this finding, Channabasavanna and Setty (1994), reported increased thousand kernel weight due to N application in rice but with lower level. Bekalu and Mamo (2016), reported that nitrogen applied at 69 kg ha^{-1} gave the highest thousand kernels weight (57.00 g) than the unfertilized plot (46.79 g) for bread wheat. Similarly, Tilahun *et al.* (2017), reported highest thousand kernels weight (59.99 g) at the highest nitrogen rate (92 kg ha^{-1}) for durum wheat.

In contrast to this result Kosmolak and Crowle (1980) indicated that N fertilizer applied at rates to optimize yield response does not necessarily give comparable improvements in thousand grain weight in cereal production. Gooding and Davis (1997), also reported non-significant effect on thousand grain weight due to different doses of N fertilizers in bread wheat cultivars**.**

The significantly highest thousand kernel weight (0.3549 g) was recorded due to the application of 150 kg ha^{-1} blended NPS while the lowest (0.3233 g) was recorded from unfertilized plot (Table 9). Generally, increased application of blended NPS from 0 to 150 kg ha^{-1} on teff showed consistently and significantly increased thousand kernel weight. Significant differences in thousand kernel weight due to application of fertilizers might result from the effects of the P fertilizers on yield parameters. FAO (2000), noted that sufficient P enhances many features of plant physiology, like fundamental process of photosynthesis, flowering, seed production, and maturation.

In accord with this result, Temesgen (2012) reported the highest thousand grain weight of teff (0.339 g) was obtained at 100 kg P ha^{-1} while the lowest (0.219 g) was obtained from control plot. Similar to the current study, Channabasavanna and Setty (1994), also noted that P showed considerable effect on thousand grain weight increment in rice. Significant differences in thousand grain weight among various wheat varieties were reported by Melesse (2007). The result of the current study is however, not in accord with those of Legesse (2004) and Gurmessa (2002), who found that neither the main effect of N and P application nor their interaction brought about significant difference in thousand grain weights in teff and wheat, respectively. Similarly, Seifu (2018), reported that thousand kernel weight of teff was not significantly influenced by blended NPSB and N fertilizer rates as well as the interaction of these two.

Straw yield

The main effects of blended NPS was highly significant (P<0.01) on straw yield of teff While main effects of N fertilizer rates and the interaction effect of the two factors on straw yield of teff were not significant.

The highest straw yield (7876 kg ha^{-1}) was recorded from application of 150 kg NPS ha^{-1} fertilizer rates, though statistically at par with the application of 100 kg ha^{-1} of NPS fertilizer rates, while the lowest straw yield (4178 kg ha^{-1}) was recorded from the control (unfertilized) plot (Table 7). The significantly increased in straw yield in response to the highest rate application of NPS might be attributed to the synergic roles of the nutrients in enhancing growth and development of the crop. Similar results were found by Fayera *et al.* (2014), who indicated that the highest straw yield (5852.80 kg ha^{-1}) of teff was obtained in response to the application of higher rates (200 kg ha^{-1}) of blended NPKSZnB application.

Straw yield of teff has to be considered while evaluation of any agronomic practice as its importance has become as equal as its grain yield as it is preferred as animal feed during dry period and also sold at reasonable price.

Lodging index

The main effects of blended NPS and N fertilizer rates were highly significant (P<0.01) on lodging index of teff while the interaction effect of the two factors was not significant.

The highest lodging index 66.67% was obtained from application of 69 kg N ha^{-1} and the lowest 33.33 from the control plot (Table 7). Marked increases in lodging index due to the increased application of nitrogen fertilizer were observed. This may be due to increasing rate of total nitrogen that enhanced fast vegetative growth, plant height and succulent stem elongation of teff. According to Bekabil *et al.* (2011), almost all teff varieties are susceptible to lodging. However, there is trade-off between fertilizer use and lodging as fertilizer leads to increase in the number of panicles and grains per panicle, which in turn increases the weight of the stem and the likelihood of lodging. This result is consistent with that of Abraha (2013), who reported that lodging in cereals is considered to be caused by high rate of nitrogen fertilizer application.

Similarly, Tekalign *et al.* (2000), obtained significant differences in lodging percentage of teff due to N application above the rate of 60 kg ha^{-1}. This result is consistent with the suggestion of Brady and Weil (2002), that excess N application causes high vegetative growth, and enlargement of stem cells that consequently leads to weak stem and lodging.

The highest lodging index 70.83% was obtained from 150 kg ha^{-1} blended fertilizer, while the lowest 31.25% was from the control plot. This result was in line with the findings of Teshome (2018), who reported highest lodging of teff (38.92 %) at 150 kg ha^{-1} of blended fertilizer rates. Similarly, Shiferaw (2012), reported highest lodging of teff (74%) at N/P2O5 rate of 64/46 kg ha^{-1}. Likewise, Fayera *et al*. (2014) reported the highest lodging percentage (79.74%) of teff with the highest rate of NPK (138 kg N ha^{-1} combined with 55 kg P $ha^{-1}$and 0 kg K2O ha^{-1}) application.

Table 9. Mean aboveground biomass yield, grain yield, thousand kernels weight, straw yield, and lodging index of teff as influenced by the main effects of blended NPS and N fertilizer rates

Treatment	Aboveground biomass yield (kg ha^{-1})	Grain yield (kg ha^{-1})	Thousand kernels weight (g)	Straw yield (kg ha^{-1})	Lodging index (%)
Blended NPS rate (kg ha^{-1})					
0	5222^{c}	1045^{c}	0.3233^{d}	4178^{c}	31.25^{c}
50	7916^{b}	1743^{b}	0.3371^{c}	6173^{b}	37.50^{c}
100	9421^{a}	2106^{a}	0.3468^{b}	7315^{a}	56.25^{b}
150	10038^{a}	2162^{a}	0.3549^{a}	7876^{a}	70.83^{a}
LSD (5%)	892.2	139.7	0.0062	867.7	11.50
N rate (kg ha^{-1})					
0	7661	1721	0.3333^{b}	5939	33.33^{c}
23	8139	1724	0.3414^{a}	6375	43.75^{bc}
46	8237	1764	0.3428^{a}	6413	52.08^{b}
69	8560	1796	0.3446^{a}	6814	66.67^{a}
LSD (5%)	NS	NS	0.0062	NS	11.50
CV (%)	11.0	9.5	1.9	13.4	11.2

Where, LSD (0.05) = Least Significant Difference at 5% level; CV= coefficient of variation; NS= non-significant. Means in column followed by the same letters are not significantly different at 5% level of significance.

Partial Budget Analysis

As indicated in Table 10, the highest net benefit of 61315.41 Birr ha^{-1} with marginal rate of return (MRR) of 852.50% was obtained in response to application of 150 kg blended NPS ha^{-1} combined with 46 kg N ha^{-1}. However, the lowest net benefit 24348.61 Birr ha^{-1} was obtained for the control treatment without the application of both NPS and N fertilizer rates. Thus, applications of 150 kg blended NPS ha^{-1} combined with 46 kg N ha^{-1} rate is economically beneficial as compared to the other treatments in the study area because the highest net benefit and the marginal rate of return was above the minimum level (100%). This implies that for every one birr invested in Urea and blended fertilizer application, farmers can expect to recover the 1 birr ha^{-1} and obtain an additional 852.50 birr ha^{-1}.

Table 10. Summary of partial budget analysis of the effects of blended NPS and N fertilizer rates application on teff

Treatment		Adjusted grain yield (kg ha^{-1})	Adjusted straw yield (kg ha^{-1})	Total revenue (ETBha^{-1})	Total variable cost (ETB ha^{-1})	Net benefit (ETBha^{-1})	MRR (%)
Blended NPS (kg ha^{-1})	N (kg ha^{-1})						
0	0	810.73	3260.69	24348.61	0	24348.61	0
0	23	889.28	3207.13	26153.59	556.0	25597.59	225.00
0	46	1037.14	3285.71	29820.04	1092.0	28728.04	584.04
0	69	1053.57	5285.75	33214.30	1628.0	31586.30	534.00
50	0	1457.15	5260.698	42862.81	672.5	42190.31	D
50	23	1632.14	5682.174	47694.71	1228.5	46466.21	769.05
50	46	1617.87	5439.285	46987.95	1764.5	45223.45	D
50	69	1567.85	5839.28	46387.49	2300.5	44086.94	-212.04
100	0	1839.28	6657.14	54128.62	1345.0	52783.62	D
100	23	1785.71	7200.03	53657.18	1901.0	51756.18	-185.00
100	46	1892.85	6210.71	54744.61	2437.0	52307.61	103.00
100	69	2078.60	6264.31	59283.04	2173.0	57110.04	D
150	0	1849.99	6203.57	53705.30	1950.5	51687.80	3487.00
150	23	2042.85	6860.72	59319.55	2573.5	56746.05	812.00
150	46	2049.99	8350.00	64424.91	3109.5	61315.41	852.50
150	69	1825.00	7139.28	54508.97	3645.5	50863.47	D

Where, D = dominated treatments. ETB ha^{-1} = Ethiopian Birr per hectare; Market price of teff = 24 ETB kg^{-1}; Market price of straw= 1.5 ETB kg^{-1}; Cost of blended NPS fertilizer =12.65 ETB kg^{-1}; Cost of Urea (N-source) fertilizer = 10.50 ETB kg^{-1}, Labor cost for fertilizer application=2 persons ha^{-1}, each at 70 ETB day^{-1}.

SUMMARY AND CONCLUSION

Nutrient requirement of teff can be varied from location to location depending on different factors such as soil and other agro-ecologies. For sustainable production of teff for a particular area, specific fertilizer recommendation is very crucial. For this reason a field experiment was conducted during the 2018 to 2019 main cropping season with the objective to investigate the effect of blended NPS and N fertilizers rates on growth, yield components, and yield of teff and to identify economically feasible rates of blended NPS and N fertilizers rate for high yield of teff at Adola District, Southern Ethiopia

The treatments consisted of factorial combinations of four levels of blended NPS (0, 50, 100 and 150 kg ha^{-1}) and four levels of nitrogen (0, 23, 46 and 69 kg ha^{-1}) fertilizer rates. The experiment was laid out as a randomized complete block design in a factorial arrangement with three replications. The teff variety 'Dagim' (DZ-Cr-438 RILNo.91A) was used for the study. The fertilizer materials used were urea (46% N) and blended NPS (19% N, 38% P_2O_5, and 7% S).

Analysis of the results revealed that number of total tillers, number of productive tillers, thousand kernel weight and lodging index were highly significantly ($P<0.01$) affected by main effect of NPS as well as by the main effect of N while aboveground dry biomass yield, grain yield, straw yield were highly significant ($P<0.01$) only main effect of NPS fertilizer rates. The highest number of total tillers (1291 plants m^{-2}), productive tillers (1192 plants m^{-2}), aboveground dry biomass yield (10038 kg ha^{-1}) grain yield (2162 kg ha^{-1}), thousand grain weight

(0.3549 g), and lodging index (70.83 %), were recorded at NPS rate of 150 kg ha^{-1}, whereas the highest number of total tillers (1232 plants m^{-2}), number of productive tillers (1138 plants m^{-2}), thousand kernel weight (0.3446 g) and lodging index (66.67%) were obtained at the highest rate of N (69 kg N ha^{-1}). Generally, as the rates of NPS and N fertilizers increased the number of total tillers, productive tillers, thousand grain weight and lodging index were increased.

The interaction of the two fertilizers were significant on days to 50% panicle emergence, 90% physiological maturity, panicle length, and plant height. The highest days to panicle emergence (49 days) and days to physiological maturity (86.33 days) were obtained from control (unfertilized) treatments. The maximum plant height (105.72 cm) and panicle length (43.33 cm) were recorded at combination of 150 kg NPS with 69 kg N ha^{-1}, respectively.

The partial budget analysis revealed that combined applications of 150 kg NPS and 46 kg N ha^{-1} gave the best economic benefit of 61315.41 Birr ha^{-1} with MRR of 852.50%. Therefore, it can be concluded that combined application of 150 kg NPS and 46 kg N ha^{-1} can be recommended for production of teff in the study area and other areas with similar agro-ecological conditions.

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