Advances in Crop Science and Technology
ISSN: 2329-8863

Mebratu et al., Adv Crop Sci Tech 2016, 4:6
DOI: 10.4172/2329-8863.1000249

Research Article OMICS International

# Production Potential of Tef (*Eragrostis tef* (Zucc.) Trotter) Genotypes in Relation to Integrated Nutrient Management on Vertisols of Mid High lands of Oromia Region of Ethiopia, East Africa

**Yonas Mebratu, Cherukuri V Raghavaiah* and Habtamu Ashagre**

*Department of Plant Science, College of Agriculture and Veterinary Sciences, Ambo University, Ambo, Ethiopia*

**Abstract**

Tef is a highly valued nutritious cereal crop which plays an important role in the diet of Ethiopians. Soil fertility depletion pose a serious threat to tef production in high lands of Ethiopia which are characterised by high rainfall, soil acidity, soil erosion, leaching and the attendant non availability of plant nutrients to the crop. In view of this a field experiment was carried out during 2014/15 cropping season on a field belonging to Hommicho Ammunition Engineering Industry with the objective to evaluate the response of Tef genotypes to integrated nutrient management in terms of productivity and yield components in Guder, Toke kuttai district. The treatments consisted of six levels of integrated nutrient management practices: 1) 0-0-0 (check) 2) 40-60-0 NPK (RDF) 3) 50%RDF+50% N (FYM) 4) 75%RDF+25% N (FYM) 5) 100% RDF+5 t FYM/ha and 6)RDF through new complex fertilizer (19-38-7 NPS) tested on five genotypes (Magna, Simoda, Quncho, Dz-Cr-409, Local variety). The experiment was laid out in a randomized complete block design with factorial arrangement with three replications. The results revealed that there was significant interaction between genotypes and integrated nutrient management practices where in application of 75% RDF+25% FYM and 100% RDF+5 t/ha FYM to genotypes DZ-CR-387 and DZ-01-196 delayed days to flowering and days to maturity, but in other genotypes these were not altered due to fertilizer application. In plant height, variety DZ-CR-385 and DZ-CR-409 responded better to 100%RDF+5 t/ha FYM combination, while DZ-01-196 and local variety was significantly affected over all fertilizer treatments. Significantly higher initial tiller capacity and fertile tiller production were obtained with application of 75% RDF+25% FYM and 100% RDF+5 t/ha FYM. Local variety had significantly higher number of leaves with 100% RDF+5 t/ha FYM followed closely by DZ-CR-409 with 75% RDF+25% FYM, and DZ-CR-385 and DZ-CR-387 with 75% RDF+25%FYM. Length of panicle and panicle weight were significantly affected where integrated nutrient management in new varieties DZ-CR-409 and DZ-CR-387 gave higher seed weight with 50%RDF+50% FYM and 75% RDF+25%FYM. There was significant interaction between varieties and integrated nutrient management on grain and straw yield, where DZ-01-196 recorded maximum grain and straw yield with application of 100% RDF+5 t/ha FYM which was comparable with 75%RDF+25% FYM. Therefore application of 50% RDF+50%FYM, 75%RDF+25%FYM and 100% RDF+5 $tha^{-1}$ to DZ-01-196, DZ-CR-409 and Local varieties of Tef, respectively exhibited best production performance on vertisols of mid high lands of Ethiopia.

**Keywords:** Tef; Genotypes; Nutrient management; Vertisols; Midhigh lands; Productivity; Yield components

## Introduction

Agriculture is the basis of the Ethiopian economy accounting for 46% of Ethiopia GDP and 90% of its export earnings and employ 85% of the countries labour force [1,2]. Cereals including tef are the most important crops for human consumption. Tef is a superior cereal grain crop solely produced and is considered as the noble grain of Ethiopia. Most of the areas used for production of grains especially tef, wheat and barley fall under the low fertility [3]. Soils in the highlands of Ethiopia usually have low levels of essential plant nutrients and organic matter content, especially low availability of nitrogen and phosphorus has been demonstrated to be major constraint to cereal production [4]. There are now Ethiopian restaurants in USA that are flourishing due to demand for ethnic foods, enjera and watt (stew) for human consumption. It grows well in most of the agro-ecological zones of the country.

Tef [*Eragrostis tef* (Zucc.) Trotter] is one among the major cereals of Ethiopia and occupies about 2.7 million hectares (27% of the grain crop area) of land which is more than any other major cereals such as maize (22.7%), sorghum (19%) and wheat (16%) (5,36). It is an indigenous cereal crop to Ethiopia and it has been recognized that Ethiopia is the centre of origin and diversity of tef. It is a C4 self pollinated chasmogamous annual cereal which belongs to the family poacea, sub family Eragrostidae and genus *Eragrostis*. Of the 82% gross grain production (about 17 million tonnes) contributed by cereals, tef accounts for 19.9% during the main season of 2010/11 [5].

Ethiopian farmers grow tef due to a number of merits, which are mainly attributed to the socio-economic, cultural and agronomic benefits [6]. Tef has more food value than the major grains such as wheat, barley and maize. Tef grain contains 14-15% proteins, 11-33 mg iron, 100-150 mg calcium, and rich in potassium and phosphorus nutrients [6]. Tef has got many prospects outside of Ethiopia due to its gluten free nature, tolerance to biotic and abiotic stresses, animal feed value and soil erosion control quality [7]. Small-scale commercial production of tef has begun in areas of the wheat belts of the USA, Canada and Australia (34). Tef has been introduced to South Africa

***Corresponding author:** Cherukuri V Raghavaiah, Department of Plant Science, College of Agriculture and Veterinary Sciences, Ambo University, Ambo, Post Box No 19, Ethiopia, Tel: 0933907158; E-mail: cheruraghav@yahoo.in

**Received** December 07, 2016; **Accepted** December 16, 2016; **Published** December 23, 2016

**Citation:** Mebratu Y, Raghavaiah CV, Ashagre H (2016) Production Potential of Tef (*Eragrostis* tef (Zucc.) Trotter) Genotypes in Relation to Integrated Nutrient Management on Vertisols of Mid High lands of Oromia Region of Ethiopia, East Africa. Adv Crop Sci Tech 4: 249. doi: 10.4172/2329-8863.1000249

and cultivated as a forage crop, and in recent years cultivated as a cereal crop in Northern Kenya [7].

Tef production has been increasing from year to year and so does the demand for it as staple grain in both rural and urban areas of Ethiopia [8]. Although tef is found in almost all cereal growing areas of Ethiopia, the major areas of production are Shewa, Gojam, Gonder, Wellega and Wello with central highlands of the country [9]. In those areas where it is consumed as a staple food, tef contributes about two-thirds of the dietary protein intake [7].

Tef is adapted to diverse agro-ecological zones which are marginal to most other crops [10]. Tef suffers less from diseases and gives better grain yield and possesses higher nutrient content especially protein when grown on Vertisols rather than Andosols [8]. Since tef tolerates water logging, it is sown during the wetting part of the rainy season, that is, from late July to mid August. It is mainly cultivated as a mono-crop. It is also among the most suitable crops for multiple cropping systems such as double and relay cropping.

Tef is predominantly cultivated on sandy-loam to black clay soils. Moreover, tef withstands low moisture conditions and it is often considered as a rescue crop that survives and grows well in the season when early planted crops (e.g., maize) fail due to low moisture. In addition, its ability to tolerate drainage problems makes it a preferred cereal by farmers. It is a highly valued crop primarily grown for its grain that is used for making injera. It is typically hand-broadcast on the field and, in most cases, seeds are left uncovered. Tef can produce a crop in a relative short growing season and will produce both grain for human food and fodder for cattle [7]. Regardless of its high area coverage, adaptation to different environmental conditions and requirement as a staple food in Ethiopia, the yield of tef grain is not increasing above the national average grain yield of 1.2 t/ha [5]. Its low productivity may be due to several production constraints like growing on marginal soils, traditional method of seed sowing, low application of fertilizers, and late planting of the crop exposing it to moisture stress.

Moreover, tef yields are almost stagnant probably because of the occurrence of accelerated soil erosion and lack of appropriate cultural practices on farmer's fields [11]. Lodging being among the most important factors threatening production and productivity of tef [12] up to 22% grain yield reduction and reduces straw quality [6]. Likewise, lodging restricts the use of high doses of nitrogen fertilizer in order to enhance grain yield [13].

Increasing agricultural productivity is absolutely necessary to feed the ever growing demography by enhancing land productivity. The national average yield of tef is currently below 1 ton per hectare and the present production system of tef cannot satisfy the consumer's demand as the current farming system that farmer adopts is traditional and is at subsistence level which is not supported by modern technologies [14].

Improved tef varieties have been developed since the mid-1950s, only about 20 improved varieties have been released [11]. Its grain is mainly used for making enjera, spongy flatbread, the main national dish in Ethiopia. Tef is also valued for its fine straw, which is used for animal feed as well as mixed with mud for building purposes. Tareke found sowing tef with application of 46 kg N/ha$^{-1}$, 46 kg $P_2O_5$/ha, 32 kg $K_2O$ /ha, 12 kg S/ha and 0.3 kg Zn /ha provided a grain yield of up to 6 t /ha [14]. However, this result has not been validated under farmer's fields.

The principal factors for low productivity of tef are: improper use of recommended fertilizer rates, lack of information on response of different varieties, non-availability of genotypes suitable for this area and paucity of information on integrated nutrient management practices in tef. Therefore, the current investigation was made to evaluate the response of tef varieties in terms of growth, yield and yield parameters to integrated nutrient management practices on vertisols of mid high lands of Ethiopia.

## Materials and Methods

### Description of the study area

The field experiment was conducted under rain fed condition during the main cropping season from July to December, 2014 at Guder located in the central high lands of west Shoa zone of Oromiya Regional state, Ethiopia. Guder is one of the main Tef growing areas of West Shoa zone in the Ethiopia. It is situated at 8°56'30"-8°59'30" N latitude and 37°47'30"-37°55'15" longitude the altitude of the area ranges from 1380-3030 masl, characterized by warm temperate weather which is locally called Bada-dare (mid altitude). The temperature ranges from 15°C-29°C with an average of 22°C. It receives a mean annual rain fall ranging from 800-1000 mm with an average of 900 mm. The highest rainfall occurs from June to September, and the mean monthly relative humidity varies from 64.6% in August to 35.8% in December. The soil is clay loam in texture with good moisture holding capacity.

### Seed material of the varieties

Four improved varieties of tef which are adapted to the agro-ecology of high lands were evaluated. The variety Quncho (Dz-CR-387), Magna (DZ-01-196) Simada (DZ-CR-385) and DZ-CR-409 were tested for their performance and compared with a local variety.

### Farmyard manure and soil analysis

The field selected for the study was analysed for initial soil nutrient status in terms of physical (Texture), Chemical parameters (PH, EC, OC, Available N, P, K). The farm yard manure was analysed for available N, P, and K content before its application as an organic source. Auger samples were taken from 10 spots of the experimental area at a depth of 0-30 cm and composite sample of approximately 1 kg soil was made separately before sowing. After crop harvesting, soil sample was taken from each plot and the same treatments from each block were composited and 1 kg soil sample was made for each treatment. The composited soil was air dried, ground and sieved through 2 mm mesh sieve before laboratory analysis. The analysis for specific soil parameters was carried out at the National Soil Laboratory. Soil colour was determined using the Munsell soil colour chart, whereas soil pH was determined in a 1: 2.5 soil water suspension using glass electrode pH meter [15]. Determination of particle size distribution (texture) was carried out using the hydrometer method [16]. Based on the oxidation of organic carbon with acid potassium dichromate, organic matter was determined using the Walkley and Black wet digestion method as described by Nelson and Sommers, and total nitrogen was analyzed using the Kjeldhal method [17]. Available and total phosphorus were determined using the Olsen ($NaHCO_3$) extraction method [18]. Cation exchange capacity (CEC) of the soil was determined from ammonium-saturated sample that was subsequently replaced by sodium (Na) from a percolating sodium chloride solution. The excess salt was removed by washing with alcohol and the ammonium that was displaced by sodium was measured by Kjeldahl method. Exchangeable K was determined with flame photometer.

### Layout of the experiment

After analysing the soil for chemical and physical parameters, land preparation with two times ploughing, harrowing and levelling were done to obtain a fine tilth. The field was then marked out into 90 plots of 3.2 m × 2.0 $m^2$. After preparing the land the layout of the experiment was done as per the treatments randomly in factorial randomized block design with 3 replications. Farm yard manure was applied to the plots as per the treatments 20 days before application of inorganic fertilizer. Before seeding, inorganic fertilizer as per treatments was applied. Urea was top dressed 2 times, once before sowing as basal dose and the other 7 days after emergence.

## Treatments and design

There were six nutrient management treatments and five varieties of tef. The experiment was laid out in 5 × 6 factorial randomized Complete Block Design with three replications.

**Varieties of Tef:** 1. Magna (DZ-01-196), 2. Simada (DZ-Cr-385), 3. Quncho (Dz-Cr-387) 4. Dz-Cr-409), 5. Local variety.

**Nutrient management practices:** T1-0-0-0 (check), T2-40-60-0 NPK (RDF), T3-50% RDF+50% N (FYM), T4-75% RDF+25% N (FYM), T5-100% RDF+5 t FYM/ ha, T6- RDF through new complex fertilizer (19-38- 7 NPS). The net plot size was 3.2 m × 2.0 m=6.2 $m^2$. Sowing was done on 23 July 2015, adapting a row spacing of 20 cm using a seed rate of 5 $Kg/ha^{-1}$. The crop was harvested at physiological maturity in November 2014.

## Data collection

***Plant growth parameters:*** The following parameters were recorded at harvest from 5 randomly selected and tagged plants in the net plot.

***Plant height (cm):*** It was measured from the base of the main stem to the base of the fully opened top leaf until panicle emergence. Later it was measured from the base of plant to the collar of flag leaf from five randomly selected plants from demarcated area in the net plot.

***Number of total tillers:*** The average number of total tillers with and without panicle excluding the main shoot from five randomly selected plants in demarcated area.

***Number of leaves:*** The average number of leaves from five randomly selected plants in demarcated area.

***Number of fertile tillers:*** The average number of tillers with panicle excluding the main shoot from five randomly selected plants in demarcated area.

***Leaf area ($cm^2$):*** It was recorded as length × breath × 0.73 from five randomly selected plants in demarcated area.

**Yield and yield components:** The panicles from five randomly selected and tagged plants from the net plot at the time of harvest were used.

***Days to 50% flowering:*** This parameter was determined by counting the number of days from sowing to the time when 50% of the plants started flowering through visual observation.

***Days to maturity:*** It was determined as the number of days from sowing to the time when the plants reached maturity based on visual observation. It was indicated by senescence of the leaves as well as free threshing of grain from the glumes when pressed between the forefinger and thumb.

***Number of Panicles/$m^2$:*** The number of panicles per meter was counted from the net plot area.

***Panicle length (cm):*** It is the length of the panicle from the node where the first panicle branches emerge to the tip of the panicle which was determined from an average of five selected plants per plot.

***Panicle weight(g):*** The average panicle weight of the main panicle at harvest was recorded from the average of five randomly selected pre-tagged plants from net plot.

***1000 seed weight (g):*** The weight of 1000 seeds was determined by carefully counting the grains and weighing them using a sensitive balance.

***Grain yield (Kg/ha-1):*** Grain yield was measured by harvesting the crop from the net plot area of 3.2 × 2 m to avoid border effects.

***Straw yield ($Kg/ha^{-1}$):*** After threshing and recording the grain yield, the straw yield was measured by drying the straw to a constant weight.

**Lodging index:** It was scored visually at the time of harvest according to the procedure described by Caldicott and Nuttall in which lodging percentage was taken as the sum of the product of each scale of lodging (0-5 scale) and its respective percentage divided by five, where 0 stands for upright stand, 1 for slightly slant, 2 for medium slant, 3 for very slant and 4 for extremely slant and 5 stands for 100% plants lodged.

**Statistical analysis:** The crop data collected were subjected to analysis of variance (ANOVA) using SAS software program version 9.0 [19]. Significant differences among treatment means were separated using the least significant difference (LSD) at 5% level of probability [20].

# Results and Discussion

## Initial soil physic-chemical properties

The soil particle distribution has 2.5% Sand, 22.5% Silt and 75%Clay which can be classified as clay loam soil with better moisture holding capacity suitable for rising a successful crop of tef. The soil pH of the experimental field was 6.79 and neutral in reaction (Table 1). The organic matter and organic carbon content of 2.91 and 1.69%, respectively are considered to be medium. Total N of 0.12% which is low, available Phosphorous content of 12.8 ppm which is medium; available Potassium content of 1.63 mg/100 g of soil which is high and cation exchange capacity of 1.17 mg/100 g of soil which is very low.

**Chemical composition of farmyard manure (FYM):** The FYM used in the current study has organic matter content of (51.76 $g/kg^{-1}$), Organic carbon content of 33.21 $g/kg^{-1}$; Nitrogen (2.24 $g/kg^{-1}$); Phosphorous (58.29 $mg/kg^{-1}$) and exchangeable K content of 2.55 $cmol/kg^{-1}$ (Table 1).

**Days to flowering:** Tef flowered earlier (37 days) without fertilizer application. Integration of inorganic fertilizer with farmyard manure (FYM) resulted in delayed flowering by a week (45 - 49 days) due to slow release of nutrients and better vegetative growth of the crop this result is in agreement with the report of Seyfu [6]. The days to flowering of varieties differed significantly, with DZ-CR-385(37 days) and DZ-CR-409(34 days) were early to flowering as compared with DZ-01-196 and DZ-CR-387 which are late to flowering (51 days), whereas the local variety was intermediate (46 days) in anthesis and flowering. Seyfu also reported genetic variation in flowering in tef in Ethiopia [6]. There was significant interaction between varieties and nutrient management where DZ-CR-387 and DZ-01-196 fertilized with 75% RDF+25% FYM remained comparable with 100% RDF+5 t FYM $/ha^{-1}$ in days to flowering(58 days) in comparison with the rest of the treatments (Table 2).

| Chemical property | pH | OM (%) | O.C (%) | Total N (%) | Av.P (ppm) | Av.K (mg/100 g) | CEC (mg/100 g) | Physical Properties | | | Textural classification Clay loam |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Soil** | 6.97 | 2.91 | 1.69 | 0.12 | 12.8 | 163 | 1.17 | **Sand %** | **Silt%** | **Clay%** | |
| **FYM** | - | 51.76 | 33.21 | 2.24 | 58.29 | 2.55 | - | 2.5 | 22.5 | 75 | |

**Table 1:** The initial physico-chemical properties of the experimental soil and analysis of FYM.

| | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | Mean |
|---|---|---|---|---|---|---|---|
| **DZ-01-196** | 43.3$^{e}$ | 38.3$^{fg}$ | 52.0$^{d}$ | 58.0$^{ab}$ | 58.0$^{ab}$ | 56.0$^{bc}$ | 50.9 |
| **DZ-CR-385** | 39.0$^{fg}$ | 38.0$^{fgh}$ | 32.0$^{j}$ | 36.0$^{hi}$ | 38.0$^{fgh}$ | 36.0$^{hi}$ | 36.5 |
| **DZ-CR-387** | 32.0$^{j}$ | 45.0$^{e}$ | 56.0$^{bc}$ | 59.0$^{a}$ | 58.0$^{ab}$ | 54.0$^{cd}$ | 50.6 |
| **DZ-CR-409** | 32.0$^{j}$ | 34.0$^{ij}$ | 33.0$^{j}$ | 34.0$^{ij}$ | 38.3$^{fg}$ | 32.0$^{j}$ | 33.8 |
| **Local Varity** | 39.7$^{f}$ | 45.3$^{e}$ | 58.3$^{a}$ | 39.3$^{fg}$ | 54.0$^{cd}$ | 37.3$^{gh}$ | 45.6 |
| **Mean** | 37.18 | 40.12 | 46.2 | 45.2 | 49.2 | 43 | 43.4 |
| **LSD (5%) 2.2** | | | | | | | |
| **CV (%) 1.56** | | | | | | | |

Where, $T_1$=Control (0-0-0); $T_2$=RDF(40-60-0); $T_3$=50% RDF+50% FYM; $T_4$=75% RDF+25% FYM; $T_5$=100% RDF+5 t/ha FYM and $T_6$=RDF NPS 23-10-5. Value within a column followed by the same letter is not significantly different at LSD 5% probability level.

**Table 2:** Interaction effect of genotypes and fertilizer on days to flowering.

| | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | Mean |
|---|---|---|---|---|---|---|---|
| **DZ-01-196** | 109.3$^{d}$ | 98.0$^{f}$ | 112.0$^{b}$ | 114.0$^{a}$ | 110.0$^{cd}$ | 112.0$^{b}$ | 109.1 |
| **DZ-CR-385** | 89.0$^{ij}$ | 89.0$^{ij}$ | 91.0$^{h}$ | 87.0$^{k}$ | 87.0$^{k}$ | 83.0$^{m}$ | 87.6 |
| **DZ-CR-387** | 100.0 $^{e}$ | 110.0 $^{cd}$ | 112.0$^{b}$ | 114.0$^{a}$ | 115.0$^{a}$ | 114.0$^{a}$ | 110.8 |
| **DZ-CR-409** | 84.0$^{lm}$ | 85.0$^{l}$ | 90.0$^{hi}$ | 84.0$^{lm}$ | 88.0$^{jk}$ | 94.0$^{l}$ | 86 |
| **Local Varity** | 112.0$^{b}$ | 110.0$^{cd}$ | 111.7$^{bc}$ | 98.0$^{f}$ | 110.0$^{cd}$ | 94.0$^{g}$ | 106 |
| **Mean** | 98.8 | 98.4 | 103.2 | 99.4 | 102 | 97.6 | 99.6 |
| **LSD (5%) 1.96** | | | | | | | |
| **CV (%) 0.6** | | | | | | | |

Where, $T_1$=Control (0-0-0); $T_2$=RDF(40-60-0); $T_3$=50% RDF+50% FYM; $T_4$=75% RDF+25% FYM; $T_5$=100% RDF+5 t/ha FYM and $T_6$ =RDF NPS 23-10-5. Value within a column followed by the same letter is not significant different at LSD 5%.

**Table 3:** Interaction effect of genotype and fertilizer on days to maturity.

**Days to maturity:** The number of days taken for the crop to attain physiological maturity too exhibited distinct variation with nutrient management. It was observed that the crop matured earlier when supplied with only inorganic fertilizer and no fertilizer (97-98.8 days). Integrated nutrient supply through inorganic fertilizer with farmyard manure delayed the crop maturity due to prolonged vegetative growth and balanced nutrition (99-102 days) in comparison with unfertilized control. Delay in crop maturity due to INM has also been reported by Brady and Weil [21]. Early flowering varieties (DZ-CR-385, DZ-CR-409) have taken 96 days to mature, while the late maturing varieties (DZ-01-196, DZ-CR-387) matured in 110 days, whereas the local variety matured in 106 days, indicating differing maturing groups which is a genetic character and not much altered by growing environment.

Significant interaction between varieties and fertilizer revealed that DZ-CR-387 and DZ-01-196 when fertilized with 75% RDF+25% FYM and 100%RDF+5 t/ha FYM (Table 3) delayed maturity (114 days) in comparison with control and only inorganic fertilizer (110 days). But in DZ-CR-385, DZ-CR-409 and local Varity the days to maturity was not altered much due to fertilizer management practices (Table 3).

**Lodging index:** Tef being a weak stalked plant, often is prone for lodging, especially at reproductive stage due to weight of developing spikes. It was found that the crop exhibited less lodging without fertilizer (1.1%), whereas the lodging percent increased with the application of either inorganic fertilizer alone or in integration with organic manure (1.3-1.5%) (Table 2). The role of P in providing strength of straw and thus preventing lodging has been reported [21,22]. This calls for a need for balanced/optimum fertilization of tef to obtain less lodging so as to avoid pre and postharvest loss of grain. Different varieties did not exhibit discernible variation in lodging percent; however local variety tended to lodge more (1.87%) than improved tef varieties (1.2%). Traditional varieties are tall in stature and prone to lodging in comparison with the improved genotypes, which are medium in stature and have stiff straw and consequently are less prone to lodging.

**Plant height (cm):** Application of nutrient either in the form of inorganic or organic forms resulted in enhanced plant height (76.7 to 82.3 cm) in comparison with unfertilized crop (61.5 cm) elucidating better vegetative growth. Enhanced crop growth due to N fertilizer treatment has also been reported by Haftom et al. [23]. Local tef variety grew significantly taller(83 cm), while DZ-01-196 and DZ-CR-387 were comparable (80 cm) followed closely by DZ-CR-409 (72 cm), whereas DZ-CR-385 was of short stature (65 cm). The plant height is a genetic attribute and is little influenced by growing environment as observed in the current study.

The varieties and nutrient management practices showed significant interaction on plant height (Table 4). Tef variety DZ-CR-385 and DZ-CR-409 responded to 100% RDF+5 t FYM /ha$^{-1}$ in comparison with rest of the fertilizer treatments. The genotypes DZ-01-196, DZ-CR-387 and local Varity showed significantly different effect with all fertilizer management practices over unfertilized check (Table 4).

**Tillering capacity:** Tillering capacity at the vegetative growth stage and the productive tillers at reproductive stage represent yielding ability of the crops, as it is a major yield component. The integration of inorganic fertilizer with farmyard manure resulted in production of significantly greater number of tillers per unit area (23-25.5) than that could be produced due to application of inorganic fertilizer alone

| | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | Mean |
|---|---|---|---|---|---|---|---|
| **DZ-01-196** | 64.7$^{gh}$ | 80.3$^{bcd}$ | 88.0$^{ab}$ | 85.5$^{ab}$ | 83.3$^{abc}$ | 81.1$^{abcd}$ | 80.5 |
| **DZ-CR-385** | 52.5$^{j}$ | 65.5$^{fgh}$ | 63.2$^{ghi}$ | 62.3$^{ghi}$ | 82.8$^{abc}$ | 64.0$^{gh}$ | 65 |
| **DZ-CR-387** | 55.1$^{ij}$ | 82.9$^{abc}$ | 86.8$^{ab}$ | 82.5$^{abc}$ | 82.5$^{abc}$ | 85.5$^{ab}$ | 79.1 |
| **DZ-CR-409** | 62.0$^{hi}$ | 76.9$^{cde}$ | 76.7$^{cde}$ | 69.3$^{efgh}$ | 80.0$^{bcd}$ | 70.6$^{efg}$ | 72.5 |
| **Local Varity** | 73.2$^{def}$ | 86.3$^{ab}$ | 84.7$^{abc}$ | 84.0$^{abc}$ | 83.1$^{abc}$ | 89.1$^{a}$ | 83.3 |
| **Mean** | 61.5 | 78.4 | 79.8 | 76.7 | 82.3 | 78 | 76.08 |
| **LSD (5%) 8.5** | | | | | | | |
| **CV (%) 3.47** | | | | | | | |

Where, $T_1$=Control(0-0-0); $T_2$=RDF(40-60-0); $T_3$=50% RDF+50% FYM; $T_4$=75% RDF+25% FYM; $T_5$=100% RDF+5 t/ha FYM and $T_6$=RDF NPS 23-10-5. Value within a column followed by the same letter is not significant different at LSD 5% probability level.

**Table 4:** Interaction effect of genotypes and fertilizer on plant height (cm).

| | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | Mean |
|---|---|---|---|---|---|---|---|
| **DZ-01-196** | 11.1$^{h}$ | 16.4$^{g}$ | 24.3$^{abcd}$ | 25.0$^{abcd}$ | 25.9$^{ab}$ | 24.4$^{abcd}$ | 21.1 |
| **DZ-CR-385** | 9.4$^{h}$ | 21.0$^{ef}$ | 23.4$^{bcd}$ | 25.2$^{abc}$ | 27.6$^{a}$ | 24.3$^{abcd}$ | 21.8 |
| **DZ-CR-387** | 10.9$^{h}$ | 21.4$^{def}$ | 24.5$^{abcd}$ | 26.1$^{ab}$ | 26.7$^{ab}$ | 23.2$^{bcde}$ | 22.1 |
| **DZ-CR-409** | 10.1$^{h}$ | 17.9$^{fg}$ | 23.1$^{bcde}$ | 25.7$^{ab}$ | 23.7$^{bcde}$ | 26.1$^{ab}$ | 21.1 |
| **Local Varity** | 8.6$^{h}$ | 17.9$^{fg}$ | 21.5$^{cdef}$ | 23.3$^{bcde}$ | 24.8$^{abcd}$ | 21.5$^{cdef}$ | 19.6 |
| **Mean** | 10 | 18.9 | 23.3 | 25 | 25.8 | 23.8 | 21.1 |
| **LSD (5%) 3.8** | | | | | | | |
| **CV (%)5.53** | | | | | | | |

Where, $T_1$=Control(0-0-0); $T_2$=RDF(40-60-0); $T_3$=50% RDF+50% FYM; $T_4$=75%RDF+25% FYM; $T_5$=100%RDF+5 t/ha FYM and $T_6$=RDF NPS 23-10-5. Value within a column followed by the same letter is not significant different at LSD 5% probability level.

**Table 5:** Interaction effect of genotypes and fertilizer on initial tillering.

| | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | Mean |
|---|---|---|---|---|---|---|---|
| DZ-01-196 | 9.1$^{i}$ | 14.1$^{h}$ | 22.0$^{abcdef}$ | 22.7$^{abcde}$ | 23.7$^{abc}$ | 22.1$^{abcdef}$ | 18.9 |
| DZ-CR-385 | 7.2$^{i}$ | 18.7$^{fg}$ | 20.9$^{bcdef}$ | 22.7$^{abcde}$ | 24.7$^{ab}$ | 21.3$^{abcdef}$ | 19.2 |
| DZ-CR-387 | 8.4$^{i}$ | 18.8$^{fg}$ | 22.3$^{abcdef}$ | 23.7$^{abc}$ | 24.9$^{a}$ | 20.8$^{cdef}$ | 19.8 |
| DZ-CR-409 | 7.9$^{i}$ | 15.3$^{gh}$ | 20.8$^{cdef}$ | 23.4$^{abc}$ | 21.7$^{abcdef}$ | 23.1$^{abcd}$ | 18.6 |
| Local Varity | 6.5$^{i}$ | 15.5$^{gh}$ | 19.3$^{cdef}$ | 21.0$^{bcdef}$ | 22.1$^{abcdef}$ | 19.1$^{efg}$ | 17.2 |
| Mean | 7.8 | 16.4 | 21 | 25 | 25.8 | 21.2 | 18.7 |
| LSD (5%) 3.8 | | | | | | | |
| CV (%) 6.33 | | | | | | | |

Where, $T_1$=Control(0-0-0); $T_2$=RDF(40-60-0); $T_3$=50% RDF+50% FYM; $T_4$=75% RDF+25% FYM; $T_5$=100% RDF+5 t/ha FYM and $T_6$=RDF NPS 23-10-5. Value within a column followed by the same letter is not significant different at LSD 5% probability level.

**Table 6:** Interaction effect of genotype and fertilizer on fertile tillers.

(18.9) or no fertilizer check (10.0). This result corroborates with the findings of Haftom et al., Al Abdul Salam and Warraich et al. [23-25]. The different genotypes did not show discernible variation in the initial tiller counts, though the traditional cultivar tended to produce less tillers than the improved test varieties.

Significant interaction between varieties and nutrient management practices (Table 5) showed that all the improved varieties produced significantly greater number of tillers than local variety with the application of 75% RDF+25% FYM and 100% RDF+5 t/ha FYM when compared with RDF, 50% RDF+50% FYM and control. Application of FYM improved tillering capacity.

**Effective/productive tillers:** Effective tillers are those bearing panicles that contribute to the grain yield. There was a decrease in the number of tillers at reproductive stage in comparison with those observed at vegetative stage owing mainly to mortality and variable source to sink relationships. The effective tillers followed a trend akin to the vegetative tillers in relation to the nutrient management practices; in that integrated nutrient management had an edge (21-23.4 tillers)over exclusive application of inorganic fertilizer(16.4 tillers) or no fertilizer control (7.8 tillers) in manifestation of tillering capacity. Enhancement in productive tillers due to application of nitrogen has also been reported by Al-Abdul Salam and Warraich et al. [25]. Tef varieties showed distinct variation in panicle bearing tillers where variety DZ-CR-387(20 tillers) remaining comparable with DZ-CR-385(19 tillers), DZ-01-196 and DZ-CR-409 produced greater number of tillers than local cultivar (17 tillers). Variation in productive tillers has also been reported by Belay and Baker [26].

Significant interaction between varieties and nutrient management revealed that all the improved varieties exhibited significant improvement in effective tillers over local variety with the application of 75% RDF+25% FYM (Table 6). Application of 100% RDF+5 t/ha FYM for all varieties produced higher number of effective tillers. The fertile tillers were significantly lower with RDF through inorganic fertilizer, which in turn was superior to unfertilized control.

**Leaf number plant$^{-1}$:** Application of fertilizer showed substantial improvement in the number of leaves/plant (42.9-56.2) over unfertilized check (25.3). Integrated application of inorganic fertilizer with farmyard manure produced significantly higher number of leaves/ plant (49 to 56) than with the application of inorganic fertilizer (42.9) or with no fertilizer check (25.3) which produced least leaf number / plant. Tef varieties differed significantly in the number of leaves/ plant where Local variety possessed grater leaf number (57) than the

| | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | Mean |
|---|---|---|---|---|---|---|---|
| **DZ-01-196** | 31.9$^{no}$ | 37.0$^{klmn}$ | 35.3$^{lmno}$ | 38.9$^{ijkl}$ | 36.3$^{klmn}$ | 43.7$^{ghij}$ | 37.1 |
| **DZ-CR-385** | 22.3$^{p}$ | 44.3$^{ghi}$ | 39.5$^{ijkl}$ | 38.6$^{jklm}$ | 52.9$^{f}$ | 36.3$^{klmn}$ | 39 |
| **DZ-CR-387** | 21.0$^{p}$ | 41.5$^{hijk}$ | 46.6$^{gh}$ | 43.0$^{hij}$ | 49.0$^{fg}$ | 33.3$^{mno}$ | 39 |
| **DZ-CR-409** | 30.5$^{o}$ | 53.6$^{ef}$ | 59.0$^{de}$ | 67.0$^{bc}$ | 61.6$^{cd}$ | 62.7$^{cd}$ | 55.6 |
| **Local Varity** | 21.0$^{p}$ | 38.3$^{jklm}$ | 70.3$^{b}$ | 61.0$^{d}$ | 81.0$^{a}$ | 72.3$^{b}$ | 57.3 |
| **Mean** | 25.3 | 42.9 | 50.2 | 25 | 56.2 | 49.6 | 45.6 |
| **LSD (5%) 5.5** | | | | | | | |
| **CV (%)3.75** | | | | | | | |

Where, $\mathbf{T_1}$=Control(0-0-0); $\mathbf{T_2}$=RDF (40-60-0); $\mathbf{T_3}$=50% RDF+50% FYM; $\mathbf{T_4}$=75% RDF+25% FYM; $\mathbf{T_5}$=100% RDF+5 t/ha FYM and $\mathbf{T_6}$=RDF NPS 23-10-5. Value within a column followed by the same letter is not significant different at LSD 5% probability level.

**Table 7:** Interaction effect of genotype and fertilizer on leaf number/plant.

| | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | Mean |
|---|---|---|---|---|---|---|---|
| **DZ-01-196** | 7.66$^{cde}$ | 6.27$^{ghi}$ | 8.57$^{c}$ | 6.42$^{fghi}$ | 7.30$^{defg}$ | 5.03$^{j}$ | 6.87 |
| **DZ-CR-385** | 7.88$^{cd}$ | 3.94$^{kl}$ | 3.56$^{lm}$ | 8.54$^{c}$ | 3.28$^{lm}$ | 6.42$^{fghi}$ | 5.6 |
| **DZ-CR-387** | 6.42$^{fghi}$ | 6.75$^{efgh}$ | 7.84cd | 8.54$^{c}$ | 7.15$^{defgh}$ | 10.78$^{b}$ | 7.91 |
| **DZ-CR-409** | 3.93$^{kl}$ | 7.04$^{defgh}$ | 4.70$^{jk}$ | 5.53$^{ij}$ | 2.82$^{m}$ | 6.87$^{defgh}$ | 5.14 |
| **Local Varity** | 7.40$^{def}$ | 4.89$^{jk}$ | 6.14$^{hi}$ | 6.25$^{hi}$ | 9.82$^{b}$ | 12.00$^{a}$ | 7.74 |
| **Mean** | 6.64 | 5.78 | 6.16 | 7.05 | 6.07 | 8.22 | 6.65 |
| **LSD (5%) 1.05** | | | | | | | |
| **CV (%)4.87** | | | | | | | |

Where, $\mathbf{T_1}$=Control(0-0-0); $\mathbf{T_2}$=RDF(40-60-0); $\mathbf{T_3}$=50% RDF+50% FYM; $\mathbf{T_4}$=75% RDF+25% FYM; $\mathbf{T_5}$=100% RDF+5 t/ha FYM and $\mathbf{T_6}$ =RDF NPS 23-10-5. Value within a column followed by the same letter is not significant different at LSD 5%.

**Table 8:** Interaction effect of genotype and fertilizer on leaf area (cm).

| | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | Mean |
|---|---|---|---|---|---|---|---|
| **DZ-01-196** | 22.6$^{h}$ | 29.5$^{bcdef}$ | 32.9$^{abcde}$ | 33.9$^{abcd}$ | 35.8$^{a}$ | 35.7$^{a}$ | 31.7 |
| **DZ-CR-385** | 23.5$^{gh}$ | 28.6$^{defg}$ | 32.7$^{abcde}$ | 32.5$^{abcde}$ | 33.8$^{abcd}$ | 33.2$^{abcde}$ | 30.7 |
| **DZ-CR-387** | 24.1$^{fgh}$ | 32.8$^{abcde}$ | 34.7$^{ab}$ | 35.1$^{a}$ | 37.0$^{a}$ | 35.7$^{a}$ | 33.1 |
| **DZ-CR-409** | 23.9$^{gh}$ | 28.9$^{cdefg}$ | 34.0$^{abcd}$ | 36.1$^{a}$ | 37.2$^{a}$ | 34.4$^{abc}$ | 32.4 |
| **Local Varity** | 24.3$^{fgh}$ | 27.9$^{efgh}$ | 36.0$^{a}$ | 37.8$^{a}$ | 36.6$^{a}$ | 36.7$^{a}$ | 33.1 |
| **Mean** | 23.6 | 29.5 | 34 | 35 | 36 | 35.1 | 32.2 |
| **LSD (5%) 5.5** | | | | | | | |
| **CV (%)5.27** | | | | | | | |

Where, $\mathbf{T_1}$=Control(0-0-0); $\mathbf{T_2}$=RDF(40-60-0); $\mathbf{T_3}$=50% RDF+50% FYM; $\mathbf{T_4}$=75% RDF+25% FYM; $\mathbf{T_5}$=100% RDF+5 t/ha FYM and $\mathbf{T_6}$=RDF NPS 23-10-5. Value within a column followed by the same letter is not significant different at LSD 5% probability level.

**Table 9:** Interaction effect of genotype and fertilizer on panicle length (cm).

improved varieties DZ-CR-409(56) which in turn had higher leaf number in comparison with the rest of the genotypes which had almost similar leaf number/plant$^{-1}$ (37-39).

Interaction of varieties and nutrient management practices significantly affected mean number of leaf plant (Table 7) where Local variety produced large number of leaves/plant with 100% RDF+5 t/ha FYM, followed by DZ-CR-409 with 75%RDF+25% FYM.

**Leaf area (cm):** Application of N at stem elongation stage has been reported to greatly stimulate leaf area growth resulting in significantly greater assimilation capacity, both before and after antithesis. Application of new complex fertilizer (NPS 23-10-5) resulted in substantially higher leaf area (8.2 cm) than the rest of the fertilizer treatments. However, 75% RDF+25% FYM was found superior to the other treatments in leaf area; whereas inorganic fertilizer alone (5.78 cm) showed least leaf area.

Leaf area, which is an indicator of assimilatory surface, varied with varieties; where the variety DZ-CR-387(7.9 cm) remaining at a par with local cultivar (7.7 cm) possessed grater leaf area than DZ-01-196(6.87 cm), DZ-CR-385(5.60 cm) and DZ-CR-409(5.1 cm).

The varieties DZ-CR-385 and DZ-CR-387 showed significant enhancement in leaf area (8.54 cm) when fertilized with 75% RDF+25% FYM as revealed by varieties and fertilizer interaction.

## Yield components

**Panicle length (cm):** Application of fertilizer either in organic or inorganic form (29.5 cm) and their integrated application (35.0 cm) brought about discernible variation in the length of panicle in comparison with unfertilized control (23.7 cm). Higher number of tillers in fertilized plots could also produce longer panicles due to less competition for sinks in comparison with unfertilized plots. This is in accordance with the reports that combined application of half dose of inorganic and half dose of organic source resulted in more panicle length apart from plant height and tiller production [23]. Panicle length is an indicator of sink capacity which differed significantly with the varieties; where the varieties DZ-CR-387(33.2 cm) remaining comparable with the local cultivar (33.2 cm) and DZ-CR-409 (32.4 cm) produced distinctly longer panicles than DZ-01-196 (31.7 cm) and DZ-CR-385(30.7 cm). Variation in panicle length among tef varieties was also reported by Belay and Baker [26].

Interaction of varieties with nutrient management practice was significant for panicle length (Tables 8 and 9) where Tef varieties showed distinct improvement in length of panicle with integrated

| | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | Mean |
|---|---|---|---|---|---|---|---|
| **DZ-01-196** | 1.1$^{ij}$ | 1.3$^{hij}$ | 1.8$^{abcdefg}$ | 1.9$^{abcde}$ | 1.9$^{abcd}$ | 1.3$^{ghij}$ | 1.53 |
| **DZ-CR-385** | 1.1$^{ij}$ | 1.5$^{efghi}$ | 1.9$^{abcde}$ | 1.8$^{abcdefg}$ | 1.9$^{abcd}$ | 1.4$^{fghij}$ | 1.59 |
| **DZ-CR-387** | 1.1$^{ij}$ | 1.6$^{cdefgh}$ | 1.9$^{abcde}$ | 2.1$^{a}$ | 1.9$^{abcde}$ | 1.8$^{abcdef}$ | 1.71 |
| **DZ-CR-409** | 1.0$^{j}$ | 1.5$^{defgh}$ | 2.0$^{abc}$ | 1.9$^{abcd}$ | 2.0$^{a}$ | 1.5$^{efghi}$ | 1.66 |
| **Local Varity** | 1.3$^{hij}$ | 1.6$^{cdefgh}$ | 1.9$^{abcd}$ | 1.9$^{abcde}$ | 1.8$^{abcdef}$ | 1.6$^{bcdefgh}$ | 1.68 |
| **Mean** | 1.1 | 1.49 | 1.88 | 1.9 | 1.92 | 1.53 | 1.63 |
| **LSD (5%) 0.4** | | | | | | | |
| **CV (%) 8.07** | | | | | | | |

Where, $T_1$=Control(0-0-0); $T_2$=RDF(40-60-0); $T_3$=50% RDF+50% FYM; $T_4$=75% RDF+25% FYM; $T_5$=100% RDF+5 t/ha FYM and $T_6$=RDF NPS 23-10-5. Value within a column followed by the same letter is not significant different at LSD 5% probability level.

**Table 10:** Interaction effect of genotype and fertilizer on panicle weight (g).

| | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | Mean |
|---|---|---|---|---|---|---|---|
| **DZ-01-196** | 0.22$^{k}$ | 0.28$^{ghij}$ | 0.28$^{ghijk}$ | 0.35$^{abcdef}$ | 0.35$^{abcde}$ | 0.38$^{abc}$ | 0.30 |
| **DZ-CR-385** | 0.28$^{ghijk}$ | 0.29$^{fghi}$ | 0.33$^{bcdef}$ | 0.32$^{defgh}$ | 0.38$^{abcd}$ | 0.29$^{efghi}$ | 0.31 |
| **DZ-CR-387** | 0.27$^{hijk}$ | 0.28$^{ghij}$ | 0.36$^{abcd}$ | 0.38$^{abcd}$ | 0.39$^{ab}$ | 0.35$^{abcdef}$ | 0.33 |
| **DZ-CR-409** | 0.25$^{ijk}$ | 0.35$^{abcdef}$ | 0.38$^{abcd}$ | 0.40$^{a}$ | 0.33$^{cdefgh}$ | 0.29$^{ghi}$ | 0.33 |
| **Local Varity** | 0.22$^{jk}$ | 0.40$^{a}$ | 0.33$^{bcdefg}$ | 0.37$^{abcd}$ | 0.39$^{ab}$ | 0.28$^{ghijk}$ | 0.33 |
| **Mean** | 0.24 | 0.31 | 0.33 | 0.36 | 0.36 | 0.31 | 0.32 |
| **LSD (5%) 0.06** | | | | | | | |
| **CV (%)5.7** | | | | | | | |

Where, $T_1$=Control(0-0-0); $T_2$=RDF(40-60-0); $T_3$=50% RDF+50% FYM; $T_4$=75% RDF+25% FYM; $T_5$=100% RDF+5 t/ha FYM and $T_6$=RDF NPS 23-10-5. Value within a column followed by the same letter is not significant different at LSD 5%.

**Table 11:** Interaction effect of genotype and fertilizer on 1000 seed weight (g).

| | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | Mean |
|---|---|---|---|---|---|---|---|
| **DZ-01-196** | 659.0$^{jkl}$ | 893.7$^{fghij}$ | 1256.0$^{bcd}$ | 1626.0$^{a}$ | 1644.0$^{a}$ | 953.0$^{efghi}$ | 1171.8 |
| **DZ-CR-385** | 680.3$^{ijkl}$ | 758.3$^{hijk}$ | 985.3$^{defgh}$ | 1113.0$^{cdefg}$ | 1156.0$^{cdef}$ | 783.3$^{hijk}$ | 912.6 |
| **DZ-CR-387** | 447.7$^{l}$ | 945.0$^{fghi}$ | 1027.0$^{cdefgh}$ | 1167.0$^{bcdef}$ | 978.7$^{defgh}$ | 846.3$^{ghij}$ | 901.8 |
| **DZ-CR-409** | 749.0$^{hijk}$ | 965.7$^{efgh}$ | 1300.0$^{b}$ | 1157.0$^{cdef}$ | 1237.0$^{bcde}$ | 749.0$^{hijk}$ | 1025.8 |
| **Local Varity** | 560.0$^{kl}$ | 999.3$^{defgh}$ | 1100.0$^{cdefg}$ | 1442.0$^{ab}$ | 1008.0$^{defgh}$ | 999.7$^{defgh}$ | 1018.1 |
| **Mean** | 619 | 912.4 | 1133.6 | 1301 | 1204.2 | 866.2 | 1006.2 |
| **LSD (5%)281.5** | | | | | | | |
| **CV (%) 8.6** | | | | | | | |

Where, $T_1$=Control(0-0-0); $T_2$=RDF(40-60-0); $T_3$=50% RDF+50% FYM; $T_4$=75% RDF+25% FYM; $T_5$=100% RDF+5 t/ha FYM and $T_6$=RDF NPS 23-10-5. Value within a column followed by the same letter is not significant different at LSD 5% probability level.

**Table 12:** Interaction effect of genotype and fertilizer on grain yield (kg/ha).

nutrient management and application of new complex fertilizer over RDF and unfertilized control. Application of RDF through inorganic source was superior to no fertilizer control in all varieties.

**Panicle weight (g):** The panicle weight has been significantly higher with integrated use of inorganic fertilizer with organic manure (1.9 g) as compared with sole application of inorganic nutrient (1.5 g) or no fertilizer (1.1 g). This is in agreement with the finding of Tekalign et al. [13]. The panicle weight tended to be in accordance with the length of the panicle. Among the varieties, DZ-CR-387 possessed panicles of greater weight (1.72 g), closely followed by local cultivar (1.68 g) and DZ-CR-409(1.66 g); while the lower panicle weight was obtained from DZ-CR-385(1.59 g) and DZ-01-196(1.54 g). These findings are in agreement with the report of Blum and Belay; Baker [26,27].

The panicle weight of all the varieties improved substantially with integrated nutrient management in comparison with application of RDF through inorganic source and no fertilizer check. The least panicle length was recorded in all the varieties with no fertilizer.

**Thousand seed weight (g):** Application of fertilizer significantly improved thousand seed weight (0.318 g) over no fertilization check (0.248 g). Further, integration of inorganic fertilizer with farm yard manure in different proportions had a synergistic effect on thousand seed weight (0.337 g-0.368 g) in comparison with sole inorganic fertilizer or no fertilizer application. Improvement in thousand seed weight due to fertilizer application has also been reported by AL-Abdul Salam [24]. The tef varieties differed significantly in their thousand seed weight where DZ-CR-387 had superior thousand seed weight (0.33 g) followed by DZ-CR-409(0.331 g) and local cultivar (0.331 g) which in turn were comparable. The variety DZ-CR-385(0.316 g) was found superior to DZ-01-196 (0.309 g) which gave the least thousand seed weight.

The interaction of varieties with nutrient management was significant on thousand seed weight of tef where DZ-CR-409 and DZ-CR-387 possessed higher thousand seed weight with 50% RDF+50% FYM and 75% RDF+25% FYM over RDF and unfertilized control (Tables 10-13). The thousand seed weight of DZ-01-196, DZ-CR-385 and Local cultivar improved with 100% RDF+5 t FYM/ha$^{-1}$. All the varieties recorded least thousand seed weight with no fertilizer treatment.

**Grain yield (kg/ha):** Application of 50% recommended dose of fertilizer through inorganic source and 50% through farmyard manure resulted in significant improvement in grain yield (1133 kg/ha$^{-1}$) over no fertilizer check (619 kg/ha). Application of RDF through complex fertilizer (866 kg/ha$^{-1}$); and remained comparable with 75%

| | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | Mean |
|---|---|---|---|---|---|---|---|
| **DZ-01-196** | 2790$^{jk}$ | 3205$^{efghi}$ | 3949$^{c}$ | 4771$^{a}$ | 4824$^{a}$ | 2810$^{jk}$ | 3724.7 |
| **DZ-CR-385** | 2834$^{jk}$ | 2980$^{ghij}$ | 3333$^{ef}$ | 3352$^{e}$ | 3955$^{c}$ | 2995$^{fghij}$ | 3241.4 |
| **DZ-CR-387** | 1139$^{l}$ | 3251$^{efgh}$ | 3440$^{de}$ | 4045$^{bc}$ | 3296$^{efg}$ | 3311$^{efg}$ | 3080.3 |
| **DZ-CR-409** | 2909$^{hij}$ | 3292$^{efg}$ | 4333$^{b}$ | 3841$^{c}$ | 3955$^{c}$ | 2904$^{ij}$ | 3538.9 |
| **Local Varity** | 2553$^{k}$ | 3332$^{ef}$ | 3771$^{cd}$ | 3930$^{c}$ | 3470$^{de}$ | 3342$^{e}$ | 3399.6 |
| **Mean** | 2444.9 | 3212.1 | 3764.9 | 3987.7 | 3899.8 | 3072.5 | 3397.03 |
| **LSD (5%) 342.9** | | | | | | | |
| **CV (%)3.18** | | | | | | | |

Where, $T_1$=Control(0-0-0); $T_2$=RDF(40-60-0); $T_3$=50% RDF+50% FYM; $T_4$=75% RDF+25% FYM; $T_5$=100% RDF+5 t/ha FYM and $T_6$=RDF NPS 23-10-5. Value within a column followed by the same letter is not significant different at LSD 5% probability level.

**Table 13:** Interaction effect of genotype and fertilizer on straw yield (kg/ha).

| | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | Mean |
|---|---|---|---|---|---|---|---|
| **DZ-01-196** | 23.62$^{kl}$ | 27.89$^{fghij}$ | 31.80$^{bcde}$ | 34.07$^{b}$ | 34.09$^{b}$ | 33.91$^{bc}$ | 30.89 |
| **DZ-CR-385** | 24.00$^{kl}$ | 25.44$^{jk}$ | 29.57$^{efg}$ | 33.19$^{bcd}$ | 29.21$^{efgh}$ | 26.15$^{ghijk}$ | 27.92 |
| **DZ-CR-387** | 39.31$^{a}$ | 29.06$^{efghi}$ | 29.84$^{def}$ | 28.85$^{efghij}$ | 29.69$^{def}$ | 25.55$^{ijk}$ | 30.38 |
| **DZ-CR-409** | 25.75$^{hijk}$ | 29.33$^{efg}$ | 30.34$^{def}$ | 30.12$^{def}$ | 31.20$^{bcdef}$ | 25.79$^{hijk}$ | 28.74 |
| **Local Varity** | 21.88$^{l}$ | 29.99$^{def}$ | 29.17$^{efgh}$ | 30.48$^{cdef}$ | 29.06$^{efghi}$ | 28.90$^{efghij}$ | 28.24 |
| **Mean** | 26.9 | 28.33 | 29.17 | 31.33 | 30.64 | 28.05 | 29.23 |
| **LSD (5%) 3.54** | | | | | | | |
| **CV (%) 3.7** | | | | | | | |

Where, $T_1$=Control(0-0-0); $T_2$=RDF(40-60-0); $T_3$=50% RDF+50% FYM; $T_4$=75% RDF+25% FYM; $T_5$=100% RDF+5 t/ha FYM and $T_6$ =RDF NPS 23-10-5. Value within a column followed by the same letter is not significant different at LSD 5% probability level.

**Table 14:** Interaction effect of genotype and fertilizer on Harvest index of Tef.

RDF through inorganic fertilizer+25% N through farmyard manure (1300 kg/ha$^{-1}$). Thus the superior performance of integrated nutrient management comprising 50%+50% through inorganic and farmyard manure of nutrients could be attributed to enhancement in various growth parameters and increased seed yield. In line with the present finding, at Holleta Research centre on Nitosols, incorporation of organic mustard meal at 31 kg/ha$^{-1}$ 20 days ahead of sowing tef resulted in yield increase of 42, 32 and 25% over control [28]. Improvement in yield due to fertilizer application has also been reported by Haftom et al., Al-Abdul Salam and Warriach et al., ZARC [23-25,29]. NFIU reported response of tef to 60 kg N/ha$^{-1}$ on high land Vertisols of Ethiopia [30]. Kenea et al. reported that the recommended fertilizer for tef is 100 kg DAP and 100 kg urea/ha$^{-1}$ [31].

Grain yield is a product of all the yield attributes and is the principal economic output of the crop. Tef varieties exhibited significant variations in the grain yields. Improved tef variety DZ-01-196 (1172 kg/ha$^{-1}$) remaining comparable with DZ-CR-409(1026 kg/ha$^{-1}$) and local cultivar (1018 Kg/ha$^{-1}$) offered substantially greater grain yield than DZ-CR-385 (913 Kg/ha) and DZ-CR-387 (902 Kg/ha) which in turn were comparable. In the present study, the lower yield of DZ-CR-385 and DZ-CR-387 could probably be attributed to genetic potential of varieties as compared to others. Differential performance tef varieties with varied grain yield was also reported by Kelsa on three tef varieties at Awassa and Areka areas of Ethiopia [32]. Considerable genetic variability in grain yield and dry matter accumulation has been reported to exist between and within crop species [27]. Belay and Baker also reported variation in biological yield of tef varieties [26].

There was significant interaction between varieties and nutrient management on grain yield of tef (Table 12) where DZ-01-196 yielded higher with 100% RDF+5 tFYM/ha$^{-1}$.(1644 kg/ha$^{-1}$.) which was comparable with 75% RDF+25%FYM (1626 kg/ha$^{-1}$) and local variety fertilized with 75% RDF+25% FYM (1442 kg/ha$^{-1}$). The variety DZ-CR-409 yielded better with 50% RDF+50% FYM (1300 kg/ha$^{-1}$). Tef varieties DZ-CR-385 and DZ-CR-387 performed well with 75% RDF+25% FYM application. Abuhay also reported variation in grain yield of tef [33].

**Straw yield (kg/ha):** Application of 75% recommended dose of fertilizer through inorganic source and substitution of 25% RDF with farm yard manure resulted in significantly higher straw yield (3988.6 kg ha$^{-1}$) than other treatments. This was followed by RDF+5 t/ha FYM (3900.9 kg ha$^{-1}$) and 50% RDF+50% through FYM (3765 kg ha$^{-1}$). The least straw production was obtained from unfertilized control (2445.1 kg ha$^{-1}$) and the RDF through new complex fertilizer (3073.1 kg ha$^{-1}$). Thus integration of inorganic and farmyard manure had a beneficial effect on production of biological yield of tef in comparison with use of inorganic fertilizer alone or no fertilizer application. Tef variety DZ-01-196 gave significantly higher straw yield (3725 kg ha$^{-1}$) over other varieties. This was followed by DZ-CR-409(3539 kg ha$^{-1}$), local variety (3399 kg ha$^{-1}$), DZ-CR-385(3241 kg ha$^{-1}$) and DZ-CR-387 (3080 kg ha$^{-1}$) [34].

Significant interaction between varieties and nutrient management elucidated that the improved variety DZ-01- 196 produced higher straw yield of 4824 kg/ha$^{-1}$ with 100% RDF+5 t/ha FYM which was comparable with 75% RDF+25% FYM (4771 kg ha$^{-1}$) (Table 13). The variety DZ-CR-409 and DZ-CR-385 gave higher straw yield with 50% RDF+50% FYM (4333 kg ha$^{-1}$) and (3955 kg ha$^{-1}$), whereas DZ-CR-387 with 75% RDF+25% FYM gave 4045 kg ha$^{-1}$.

**Harvest index:** Harvest index of tef was significantly higher with 75% RDF+25%FYM (31.3) which was comparable to 100% RDF+5 t/ha FYM (30.64) and superior to the rest of the fertilizer treatments. The second best treatments was 50% RDF+50% FYM (30.14) which in turn was superior to RDF (28.34) and RDF through complex fertilizer (28.05). The least harvest index of 26.91 was recorded with unfertilized control [35].

Among the tef varieties, DZ-01-196 gave the highest harvest index of 30.89 which was comparable with DZ-CR-387(30.38) and superior to the other varieties. Tef variety DZ-CR-409 remaining at a par with local variety (28.24) was found superior to DZ-CR-385 (27.92).

Interaction of varieties of Tef with nutrient management practice on harvest index was significant (Table 14) where Tef variety DZ-01-196 with integrated nutrient management practice produced significantly greater harvest index (34.09), which was comparable with DZ-CR-385 with 75% RDF+25% FYM (33.19) and DZ-CR-409 with 100% RDF+5 t/ha FYM (31.20). There was distinct improvement of harvest index of local variety with fertilizer use (31.33) over no fertilizer (21.88).

## Conclusion

From the foregoing account it can be inferred that in rain fed Tef crop raised on Vertisols, Integrated use of FYM in conjunction with inorganic fertilizer is more efficient than use of RDF through inorganic source and unfertilized crop employing selected improved Tef genotype can considerably improve grain yields. In this study, application of 50% RDF+50% FYM, 75% RDF+25% FYM and 100% RDF+5 t/ha FYM using DZ-01-196, DZ-CR-409 and Local variety, respectively exhibited best yield performance in the mid high lands of West Shoa zone in Oromia region of Ethiopia.

### References

1. Mulat D (1999) Agricultural Technology, Economic Viability and Poverty Alleviation in Ethiopia, Paper presented to the Agricultural Transformation Policy Workshop, Kenya.
2. UNDP (2002) UNDP assistance in the fifth country program to the agricultural sector.
3. Yihenew G (2002) Selected chemical and physical characteristics of soils of Adet Research Centre and its testing sites in north western Ethiopia. Ethiopian Journal of Natural Resources 4: 199-215.
4. Tekalign M (1998) Effect of source, rate and timing of nitrogen applied to wheat on soil N level in a vertisol in central highland of Ethiopia. In: Crop Management Options to sustain Food Security, pp: 85-100.
5. Central Statistic Authority (2008) Agricultural Sample Survey. Report on area and production for major crops (private peasant holdings Meher season) Statistical Bulletin 417, Addis Ababa.
6. Seyfu K (1993) Tef [Eragrostis tef (Zucc.)Trotter]. Breeding, Genetic Resources, Agronomy, Utilization and Role in Ethiopian Agriculture. Institute of Agricultural Research, Addis Ababa, Ethiopia.
7. Seyfu K (1997) Tef [Eragrostis tef ( Zucc.) Trotter]. Promoting the conservation and use of underutilized and neglected crops. Biodiversity institute, Addis Ababa, Ethiopia.
8. Mitiku H, Fassil K (1996) Soil and moisture conservation in Semi-arid areas of Ethiopia. In: Proceedings of the Third Conference of Ethiopian Soil Science Society (ESSS). Addis Ababa, Ethiopia.
9. Piccinin D (2010) More About Ethiopian Food: Teff. Ethno Med: Ethiopian food. Online. Internet available.
10. Hailu T, Seyfu K (1990) Variability and genetic advance in tef (Eragrostis tef) cultivars. Tropical Agriculture 67: 317-320.
11. Fufa H, Tesfa B, Hailu T, Kebebew A, Tiruneh K, et al. (2001) Agronomy Research in tef. In: Hailu Tefera, Getachew Belay and M. Sorrels (ed.), Narrowing the Rift: Tef Research and Development, Proceedings of the International Workshop on Tef Genetics and Improvement, Addis Ababa, Ethiopia, pp: 167-176.
12. Yu JK, Graznak E, Breseghello F, Hailu T, Sorrells ME (2007) QTL mapping of agronomic traits in tef [Eragrostistef (Zucc) Trotter]. BMC Plant Biol 7: 13.
13. Tekalign M, Teklu E, Balesh T (2001) Soil Fertility and Plant Nutrition Research on Tef in Ethiopia. In: Hailu T, Getachew B, Mark S (eds.), Narrowing the Rift. Tef Research and Development, Proceedings of the International Workshop on Tef Genetics and Improvement, Addis Ababa, Ethiopia, pp: 167-176.
14. Tareke B (2008) Increasing Productivity of Tef, Eragrostis tef (Zucc.) Trotter: New Approaches with Dramatic results (Unpublished Report), Addis Ababa, Ethiopia.
15. Van Reeuwijk LP (1992) Procedures for soil analysis. 6th edn. International soil reference and information center, Wageningen (ISRIC).
16. Day PR (1965) Hydrometer method of particle size analysis. In: Back CA (ed.), Method of Soil Analysis. Amer. Soc. Agron. Madison, Wisconsm Agron, p: 562.
17. Nelson DW, Sommers LE (1982) Total carbon, organic carbon and organic matter. In: Page AL, Miller RH, Keeney DR (eds.), Methods of Soil Analysis. American Society of Agronomy, Madison, USA, pp: 539-579.
18. Olsen S, Sommer L (1982) Phosphorus method for soil analysis. Chemical and microbiological properties. ASA Monograph number 9: 403-430.
19. SAS Institute (2004) JMP 5.1.1 Users Guide. SAS Institute Inc. Cary, NC, USA.
20. Steel RGD, Torrie JH (1984) Principles and Procedures of Statistics. McGraw Hill Book Co., Inc., Singapore, p: 481.
21. Brady NC, Weil RR (2002) The Nature and Properties of Soils. 13th edn. Person Education Ltd, USA, p: 740.
22. Miller RW, Donahue RL (1995) Soils in Our Environment. 7th edn. Prentice-Hall Englewood Cliffs, New Jersey, USA.
23. Haftom G, Mitiku H, Yamoah CH (2009) Tillage frequency, soil compaction and N-fertilizer rate effects on yield of tef (Eragrostis tef (Zucc.) Trotter). Ethiopia Journal of Science 1: 82-94.
24. Al-Abdul Salam MA (1997) Influence of nitrogen fertilization rates and residual effect of organic manure rates on the growth and yield of wheat. Arab Gulf J Sci Res 15: 647-660.
25. Warraich EA, Ahmad N, Basra SM, Afzal I (2002) Effect of nitrogen on source-sink relationship in wheat. Int Journal Agri Biol 4: 300-302.
26. Belay S, Baker DB (1996) Agronomy and Morphological response of tef to drought. Trop sci 36: 41-50.
27. Blum (1989) Considerable genetic variation in grain yield and dry matter accumulation exist between and within in crop species.
28. Balesh T, Bernt Aune J, Breland T (2007) Availability of organic nutrient sources and their effects on yield and nutrient recovery of tef [Eragrostis tef (Zucc.) Trotter] and on soil Properties. Journal of Plant Nutrition and Soil Science 170: 543-550.
29. DzARC (Debrezeit Agricultural Research Center) (1988) Annual research report for 1987/88. Debrezeit, Ethiopia, p: 147.
30. NFIU (National Fertilizer and Input Unit) (1993) Agronomic feasibility of the proposed recommendation and comparison with the previous recommendation. NFIU general paper No. 17, Addis Ababa.
31. Kenea Y, Getachew A, Workneh N (2001) Farming Research on Tef: Small Holders Production Practices. In: Hailu T, Getachew B, Sorrels M (eds.), Narrowing the Rift: Tef Research and Development.Proceeding of the International Work shop on tef genetics and improvement, Addis Ababa, Ethiopia.
32. Kelsa K (1998) Effect of DAP and Urea fertilizers on grain yield of three tef varieties in Awassa and Areka. In: Tadele G, Selasssie S, Sahlemedhin S (eds.). Proceedings of the Fourth Conference of the Ethiopian Society of Soil Science. Addis Ababa, Ethiopia, pp: 122-127.
33. Abuhay T (1997) Genetic variability in dry matter production, partitioning and grain yield of tef [Eragrostis tef (zucc) Trotter] under moisture deficit. SINET: Ethiopia J Sci 20: 177-188.
34. National Academy of Sciences (1996) Lost crops of Africa Volume 1, Grains. Bostid National Research Council. National Academy Press. Washington DC, USA.
35. Landon JR (1991) Booker Tropical Soil Manual: A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Sub-tropics. Longman Scientific and Technical, Essex, New York, USA, p: 474.

**Citation:** Mebratu Y, Raghavaiah CV, Ashagre H (2016) Production Potential of Tef (*Eragrostis* tef (Zucc.) Trotter) Genotypes in Relation to Integrated Nutrient Management on Vertisols of Mid High lands of Oromia Region of Ethiopia, East Africa. Adv Crop Sci Tech 4: 249. doi: 10.4172/2329-8863.1000249