Scientific Papers. Series A. Agronomy, Vol. LXII, No. 1, 2019
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

# EFFECT OF ORGANIC AND INORGANIC FERTILIZATION ON YIELD AND YIELD COMPONENTS OF TEFF [*Eragrostis tef* (Zucc.) Trotter] CULTIVATED UNDER MEDITERRANEAN SEMI-ARID CONDITIONS

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***Abstract***

*Teff [Eragrostis tef (Zucc.) Trotter] has the potential to be one of those crops that have gained the interest of people of the Western world due to their beneficial health effects. The purpose of the present study was to evaluate the effect of organic and inorganic fertilization on yield and yield components of teff crop. A field experiment was laid out according to a randomized complete block design, with three replicates and three fertilization treatments [untreated, organic fertilizer (Bokashi) and inorganic fertilizer (34.5-0-0)]. The results showed that the higher plant height (85.9 cm), panicle length (33.4 cm), number of branches per panicle (9.3), number of grains per panicle (815.6), grain yield (1652 kg ha$^{-1}$) and straw yield (3793 kg ha$^{-1}$) were achieved through the application of inorganic fertilizer; however, the differences between the organic and inorganic fertilization were not statistically significant. The number of panicles per plant (9.6-10.4) and thousand grain weight (0.316-0.327 g) were not affected by fertilization. Finally, the results indicated that the organic fertilizer (Bokashi) should be considered as an alternative to chemical fertilizers for teff production.*

***Key words***: *Bokashi, grain yield, nitrogen fertilizer, teff, yield components.*

## INTRODUCTION

Consumer's health consciousness has exhibited continued growth over the last two decades and the majority of population is trying to improve its health by consuming proper diet, containing foods which are not intended only to appease hunger and provide necessary nutrients for humans, but also to prevent nutrition-related diseases and improve mental and physical health of the consumers (Menrad, 2003). Cereals are getting appreciation from consumers and nutritionists, as they constitute the major source of carbohydrates and energy in diets worldwide. In addition, most of the cereals also contribute to the intake of a fair amount of dietary fiber, as well as, several vitamins, trace minerals, and phytochemicals (Poutanen et al., 2014). Wholegrain foods are recognized as an essential part of a healthy diet and many medical and epidemiological studies during the past 15 years have shown that higher consumptions of whole grains are strongly connected with reduced risk of acute and chronic diseases, including cardiovascular disease, type 2 diabetes, coronary heart disease, obesity, and certain cancers, including colorectal cancer (Aune et al., 2016).

Nowadays, the term "super-grain" has been become popular, and fewer cereals and pseudo-cereals are joined in this group. Some of these cereals like teff are endemic to limited to some parts of the globe but recent times due to their proven health beneficial effects, cultivation and consumption of them are spreading from origin to the different countries (Poutanen et al., 2014). In the case of the teff now it is gaining the interest of people particularly in the Western world and serious efforts are made to expand its cultivation in Europe and America (Belay et al., 2009). It has to be noted that a discussion has already been started in the scientific media as teff is the next super grain to replace quinoa (Satheess & Fanta, 2018).

Teff [*Eragrostis tef* (Zuccagni) Trotter] is a warm season $C_4$ annual plant that is a member of the Poaceae family, and it has been cultivated in the Horn of Africa for at least 3,000 years (Stallknecht et al., 1993). It is the major food crop in Ethiopia where it is annually cultivated on more than three million hectares of land (CSA, 2014). Compared to other cereals, teff can adapt to a wide range of agroecological conditions, such as marginal water-logged soils to drought conditions. Moreover, unlike other cereals, teff grain is less prone to attacks by storage pests and, thus, it can be safely stored under traditional storage conditions with no chemical protection and without losing its viability (Ketema, 1997).

Teff seeds are very minute (thousand grain weight = 0.18-0.38 g; thousand grain weight of *Arabidopsis* = 0.17-0.21 g) and, for marketing purposes, they are classified on the basis of outer caryopsis color: *netch* (white), *qey* (red/brown) and *sergegna* (mixed) (Tefera et al., 1995). The height of the plant ranges from 20 to 155 cm with the culm (11-72 cm) and the panicle (10-65 cm) accounting for about 47-65% and 35-53% of the total aboveground height, respectively (Assefa et al., 2001).

The importance of teff is mainly due to the fact that it has an exceptional nutritional profile and has additional health benefits including that its grains are free from the gluten and gluten-like proteins contained in other common cereals, such as wheat, rye, barley, and corn (Spaenij-Dekking et al., 2005). The increasing demand for gluten-free products is derived from the growing number of people who are diagnosed with celiac disease and other types of gluten sensitivity (Bultosa & Taylor, 2004; Spaenij-Dekking et al., 2005). Teff is a rich source of protein (9.4-13.3%) with a balanced essential amino-acid spectrum of leucine, valine, proline, alanine, and glutamic and aspartic acids. Studies showed that like other cereals teff is predominantly starchy (73%), as the starch content of teff is higher than that of most other cereals (Bultosa & Taylor, 2004). Teff starch granules consist of conglomerates of many polygonal simple granules (Helbing, 2009). Furthermore, it contains 2.6-3.0% ash and 2.0-3.1% lipid and constitutes a rich source of Fe, Ca, Zn, Mg than other cereal grains (Bultosa & Taylor, 2004). In a recent study, it was observed that the bio-available iron content was significantly higher in tef bread than in wheat bread (Alaunyte et al., 2012). Forsido et al. (2013) reported that the antioxidant properties of teff could be used for producing healthy food products.

Despite its versatility under various extreme environmental conditions, the productivity of teff is low with the yield standing at 1500 kg $ha^{-1}$ in Ethiopia (CSA, 2014). The most important yield limiting factor is lodging. Under natural conditions, grain yield losses due to lodging are estimated at an average of 17%. (Assefa et al., 2011). In addition, lodging can reduce the quality of the seed in terms of germination capacity and energy, color and nutritional value (Assefa et al., 2015). However, farmers using improved cultivars and management practices can obtain yields up until 2500 kg $ha^{-1}$ (Tefera & Belay, 2006).

Low soil fertility is intensified by soil fertility depletion through nutrient removal with harvest, tillage, weeding, and losses in runoff and soil erosion (Gebregziabher et al., 2006). Lower tef grain yield is mainly attributed to low soil fertility, and especially, nitrogen and phosphorus deficiencies (Kebede & Yamoah, 2009). According to several studies, grain yield exhibited a linear increase with the increasing rate of application of nitrogen fertilizer in teff (Giday et al., 2014; Assefa et al., 2016).

Since teff is a crop that has been systematically studied only during the last two decades, the available literature on plant growth and yield under organic fertilization is still quite limited. Substantial studies have shown the beneficial effects of organic fertilization on the yield and quality of several crops (Bilalis et al., 2012; 2018).

Bokashi is a soil fertilizer of Japanese origin made by fermenting organic wastes with a microbial inoculant. It is widespread to farming communities in Nicaragua, Mexico, and China. The use of Bokashi has even extended to developed countries, such as USA, where the microbial inoculant Effective Microorganisms or EM, a consortium of lactic acid bacteria, photosynthetic bacteria and yeasts, is used. A study conducted in China showed that application of EM bokashi significantly increased grain yields, nutrient content in straw and grain, and straw biomass in wheat (Hu & Qi, 2013).

Literature survey revealed that there was a lack of knowledge the performance of teff growth under Mediterranean semi-arid conditions and organic cropping system. Therefore, the aim of this study was to determine the effects of organic and inorganic fertilization on yield and yield components of teff crop.

## MATERIALS AND METHODS

A teff crop was established in the organic experimental field of the Agricultural University of Athens (Latitude: 37°59′ 1.70″ N, Longitude: 23°42′ 7.04″ E, Altitude: 29 m above sea level) from April to August 2015. The soil was a Leptosol and soil texture was clay loam (29.8% clay, 34.3% silt and 35.9% sand) with pH (1:1 $H_2O$) 7.29, nitrate-nitrogen ($NO_3$-N) 12.4 mg $kg^{-1}$ soil, available phosphorus (P) 13.2 mg $kg^{-1}$ soil, available potassium (K) 201 mg $kg^{-1}$ soil, 15.99% $CaCO_3$ and 1.47% organic matter.

The site was managed according to organic agricultural guidelines (EC 834/2007). Weather data (mean monthly air temperature and precipitation) pertaining to the experimental period were recorded by the weather station of Agricultural University of Athens and are presented in Table 1.

The mean temperature during the growing season (April-August) was higher (24.2°C) as compared to 30-year average (23.4°C).

The total rainfall of cultivation period 57.8 mm, which means it was the three-fourths of the 35 years average (75.9 mm).

Table 1. Monthly means of maximum (Max.), minimum (Min.) and average (Avg.) air temperature and precipitation for 2015 growing season and the 30 years average in Athens, Greece

| Month | Max (°C) | Min (°C) | Avg. (°C) | Precipitation (mm) | Max (°C) | Min (°C) | Avg. (°C) | Precipitation (mm) |
|---|---|---|---|---|---|---|---|---|
| | | | **2015** | | | **30 year average** | | |
| April | 24.5 | 5.3 | 16.1 | 8.8 | 20.2 | 9.6 | 15.3 | 30.8 |
| May | 31.3 | 14.5 | 21.8 | 31.8 | 26.0 | 13.9 | 20.7 | 22.7 |
| June | 35.1 | 16.8 | 24.7 | 15.8 | 31.1 | 18.2 | 25.6 | 10.6 |
| July | 37.2 | 19.4 | 29.3 | 0.8 | 33.5 | 20.8 | 28.0 | 5.8 |
| August | 36.1 | 21.6 | 29.3 | 0.4 | 33.2 | 20.7 | 27.4 | 6.0 |
| Total | - | - | - | 57.6 | - | - | - | 75.9 |

The experiment was set up on an area of 238 $m^2$ according to a randomized complete block design (RCBD), with three fertilization treatments: control (untreated), organic fertilizer (EMIKO® Bokashi Organic NPK Fertilizer with EM, 1.06% N, EMIKO Handelsgesellschaft mbH) at a rate of 4200 kg $ha^{-1}$ and inorganic fertilizer (Nutramon® 34.5-0-0, Hellagrolip S.A.) at a rate of 60 kg N $ha^{-1}$, and three replications for each treatment. The plot size was 20 $m^2$ (5 m x 4 m). There was a space of 1 m between plots and 1 m between replications. Soil was prepared by ploughing at a depth of about 0.25 m. Fertilizers were applied by hand on the soil surface and then harrowed in. Teff seeds were sown on 19th April by hand in rows 30 cm apart, at a rate of 5 kg $ha^{-1}$ and a depth of 1 cm. Overhead sprinkler system was also set up on the field. The field area was irrigated 5 times. The total quantity of water applied during the experimental period was 328 mm. Throughout the experimental period, there was no incidence of pest or disease on teff crop. Weeds were controlled by hand hoeing when it was necessary.

Data were recorded on some growth and yield parameters including plant weight, number of panicles per plant, plant length and number of branches per panicle using five randomly selected plants in each plot at 100 days after sowing (DAS). Moreover, thousand grain weight, grain yield, and straw yield were assessed at 120 DAS. Thousand grain weight was counted on five randomly selected plants from each plot. For the determination of grain yield and straw yield, the middle sub-plot area of 4 $m^2$ (2 m x 2 m) was used. Biological yield was recorded by measuring the whole weight of plants from middle sub-plot areas after harvesting and drying for three days. Grain yield was determined by measuring the grain weight of plants used for straw yield.

The experimental data were checked for normality and subjected to statistical analysis according to the split-plot design. The statistical analysis was performed with the SigmaPlot 12 statistical software (Systat Software Inc., San Jose, CA, USA).

Differences between means were separated using Least Significance Difference (LSD) test. Correlation analyses were used to describe the relationships between yield and yield components using Pearson's correlation. All comparisons were made at the 5% level of significance.

## RESULTS AND DISCUSSIONS

The effects of organic and inorganic fertilization on the plant height of teff are presented in Table 2. Regardless of the type of fertilizers, the teff plants in the plots received inorganic or organic fertilizer were significantly taller as compared to their respective plant heights in the untreated plots. In particular, the higher plant height (85.92 cm) was recorded in inorganic fertilization treatment followed by organic fertilization (82.44 cm); however, the differences among these values were not statistically significant. Plant height affects above-ground biomass yield of a crop. In earlier studies, nitrogen significance to teff's productivity has been described (Tesfahunegn, 2014; Assefa et al., 2016). Giday et al. (2014) reported that plant height of teff increased consistently with increasing rates of nitrogen and the maximum plant height of 122.33 cm was found in plants treated with 69 kg N $ha^{-1}$ of slow release urea fertilizer. In contrast to this, Berhane et al. (2013) reported superior plant height of teff in plots received organic fertilizers as compared to conventional once. The values of our results are lower as compared to other studies, probably due to the different variations in environmental conditions and the genetic potential of populations (Roussis et al., 2017).

Table 2. Plant height, number of panicles per plant, panicle length, number of branches per panicle of teff crop as affected by organic and inorganic fertilization

| Fertilization | Plant Height (cm) | Number of panicles per plant | Panicle length (cm) | Number of branches per panicle |
|---|---|---|---|---|
| Control | 74.86 b | 9.6 a | 27.04 b | 7.6 b |
| Organic | 82.44 a | 10.2 a | 31.09 ab | 8.7 a |
| Inorganic | 85.92 a | 10.4 a | 33.52 a | 9.3 a |
| $F_{fertilization}$ | 10.358* | 3.087$^{ns}$ | 8.518* | 20.265** |
| *p-value* | 0.026 | 0.155 | 0.036 | 0.008 |

F-test ratios are from ANOVA. Significant at * and ** indicate significance at p ≤ 0.05 and 0.01, respectively and ns: not significant. Mean values within each column followed by different letters, differ significantly according the *LSD* test (p ≤ 0.05).

Concerning the number of panicles per plant, the effect of fertilization was found not to be statistically significant (Table 2). Despite the non-significant differences among the fertilization treatments, the highest value (10.4) was found in plants treated with inorganic fertilizer and the lowest (9.6) in the unfertilized plots. Giday et al. (2014) reported the positive and significant increase in the number of panicles per plant with the increasing rate of nitrogen fertilizer on teff. In the same way, Asefa et al. (2014) found that number of panicles was significantly increased with the increase of rate of NPK fertilizers. In contrast to above-mentioned studies, Assefa et al. (2016) observed no difference in the number of panicles per plant between the levels of compost and NP fertilizer, and the values did not present any increasing or decreasing trend. In a similar way, Tesfahunegn (2014) found that the unfertilized plot showed a significantly lower panicle number per plant as compared to others, but there were non-significant differences among the remaining which received different rates of fertilizers.

Panicle length constitutes one of the yield attributes of teff that could lead to a high increment of grain and straw yield. In our study, panicle length was significantly affected by the different fertilization treatments, with the values significantly varied between the inorganic fertilization and control (Table 2). The highest mean length (33.52 cm) was recorded in inorganic fertilization treatment, while, the lowest (27.04 cm) was obtained from the untreated plot. This may also be due to the same reason as that of plant height. The positive correlation between nitrogen fertilizer and panicle length of teff has also been reported by several authors (Giday et al., 2014; Assefa et al., 2016). The application of balanced fertilizer and efficient utilization of nutrients leads to high photosynthetic productivity and accumulation of high dry matter, resulting in increases of panicle length and grain yield (Assefa et al., 2016).

The results of the experiment indicated that the effect of organic and inorganic fertilization significantly affected the number of branches per panicle of teff (Table 2). This trait was significantly varied between the inorganic fertilization and control, and the organic fertilization and control. But, the number of branches per panicle did not significantly differ between the organic and inorganic fertilization, indicating that both treatments did show similar effect on the parameter. The highest mean branches number per panicle was observed in the inorganic treatment (9.3) and the lowest in the control (7.6). Studies have shown that nitrogen fertilizer application had a significant effect on the number of branches and spikelets in panicle (Matsui & Kagata, 2002; Kamiji et al., 2011). The panicle length and the number of panicle branches are important predictors of spikelets. Zhou et al. (2017) reported that the increase in panicle length and number of branches provided more space for spikelets development and increased spikelet density per panicle under optimized nitrogen fertilizer application.

Table 3. Thousand grain weight, grain yield and straw yield of teff crop as affected by organic and inorganic fertilization

| Fertilization | Thousand grain weight (g) | Grain yield (kg ha$^{-1}$) | Straw yield (kg ha$^{-1}$) |
|---|---|---|---|
| Control | 0.316 a | 1287 b | 3404 b |
| Organic | 0.323 a | 1535 a | 3612 ab |
| Inorganic | 0.327 a | 1652 a | 3793 a |
| $F_{fertilization}$ | 2.968$^{ns}$ | 27.431** | 9.019* |
| *p-value* | 0.162 | 0.004 | 0.033 |

F-test ratios are from ANOVA. Significant at * and ** indicate significance at p ≤ 0.05 and 0.01, respectively and ns: not significant. Mean values within each column followed by different letters, differ significantly according the *LSD* test (p ≤ 0.05).

Regarding the thousand grain weight, the analysis of variance revealed that the fertilization had no significant effect on this parameter (Table 3). However, the maximum thousand grain weight (0.327 g) was recorded after the application of inorganic fertilizer and followed by organic treatment (0.323 g). Gooding and Davies (1997) observed neither improvement nor reduced thousand kernel weight due to nitrogen fertilization even when yields increased. In general, a wide range of factors, including variety, growing conditions, climatic factors, and soil properties affect the thousand grain weight.

Grain yield was significantly responded to the fertilization (Table 3). The highest mean grain yield of teff (1652 kg ha$^{-1}$) was obtained in the inorganic fertilization treatment with 365 kg ha$^{-1}$ yield advantage over the control. The next highest mean grain yield (1535 kg ha$^{-1}$) was obtained from the organic fertilization treatment with no statistically significant difference ($p$>0.05) compared to the yield obtained with the application of inorganic fertilizer, and the lowest grain yield (1287 kg ha$^{-1}$) was obtained from the untreated plot. Several studies indicated the positive and linear response of grain yield to increasing levels of nitrogen fertilizer (Geleto et al., 1995; Giday et al., 2014). Geleto et al. (1995) reported that application of 120 kg N ha$^{-1}$ presented yield advantage ranging from 19 to 49% over the yield obtained with the application of 60 kg N ha$^{-1}$ depending on the inherent nitrogen status of the soil as well as the amount and distribution of precipitation during the cultivation period of the respective locations. Assefa et al. (2016) also reported that the application of 2.5 tons ha$^{-1}$ compost combined with the 50% of recommended NP (64/46 kg ha$^{-1}$ $N/P_2O_5$) rate resulted in grain yield increments of 158% compared to the control (untreated) on teff which is comparable to the full NP dose. Compost could also improve the soil structure which leads to better root development that may result in more nutrient up take from the soil in addition to its slow and gradual release of macro and micro nutrients by itself (Al-Bataina et al., 2016). Grain yield had positive and significant correlation with plant height, number of panicles per plant, panicle length, number of branches per panicle and straw yield ( $r = 0.946$, $p<0.001$; $r = 0.702$, $p = 0.034$; $r = 0.799$, $p = 0.009$; $r = 0.856$, $p = 0.003$ and $r = 0.768$, $p = 0.016$, respectively).

The application of different fertilization treatments had a significant effect on straw yield of teff. The highest mean straw yield (3793 kg $ha^{-1}$) was obtained in the inorganic fertilization treatment with 389 kg $ha^{-1}$ yield advantage over the control plot. The next highest mean straw yield (3612 kg $ha^{-1}$) was obtained from the organic fertilization treatment with no statistically significant difference (p>0.05) compared to the yields obtained from the inorganic fertilization and untreated plots. The lowest straw yield (3404 kg $ha^{-1}$) was obtained from the untreated plot. The increase in nitrogen supplement can result in a more vigorous plant growth, producing a greater total plant biomass and a higher straw yield (Giday et al., 2014). Assefa et al. (2016) observed that application of compost beyond 5 tons $ha^{-1}$ compost combined with NP beyond 32/23 kg $ha^{-1}$ $N/P_2O_5$ rate had no significant effect on straw yield. Contrariwise, Berhane et al. (2013) found that the organic fertilizer increased straw yield of teff than the inorganic fertilizer and reasoned that could be due to higher plant height of organic teff than the conventional. Straw yield had positive and significant correlation with plant height, panicle length and number of branches per panicle (r = 0.716, p = 0.029; r = 0.801, p = 0.009 and r = 0.8831, p = 0.002, respectively).

## CONCLUSIONS

The results showed that the higher plant height, panicle length, number of branches per panicle, number of grains per panicle, grain yield and straw yield were achieved through the application of inorganic fertilizer; however, the differences between the organic and inorganic fertilization were not statistically significant. The number of panicles per plant and thousand grain weight were not affected by fertilization. As a conclusion, the results of the present study indicated that the organic fertilizer (Bokashi) should be considered as an alternative to chemical fertilizers for teff production.

## REFERENCES


Al-Bataina, B. B., Young, T. M., Ranieri, E. (2016). Effects of compost age on the release of nutrients. *International Soil and Water Conservation Research*, *4*, 230–236.

Alaunyte, I., Stojceska, V., Plunkett, A., Ainsworth, P., Derbyshire, E. (2012). Improving the quality of nutrient-rich teff (*Eragrostis tef*) breads by combination of enzymes in straight dough and sourdough breadmaking. *Journal of Cereal Science*, *55*, 22–30.

Asefa, F., Debela, A., Mohammed, M. (2014) Evaluation of teff [*Eragrostis tef* (Zuccagni) Trotter] responses to different rates of NPK along with Zn and B in Didessa district, southwestern Ehiopia. *World Applied Sciences Journal, 32*, 2245–2249.

Assefa, A., Tana, T., Abdulahi, J. (2016). Effects of compost and inorganic NP rates on growth, yield and yield Components of teff [*Eragrotis teff* (Zucc.) Trotter] in Girar Jarso District, Central Highland of Ethiopia. *Journal of Fertilizers and Pesticides*, *7*, 1000174.

Assefa, K., Cannarozzi, G., Girma, D., Kamies, R., Chanyalew, S., Plaza-Wüthrich, S., Blösch, R., Rindisbacher, A., Rafudeen, S., Tadele, Z. (2015). Genetic diversity in tef [*Eragrostis tef* (Zucc.) Trotter]. *Frontiers in Plant Science*, *6*, 177.

Assefa, K., Ketema, S., Tefera, H., Hundera, F., Kefyalew, T. (2001). Genetic diversity for agronomic traits in tef. In H. Tefera, G. Belay, & M. Sorrells (Eds), *Narrowing the Rift* (pp. 33-48). Proceedings of the International Workshop on Tef Genetics and Improvement, 16-19 October 2000. Debre Zeit, Ethiopia: Tef Research and Development.

Assefa, K., Yu, J. K., Zeid, M., Belay, G., Tefera, H., Sorrells, M. E. (2011). Breeding tef [*Eragrostis tef* (Zucc.) trotter]: conventional and molecular approaches. *Plant Breeding, 130*, 1–9.

Aune, D., Keum, N., Giovannucci, E., Fadnes, L. T., Boffetta, P., Greenwood, D. C., Tonstad, S., Vatten, L. J., Riboli, E., Norat, T. (2016). Whole grain consumption and risk of cardiovascular disease, cancer, and all cause and cause specific mortality: Systematic review and dose-response meta-analysis of prospective studies. *The Biomedical Journal*, *353*, 1–14.

Belay, G., Zemede, A., Assefa, K., Metaferia, G., Tefera, H. (2009). Seed size effect on grain weight and agronomic performance of tef [*Eragrostis tef* (Zucc.) Trotter]. *African Journal of Agricultural Research*, *4*, 836–839.

Berhane, M., Kebede, F., Fitiwy, I., Abreha, Z. (2013). Comparative productivity and profitability of organic and conventional teff [*Eragrostis tef* (Zucc.) Trotter] production under rainfed condition: Tigray, Northern Ethiopia. *World Journal of Agricultural Sciences*, *1*, 303–311.

Bilalis, D., Kakabouki, I., Karkanis, A., Travlos, I., Triantafyllidis, V., Hela, D. (2012). Seed and saponin production of organic quinoa (*Chenopodium quinoa* Willd.) for different tillage and fertilization. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, *40*, 42–46.

Bilalis, D., Krokida, M., Roussis, I., Papastylianou, P., Travlos, I., Cheimona, N., Dede, A. (2018). Effects of organic and inorganic fertilization on yield and quality of pro-cessing tomato (*Lycopersicon esculentum* Mill.). *Folia Horticulturae*, *30*, 321–333.

Bultosa, G., & Taylor, J.R.N. (2004a). Teff. In C. Wrigley, H. Corke, & C. Walker (Eds.), *Encyclopedia of Grain Science* (pp. 20–36). Oxford, England: Elsevier.

CSA. (2014). *Agricultural Sample Survey for 2013/14. Statistical Bulletin 532*. Addis Ababa, Ethiopia: Central Statistical Agency.

Forsido, S.F., Rupasinghe, H.P., Astatkie, T. (2013). Antioxidant capacity, total phenolics and nutritional content in selected Ethiopian staple food ingredients. *International Journal of Food Sciences and Nutrition*, *64*, 915–920.

Gebregziabher, S., Mouazen, A.M., Van Brussel, H., Ramon, H., Nyssen, J., Verplancke, H., Behailu, M., Deckers, J., De Baerdemaeker, J. (2006). Animal drawn tillage, the Ethiopian ard plough, *maresha*: A review. *Soil and Tillage Research*, *89*, 129–143.

Geleto, T., Tanner, D. G., Mamo, T., Gebeyehu, G. (1995). Response of rainfed bread and durum wheat to source, level, and timing of nitrogen fertilizer on two ethiopian vertisols. I. Yield and yield components. *Communications in Soil Science and Plant Analysis*, *26*, 1773–1794.

Giday, O., Gibrekidan, H., Berhe, T. (2014). Response of teff (*Eragrostis tef*) to different rates of slow release and conventional urea fertilizers in vertisols of southern Tigray, Ethiopia. *Advances in Plants and Agriculture Research, 1*, 190–197.

Gooding, M.J., & Davies, W.P. (1997). *Wheat production and utilization system, quality and environment*. USA: CAB International.

Helbing, J. (2009). *Konfokale laser scanning-mikroskopie und raster- elektronenmikroskopie zur beobachtung der mälzung verschiedener zerealien und pseudozerealien*. München, Germany: Technische Universität München.

Hu, C., & Qi, Y. (2013). Long-term effective microorganisms application promote growth and increase yields and nutrition of wheat in China. *European Journal of Agronomy*, *46*, 63–67.

Kamiji, Y., Yoshida, H., Palta, J.A., Sakuratani, T., Shiraiwa, T. (2011). N applications that increase plant N during panicle development arehighly effective in increasing spikelet number in rice. *Field Crops Research, 122*, 242–247.

Kebede, F., & Yamoah, C. (2009). Soil fertility status and NuMaSS fertilizer recommendation of typic hapluusterts in the northern highlands of Ethiopia. *World Applied Sciences Journal*, *6*, 1473–1480.

Ketema, S. (1997). *Tef, Eragrostis tef (Zucc.) Trotter*. Rome: Institute of Plant Genetics and Crop Plant Research, Gatersleben/ International Plant Genetic Resources Institute.

Matsui, T., & Kagata, H. (2002). Correlation of nitrogen concentration with dry-matter portioning to spikelets and total husk volume on the panicle in japonica rice. *Plant Production Science*, *5*, 198–202.

Menrad, K. (2003). Market and marketing of functional food in Europe. *Journal of Food Engineering*, *56*, 181-188.

Poutanen, K., Sozer, N., Della Valle, G. (2014). How can technology help to deliver more of grain in cereal foods for a healthy diet? *Journal of Cereal Science*, *59*, 327–336.

Roussis, I., Travlos, I., Bilalis, D., Kakabouki, I. (2017). Influence of seed rate and fertilization on yield and yield components of *Nigella sativa* L. cultivated under Mediterranean semi-arid conditions. *Agrolife Scientific Journal*, *6*(1), 218–223.

Satheesh, N., & Fanta, S.W. (2018). Review on structural, nutritional and anti-nutritional composition of Teff (*Eragrostis tef*) in comparison with Quinoa (*Chenopodium quinoa* Willd.). *Cogent Food and Agriculture*, *4*, 1546942.

Spaenij-Dekking, L., Kooy-Winkelaar, F., Koning, F. (2005). The Ethiopian cereal tef in celiac disease. *The New England Journal of Medicine*, *353*, 1748–1749.

Stallknecht, G.F., Gilbertson, K. M., Eckhoff, J.L. (1993). Teff: food crop for humans and animals. In: J. Janick, & J. E. Simon (Eds). *New crops* (pp. 231–234). New York, USA: Wiley.

Tefera, H., Belay, G. (2006). *Eragrostis tef* (Zuccagni) Trotter. [Internet] Record from Protabase. In: M. Brink, & G. Belay (Eds) *PROTA (Plant Resources of Tropical Africa/ Ressources végétales de l'Afrique tropicale*). Wageningen, Netherlands. https://www.prota4u.org (February, 2018).

Tefera, H., Ayele, M., Assefa, K. (1995). *Improved varieties of tef (Eragrostis tef) in Ethiopia, releases of 1970-1995. Researches bulletin, No. 1.* Debre Zeit, Ethiopia: Debre Zeit Agricultural Research Center, Alemaya University of Agriculture.

Tesfahunegn, G. B. (2014). Response of yield and yield components of tef [*Eragrostis tef* (Zucc.) Trotter] to tillage, nutrient, and weed management practices in Dura Area, Northern Ethiopia. Hindawi Publishing Corporation International Scholarly Research Notices. ID 439718.

Zhou, W., Lv, T., Yang, Z., Wang, T., Fu, Y., Chen, Y., Hu, B., Ren, W. (2017). Morphophysiological mechanism of rice yield increase in response to optimized nitrogen management. Scientific Reports, 7, 17226.