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Effect of Blended NPS Fertilizer Rates on Phenology, Growth and Yield of Teff [*Eragrostis tef* (Zucc.) Trotter] Varieties in Hidhabu Abote District, North Showa

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Abstract: Teff is one of the major crops grown at Hidhabu Abote district, North Showa Oromia National Regional State; however, its productivity is low due to lack of improved varieties and poor soil fertility as result of intensive soil erosion and long history of cultivation. Therefore, a field experiment was carried out on a farmer's field in the district, during the 2019 cropping season to assess the effect of NPS fertilizer rates on production of teff varieties. The treatments consisted of factorial combinations of five levels of NPS (0, 50, 100, 150 and 200 kg ha^{-1}) fertilizer rates and four teff varieties (Nigus, Kora, Dagem and Local). The experiment was laid out in a randomized complete block design with three replications. The mean days of panicle emergence and physiological maturity, plant height and panicle length were highly significant and grain yield was significantly (P<0.01) affected by main effect of both varieties and NPS fertilizer rates. Higher days of panicle emergence (63 days) and days to physiological maturity (110 days) were recorded from Dagem and local varieties with combination of un-fertilized plot. Significantly higher plant height (143 cm), panicle length (45.44 cm) was obtained from Kora with application of 150 kg NPS ha^{-1} fertilizer rate. Significantly higher grain yield (2367 kg ha^{-1}) was obtained from application of 150 kg NPS ha^{-1} fertilizer rate. Therefore, application of 150 kg NPS ha^{-1} fertilizer could be recommended for production of teff in the study area and other areas with similar agro-ecological conditions.

Key words: NPS · Teff · Yield

INTRODUCTION

Teff [*Eragrostis tef* (Zucc.) Trotter] is a self-pollinated and warm season cereal crop originated in Ethiopia and have been domesticated and used throughout the world due to its excellent nutritional value as grains for human consumption and as forage for livestock [1]. Teff has the largest value in terms of both production and consumption in Ethiopia. The value of the commercial surplus of teff is second to coffee [2]. Moreover, the economic contribution of teff indicates that real teff output on average accounted for 6.1% of the real GDP, while growth in real teff output accounted for 6.4% of the total growth in real GDP i.e., 0.67% of the 10.7% growth in real GDP [3]. Teff is commonly grown in the altitude ranging from 1800 to 2100 meters above sea level, with the major producing areas being Amhara, Oromia, Tigray and South Nations, Nationalities and People SNNP regions. It is a versatile cereal crop with respect to adaptation for the diverse agro-climatic and soil conditions [4].

In Ethiopia, teff is the single dominant cereal that occupied 3.08 million hectares and the production is about 5.4 million tons per year [5]. Teff production in Oromia National Regional State total land area of 1, 431, 869.73ha with total production of 25, 628, 688.88qt with productivity

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1.79t ha^{-1} [5] while in North Showa, Teff production with total Area of 107, 256 ha, total production 1, 876, 980 qt and with productivity 1.75 t ha^{-1}. Teff is among major crops grown and used for home consumption and marketing in Hidhabu Abote District of North Showa Zone in Oromia Region. The total cultivated area of the district is 32, 917 ha out of which teff covers 10, 826 ha. The average yield of teff is 1750 kg ha^{-1} in that particular area and this is almost equaling to the average national yield (1756 kg ha^{-1}) of teff [5]. Teff is primarily grown to prepare '*injera',* porridge and some native alcohols drinks [6]. Nutritionally, teff grain is gluten-free, rich in phosphorous, copper, magnesium, aluminum and thiamine and is an excellent source of protein, amino acids and carbohydrates. Teff is higher in calcium, iron and zinc content than corn, wheat, or rice [1]. International demand for teff is also increasing due to its high nutritional value and its potential as water efficient fodder for livestock [7].

More than six million households' life depend on the production of teff covering the largest agricultural area of the country than any other types of grain, but its production and productivity is still very low due to traditional agronomic practices, nutrient deficiencies and susceptibility of the crop to lodging [8]. However, the amount of production is not as much as its production coverage and value [9]. The low teff crop productivity could be due to a complex interaction among the environments, lack of appropriate management practices, biotic and a biotic stress. Of these, soil fertility problem is one of the major causes of temporal and spatial yield variability [10]. Following soil fertility map made over 150 districts EthioSIS [11] reported that Ethiopian soil lacks about seven nutrients; N, P, K, S, Cu, Zn and B. Of which, the study area particularly lacks Sulphur. Although nitrogen and phosphorus nutrients are among the major teff yield limiting soil nutrients, the unbalanced and sub-optimal fertilization of Ethiopian soils by applications of only DAP and Urea (N and P containing fertilizers) for a long period of time has led to severe nutrient mining of the agricultural soils, particularly when the entire crop biomass (grain and stover) are removed from the land [12]. According to Yonas [13] lack of appropriate macro or micro-nutrients in fertilizer blends is one of the national problems which act as the major constraint to crop productivity. Hence, the continuous use of DAP and Urea should be supplemented with the application of additional compound fertilizers containing all the required and deficient in the soil macro and micro-nutrients.

The most important short coming in teff production is its inherent low productivities of local variety. The local teff has low yield potential as compared to improved teff varieties. Hence, the major factor which affects the yield of teff is lack of improved variety and different varieties are generally expected to respond differently to fertilizer applications. The local teff variety that is most often cultivated in the study area is known as '*Kacha*'. It has low yield potential. However, the genetic improvement of the crop has resulted in the development of varieties that could yield as high as 4 tons ha^{-1} [14]. Such a high yielding varieties have been released by Debre Zeit Agricultural Research Center and is being aggressively disseminated in different parts of Ethiopia. Teff varieties named 'Nigus, 'Kora' and 'Dagem' are released for optimum rainfall areas among twenty-four improved teff varieties so far been released by Debre Zeit Agricultural Research Center (DZARC) and these varieties needed to be disseminated in the study area based on their adaptation.

Farmers in Central Ethiopia use 100 kg ha^{-1} of DAP (18 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1}) and 100 kg ha^{-1} Urea (46 kg N) alone for teff production on Vertisols [15]. Those blanket recommendation brought generally, an increase in yield of improved varieties ranging from 1700 to 2200 kg ha^{-1} [16]. However, the recommendation does not work for all production aspects of various soil types of different regions. Moreover, to realize optimum yield of the crop, appropriate fertilizer rates have to be used since this could vary according to soil type and weather condition of area. The response of teff varieties to fertilizers depends on type of fertilizers, rates applied, time and method of application. Higher yield responses to recommended rates of fertilizers are obtained from released varieties than local ones. However, all growth parameter of both varieties is highly influenced by fertilizer application [17]. Thus, author also reported that it was possible to increase yield by more than two folded using improved varieties and their respective recommendation fertilizer rates.

Application of balanced fertilizers could be the basis to produce more crop output from existing land under cultivation and nutrient needs of crops according to their physiological requirements and expected yields [18]. However, the fertilizer type and rates vary according to soil type, weather conditions, varieties, agronomic practices. Even though improved teff varieties like Nigus, Dagem and Kora are not cultivated by the use of NPS fertilizers application except the blanket recommendation of DAP and Urea fertilizers which give low yields as compared to yield potential of the crops. However, higher yield responses to recommended rates of fertilizers are obtained from released varieties than local ones in many parts of the country. Lulu [17] also reported that it is possible to increase yield by more than two folded using improved varieties with their respective recommendation fertilizer rates. Hence, in the study area main research gap for low productivities of teff lack of recommended fertilizer rate and lack of information on response of different varieties. Moreover, currently there is little or no information of site-specific recommendation of NPS fertilizer for teff production in the study area especially for recently released improved teff varieties. Therefore, the objective was to assess the effect of NPS fertilizer rates on phenological, growth and yield of teff varieties for production.

MATERIALS AND METHODS

Description of the Study Area: The experiment was conducted on farmer's field in Mojo *Kebele* Hidhabu Abote District, North Showa Zone, Oromia Regional National State during the 2019 cropping season. It is located at 142 km from Addis Ababa on the way to Gojem and about 43 km from zonal town of Fitche. Geographically, the District is situated at latitude of 9.81°47' N, longitude of 38°27' E and altitude of 1850 meters above sea level.

The study area is characterized by a bimodal rainfall pattern with the main rainy season 'Ganna' extending from July to September and the short season 'Arfasa' extends from March to May. The average annual rainfall and mean annual minimum and maximum temperatures of the area based on last 10 years (2009-2019) records were 1014 mm and 8.57 and 20.87°C respectively [19]. The total rainfall of the study area during the growing season was 915 mm which was suitable for maximum teff production throughout the growth stages and the mean minimum and maximum temperatures were 11 and 20.5°C, respectively [19].

Major soil type of the study area is Nitisols. The soil is clay textured with pH of 5.56, low content of N (0.15%), organic matter (1.42%), available P (4.36 ppm) and moderate CEC (21.67 meq/100 g soil). The experimental site was under wheat cultivation during the previous growing season.

Major crops grown in the area are teff, wheat, sorghum, faba bean, lentil and field pea. The area has been under cultivation for long periods of time and so are the crops. Almost all farmers practice crop-dominated mixed crop-livestock farming system in every fragmented plots of land that allow the land no time to rest. The land is continuously exploited and poor in fertility and particularly very low in organic matter as crop residues are not left in the fields after harvest basically for straw utilization [20].

Experimental Treatments and Design: The treatments were consisting of three teff varieties 'Nigus' (DZ-Cr-429), Dagem (DZ-Cr-438(RIL-91A) and Kora (DZ-Cr-438 RIL133B) which were released from Debre Zeit Agricultural Research Center in 2016, 2015 and 2014, respectively and Local cultivar as check were used for the experiment [21] and five rates of NPS (0, 50, 100, 150 and 200 kg NPS ha^{-1}). NPS (19% N, 38% P_2O_5 and 7% S) and Urea (46% N) fertilizers were used as source of nutrient elements. The experiments were laid out as a randomized complete block design in a factorial arrangement with three replications.

Experimental Procedure: Field was ploughed and prepared according to Farmers practices before planting. In accordance with the specifications of the design, a field layout was p repared. A plot size of 2 m x2 m (4 m^2) with 20 cm row spacing and a total of 10 rows were used. Each treatment was assigned randomly to the experimental plots within a block. Rows were made manually before sowing and the whole amount of NPS fertilizer rates was applied at sowing time as basal application to each plots and nitrogen at the specified rates were applied in two splits in the form of Urea 100kg (½ of the Urea at sowing and the remaining ½ was applied at tillering stage). Teff varieties 'Nigus' Dagem, Kora and local variety was manually drilled uniformly at the rate of 10 kg ha^{-1} in rows at a depth of about 3 cm on 8 of July 2019. Half of urea fertilizer was applied in the soil as basal application (5 cm) away from the seed planting) by making a shallow furrow along the teff row to avoid the seed contact and then covering with soil.

The outermost two rows from each side of a plot and 0.1 m on both ends of each row were considered as border and not included for data recording. Thus, the net harvestable area was 1.6m x 1.8 m (2.88 m^2). Harvesting was done on 8 November 2019 when the senescence of the leaves took place as well as the grains came out free from the glumes when pressed between the forefinger and thumb. The harvested total biomass yield was sun dried for three days until constant weight. The total dry matter was weighed by using field balance. Threshing and winnowing were done manually on a mat. After threshing, the grain yield was weighed using sensitive digital balance. All other cultural practices were uniformly applied to each of the plots as per the recommendations for the test location.

Soil Sampling and Analysis: Soil samples were collected randomly in a Zig-Zag pattern from the entire experimental field using an auger to the depth of 0-20 cm before sowing from 11 spot and composited into one sample. The collected soil sample was prepared following standard procedures under the shade, grounded using mortar and pestle, sieved through a 2 mm sieve. The sieved soil was stored in a clean plastic container for subsequent physical and chemical analysis. The soil analysis was done for soil textural class, soil pH, organic carbon, total N, available P, available S and CEC at Horticoop Ethiopia (Horticulture) PLC Soil Laboratory.

Soil textural class was determined by Bouyoucos Hydrometer Method [22]. Soil pH was determined in 1:2.5 soils to water ratio using a glass electrode attached to a digital pH meter [23]. Organic carbon was determined by wet digestion method [23] then the organic matter (%) was calculated by multiplying the OC% by factor 1.724. Total N (%) was determined using the Kjeldhal method [24]. Available P (mg/kg (ppm) was determined by Bray and Kurtz method [25]. Available S (mg/kg (ppm) and exchangeable bases (potassium, magnesium, sodium and calcium) were determined by Melich-3 methods [26]. For Cation Exchange Capacity of the soil (Meq/100 g soil), the sample was first leached using 1M ammonium acetate, washed with ethanol and the adsorbed ammonium replaced by sodium (Na). Then, the CEC was determined titrimetrically by distillation of ammonia that was displaced by Na [27].

Data Collected

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Days to 50% Panicle Emergence: Was determined as the number of days from sowing to the time when 50% of the plants started to emerge the tip of panicles through visual observation.

Days to 90% Physiological Maturity: Was determined as the number of days from sowing to the time when 90% of the plants reached physiological maturity based on visual observation. It was indicated by senescence (turning to light yellow) of the leaves and vegetative parts as well as free threshing of grain from the glumes when pressed between the forefinger and thumb.

Plant Height: Was measured at physiological maturity from the ground level to the tip of panicle by hand meter from ten randomly pre-tagged plants in each net plot.

Panicle Length: Is the length of the panicle measurement from the node where the first panicle branches emerge to the tip of the panicle meter which was determined from an average of ten pre-tagged plants per net plot.

Grain Yield: Was weighted after harvesting and threshing the crop from the net plot area and the yield was expressed in kg ha^{-1}. Then the grain yield of each treatment was adjusted to the standard moisture level by computing the conversion factor for each treatment to get the adjusted yield using the following formula.

Data Analysis: The collected data were subjected to analysis of variance (ANOVA) using GenStat release 18th ed. software [28]. Means of significant treatment effects were separated using the Fishers' protected Least Significant Difference (LSD) test at 5% level of significance [29].

RESULTS AND DISCUSSION

Soil Physical and Chemical Properties: The results of the pre-sowing composite soil sample analyses are indicated in Table 1. The soil textural class of experimental site was 66% clay, 26% silt and 8% sand (Table 1). The texture of the soil was clay [30]. The pH of the soil was 5.56 (Table 1), which was moderately acidic and, in most cases, sub-optimal for the production of most field crops [31]. Teff is normally grown on soils of neutral pH, but it has been observed that it tolerates soil acidities below pH 5. This value falls in the pH range that is conducive for teff production [14].

Table 1: Soil physical and chemical properties of the experimental site before sowing

Soil properties	Values	Ratings	References
A. Physical properties			
Clay (%)	66		
Silt (%)	26		
Sand (%)	8		
Textural class	Clay		Bouyoucos (1962)
B. Chemical Properties			
pH (1:2.5 H_2O)	5.56	Moderately acid	Tekalign (1991)
Organic carbon (%)	1.42	Low	Tekalign (1991)
Total N (%)	0.15	Low	Tekalign (1991)
Available P (ppm)	4.36	Low	Bray and Kurtz (1945)
CEC (meq/100 g soil)	21.67	Moderate	Landon (1991)
Available S(ppm)	19.08	Low	Ethio-SIS (2014)

Table 2: Mean days to 50% panicle emergence of teff as affected by the interaction of varieties and NPS fertilizer rates

	NPS (kg ha^{-1}) fertilizer rates					
Varieties	0	50	100	150	200	Mean
Local	63^{a}	58^{b}	56^{c}	56^{c}	53^{d}	57.20^{b}
Kora	61.33^{a}	58^{b}	56^{c}	56^{c}	56^{c}	57.467^{b}
Dagem	63^{a}	58^{b}	58^{b}	56^{c}	53^{d}	57.600^{a}
Nigus	56^{c}	53^{d}	51^{e}	51^{e}	49^{f}	52.000^{c}
Mean	60.833^{a}	56.75^{b}	55.25^{c}	54.75^{d}	52.75^{e}	
	Varieties		NPS rates		Varieties X NPS rates	
LSD (5%)	0. 48		0.53		1.07	
CV (%)	1.2					

Means in column and row followed by the same letters are not significantly different at 5% probability level

The organic carbon content of the experimental field was low (1.42%) (Table 1) [31]. This indicates the low potential of the soil to supply nitrogen to plants through mineralization of organic carbon. The low amount of soil organic carbon might be due to complete removal of crop residues and less aeration due to soil compaction of sub-soils. Most cultivated soils of Ethiopia are poor in organic matter content due to low amount of organic materials applied to the soil and complete removal of biomass from the field.

The total nitrogen was 0.15% (Table 1) which was low [31]. The low nitrogen content might be due to the loss of nitrogen from the soil system easily through leaching, denitrification, volatilization, crop removal, soil erosion and runoff as the land is continuously cultivated. The available P of the experimental soil content was found 4.36 ppm which is considered as low P according to Bray and Kurtz (Table 1) [25]. The available sulfur indicated that the experimental soil had value of 19.08 ppm of available sulfur which is rated low [32].

Days to 50% Panicle Emergence: The main effect of Varieties and NPS fertilizer rates as well as the interaction effect of the two factors were highly significant ($P<0.01$) effects on the days to panicle emergence of teff (Table 2). The highest days to 50% panicle emergence (63 days) was recorded from the control plot of Dagem and Local varieties which was statistically at par with Kora varieties without fertilizer application with mean panicle emergence of 61.33 days; while the lowest (49 days) was recorded from the highest rates of 200 kg NPS ha^{-1} fertilizer from Nigus variety (Table 2). The lowest days to 50% panicle emergence of Nigus variety might be due to sufficient amount of growth and development of plants owing to the essential elements under soil highly utilized for production. This result was in agreement with Wakjira [33] who reported that as the rate of NPS increased from control to 120 NPS kg ha^{-1} days to panicle emergence decreased from (70 days) to (59 days) on Kuncho variety. Likewise, Solomon *et al.* [4] reported that Dagem and Kora varieties take 59 days and 46 days respectively to 50% panicle emergence. The hastened panicle emergence as a result highest rates of blended NPS fertilizers could be due to early establishment, rapid growth and development of crop. The application of P hastened the days to heading possibly because it has a role that speed up growth and development of the crop plant. This result is consistent with the result of Alemayehu [34] who reported that p fertilizer enhancing growth and development of teff.

This result was also in agreement with that of Sate [35] found that N and P_2O_5 at the rates of 64/46 kg ha^{-1} significantly reduced days to heading of teff over the control. Similarly, Getahun *et al.* [36] reported that the heading of teff plants was accelerated as NP rate increased from 0 to 69 kg N ha^{-1} and 30 kg P_2O_5 ha^{-1} fertilizer applications with Kuncho variety. Likewise, Alemu *et al.* [37] who reported that number of days required to heading decrease as increase P fertilizer rates. In contrary, Legesse [38]; Haftamu *et al*. [39]; Temesgen [40] reported non-significant differences in days to heading of teff plants in response to the application of P fertilizer.

Days to Physiological Maturity: The interaction effect of varieties and NPS fertilizer rates was highly significant ($P<0.01$) on physiological maturity of teff as well as the main effect of varieties and NPS rates were also highly significant ($p<0.01$) (Table 3). The highest days to physiological maturity of teff (110 days) was recorded from Dagem and Local varieties without fertilizer application, while the lowest (98 days) was recorded from Nigus variety with application of 200, 150 and 100 kg NPS ha^{-1} fertilizer rates (Table 3). The lowest days to physiological maturity of teff might be due to varietal variability in days to maturity; accordingly, Nigus variety has short life span than Dagem verity. This result was also in agreement with Solomon *et al.* [4] reported that Dagem variety takes 114 days to physiological maturity of teff.

The enhanced maturity with the application of the highest NPS 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 [41] described that phosphorus application could possibly shorten maturity date since it promotes rapid cell division. Onasanya *et al*. [42] 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 number of essential elements. In line with the result, Getahun *et al.* [36] 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. Likewise, Salisbury and Ross [43] who reported that maturity is often delayed compared to plants containing abundant phosphate. Similarly, Mehretab [45] reported that, days to maturity were significantly reduced as the level of phosphate fertilizer increased. In contrary, Alemu *et al.* [38] who reported that the shortest days to maturity (135 days) was -recorded at the control plots while the longest (147 days) were recorded at (16/11.5 N/P_2 O_5 kg ha^{-1}.

Plant Height: The analysis of variance showed that the interaction effect of varieties and NPS fertilizer rates was significant ($P<0.05$) and the main effect of the two factors were highly significant ($P<0.01$) on plant height of teff (Table 4). The highest plant height (143cm) was recorded from Kora teff varieties with 200 kg NPS ha^{-1} fertilizer rates while the shortest plant height (97cm) was recorded on Local cultivars without fertilizer application (Table 4). This is because the genotype characteristic of the varieties and effects of NPS fertilizer role in cell division, elongation and vegetative growth of plants [45]. Likewise, Teshoma [46] who reported that the highest plant height (114cm) was recorded on Kora varieties with NPSB 200 kg ha^{-1}, while the shortest plant height (106.4 cm) was recorded at control. Similarly, Tekle and Wassie [47] reported that the highest plant height (156.8 cm) from application of 136 $kgha^{-1}$ blended NPSZnB fertilizer rates with Kuncho variety, while the least height (112 cm) was obtained from control plot. Likewise, Wakjira [34] reported that the highest plant height (119.97cm) and lowest plant height (82.03cm) was recorded from application of 120 kg NPS ha^{-1} with Kuncho variety and control treatments respectively.

Similarly, Solomon *et al.* [4] reported that Kora and Dagem varieties take (102.5 cm) and (95.6 cm) respectively to the height of teff. Also, Alemu *et al*. [36] who reported that as the rate of P fertilizer increased to the highest rate markedly a linear increase in plant height was observed and thus, the highest plant height of (88.13 cm) was recorded at the highest P_2O_5 rate of 46 kg ha^{-1} while the shortest height (55.59 cm) was noted from the control plot of Kuncho variety. In contrary, Fissehaye *et al*. [48] who reported that the highest plant height of 61.67 cm was recorded at 69 kg P ha^{-1} with Kuncho variety. However, there was no significant difference in plant height between 46 kg P and 69 kg P ha^{-1}.

Table 3: Mean days to 90 % physiological maturity of teff as affected by the interaction of varieties and NPS fertilizer rates

	NPS (kg ha^{-1}) fertilizer rates					
Varieties	0	50	100	150	200	Mean
Local	110^{a}	105^{d}	105^{d}	105^{d}	101^{e}	105.20^{b}
Kora	108.3^{b}	106.3^{c}	107^{c}	105^{d}	105^{d}	106.33^{a}
Dagem	110^{a}	107^{c}	105^{d}	105^{d}	101^{e}	105.60^{b}
Nigus	105^{d}	101^{e}	98^{f}	98^{f}	98^{f}	100.00^{c}
Mean	108.33^{a}	104.83^{b}	103.75^{c}	103.25^{c}	101.25^{d}	
	Varieties		NPS rates		Varieties X NPS rates	
LSD (5%)	0. 5045		0.564		1.1281	
CV (%)	0.7					

Means in column and row followed by the same letters are not significantly different at 5% probability level

Table 4: Mean plant height of teff as affected by the interaction of varieties and NPS fertilizer rates

	NPS (kg ha^{-1}) fertilizer rates					
Varieties	0	50	100	150	200	Mean
Local	97.2^{j}	111.6^{i}	119.6^{g}	132.1^{cde}	138.2^{abc}	119.76^{c}
Kora	98.7^{j}	122.4^{fg}	126.5^{ef}	142.9^{a}	143.2^{a}	126.77^{a}
Dagem	100.1^{j}	119^{gh}	122.8^{fg}	140.2^{ab}	133.6^{abc}	123.15^{b}
Nigus	101.2^{j}	112.8^{hi}	118.4^{gh}	127.3^{def}	127.3^{def}	117.39^{d}
Mean	99.31^{d}	116.44^{c}	121.84^{b}	135.64^{a}	135.61^{a}	
	Varieties		NPS rates	Varieties X NPS rates		
LSD (5%)	2.95		3.298	6.597		
CV (%)	3.3					

Means in column and row followed by the same letters are not significantly different at 5% probability level

Table 5: Mean panicle length of teff as affected by the interaction of varieties and NPS fertilizer rates.

	NPS (kg ha^{-1}) fertilizer rates					
Varieties	0	50	100	150	200	Mean
Local	30.67^{h}	33.06^{fgh}	33.09^{fgh}	34.63^{efgh}	37.56^{cdefg}	33.80^{c}
Kora	30.90^{h}	35.70^{efgh}	38.44^{bcdefg}	45.44^{a}	43.32^{abc}	38.74^{a}
Dagem	31.41^{gh}	35.88^{defgh}	38.51^{bcdef}	44.75^{ab}	42.32^{abcde}	38.57^{a}
Nigus	31.50^{gh}	33.25^{fgh}	33.66^{fgh}	37.59^{cdefg}	41.00^{abcde}	35.40^{b}
Mean	31.12^{e}	34.47^{d}	35.92^{c}	40.60^{b}	41.02^{a}	
	Varieties		NPS rates	Varieties X NPS rates		
LSD (5%)	1.55		1.73	3.47		
CV (%)	5.7					

Means in column and row followed by the same letters are not significantly different at 5% probability level

Panicle Length: The interaction effect of varieties and NPS fertilizer showed significant ($p<0.05$) on panicle length and the main effect of the two factors were highly significant ($P<0.01$) on panicle length (Table 5). The highest panicle length (45.44 cm) was recorded from Kora teff varieties with application of 150 kg ha^{-1} NPS fertilizer rates, while the shortest panicle height (30.67 cm) was recorded from Local cultivars with the control plot (Table 5). This is because due the highest plant height which contribute for highest panicle length. Similarly, Yared *et al*. [49] found that panicle length of Kora and Dagim varieties were 44.29 cm and 42.77 cm respectively.

Similarly, Solomon *et al*. [4] found that panicle length of Kora and Dagim varieties were 37.3 cm and 35.5 cm respectively. Also, Wakjira [33] reported that the highest panicle length (54.63cm) and the lowest panicle length (31.33cm) were recorded from the highest NPS application with Kuncho variety and control plot respectively. Likewise, Tekle and Wassie [47] found that the highest panicle length (60.3 cm) from application of 136 kgha^{-1} blended NPSZnB fertilizer rates and the least panicle length (43 cm) with Kuncho variety was obtained from control plot. Similarly, Getahun *et al.* [36] who reported that the highest panicle length (39.6 cm) was recorded

Table 6: Means of grain yield of teff as influenced by the main effects of varieties and NPS fertilizer rates

Treatment	Grain yield (kg ha^{-1})
Varieties	
Local	1705^{b}
Kora	1926^{ab}
Dagem	2108^{a}
Nigus	2028^{a}
LSD (5%)	258.949
NPS (kg ha^{-1})	
0	1051^{c}
50	1853^{b}
100	2189^{ab}
150	2367^{a}
200	2250^{a}
LSD (5%)	289.514
CV (%)	18

Means in columns and rows followed by the same letters are not significantly different at 5% probability level

from the application of 20 kg P ha^{-1} with Kuncho variety, while the shortest was obtained from the control treatment. In contrary, Fenta [51] stated that Panicle length neither influenced by the main effect of the rate of nitrogen fertilizer and variety nor by the interaction of the two factors significantly.

Grain Yield: The main effects of NPS fertilizer rates and varieties were significantly ($P<0.01$; $P<0.05$) affected grain yield of teff respectively, while interaction effect of the two factors was not significant (Table 6).The highest grain yield (2108 kg ha^{-1}) was recorded from Dagem varieties which was statistically par with Nigus (2028 kg ha^{-1}) and Kora (1926) varieties, while the lowest grain yield (1705 kg ha^{-1}) was recorded from local cultivar (Table 6). This is because of genotypic deferential in terms of yielding ability. As compared to other varieties Dagem is high yielding than local cultivar. This result was also in agreement with Yared *et al*. [49] who reported that Dagem variety gave superior grain yield (3734 kg ha^{-1}) than the local cultivar. Similarly, Natol *et al*. [51] who reported that the highest grain yield was recorded from Magna (2.03 t/ha) followed by Local and Tsedey (1.79 t/ha). An increase in the application of NPS fertilizer rate from control to 150 kg NPS ha^{-1} increased mean grain yield, however further increase to 200 kg NPS ha^{-1} showed a decreasing trend on grain yield of teff (Table 6). The highest grain yield (2367 kg ha^{-1}) of teff was obtained at the rate of 150 kg NPS ha^{-1} fertilizer application, while the lowest grain yield of 1051 kg ha^{-1} was recorded from non-treated (control) plot. However, the highest grain yield (2367 kg ha^{-1}) recorded at 150 kg NPS ha^{-1} fertilizer rate was at par with the yield obtained from 100 and 200 kg NPS ha^{-1} fertilizer rates (Table 6).

The highest grain yield at the high NPS rates might have resulted from improved root growth and increased uptake of nutrients and better growth favored due to synergetic effect of the nutrients which enhanced yield and yield components. Likewise, Bereket *et al.* [52] reported that increasing P rate from 46 to 69 kg P_2O_5 ha^{-1} increased grain yield of bread wheat by about 6.8%. Also, Jarvan *et al*. [53] 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. On the other hand, Brhan [54] 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 is obtained 4155 kg ha^{-1} and increased 30% and 378% over treatments that receive Urea and DAP under row planting and control plots, respectively. In agreement with this study Seifu [55] reported that highest grain yield (3228 kg ha^{-1}) of teff was obtained at the highest rate of blended (150 kg NPSB ha^{-1}) fertilizer application.

CONCLUSION

The mean days of panicle emergence, days to physiological maturity, plant height and panicle length were highly significantly ($P<0.01$) affected by main effect of varieties and NPS rates. The highest days of panicle emergence (63 days) and days to physiological maturity (110 days) were recorded from Dagem and local variety from un-fertilized plot. The highest plant height (143.2 cm) and panicle length (45.44 cm) were obtained from Kora varieties with 150 kg NPS ha^{-1} fertilizer application. Significantly higher grain yield (2367 kg ha^{-1}) was obtained from application of 150 kg NPS ha^{-1} fertilizer rate. The interactions of the two factors were highly significant on days of panicle emergence and days to physiological maturity, as well as significant on plant height and panicle length. Therefore, application 150 kg NPS ha^{-1} could be tentatively recommended for production of teff in the study area and other areas with similar agro-ecological conditions. However, since the experiment was conducted for one season at one location, it is suggested that the experiment has to be repeated over seasons and locations using this and other improved teff cultivars to make a conclusive recommendation.

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