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Effect of Inorganic Fertilizer and Sowing Methods on Tef (Eragrostistef (Zucc.) Trotter) Production in Ethiopia: Review

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Summary
Tef [Eragrostistef (Zucc.) Trotter] is one of the major small cereal crops in Ethiopia in terms of production and consumption. But in Ethiopia, it is yield low as compared with other major cereal crops growing due to many production constraints such as low soil fertility, lack of appropriate management practices, minimum use of improved varieties, and lack of location specific fertilizer recommendation. Synthetic fertilizer and sowing method have great role on yield and yield components of Tef. So, objective of this study is to review the effects of inorganic fertilizer and sowing methods on yield and yield components of Tef in Ethiopia. Most research work so far focused on NP requirements of crops, but limited information is available on various sources of fertilizers like S, Zn, B and other. Tef responds differently to fertilizer rates and types depending on soil type and cultivars. Application of other sources of nutrients beyond urea and DAP, especially those containing S, Zn, B and other micro-nutrients and different method of sowing could increase Tef crop production and productivity in different area and different agro ecology. Therefore, to increase the production and productivity of tef in country use of Synthetic fertilizer and row sowing are important.
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1. INTRODUCTION

Tef (Eragrostistef (Zucc.) Trotter) is a small grain cereal indigenous and has been recognized that Ethiopia is the center of origin and diversity of *tef* (Vavilov, 1951). It is most probably domesticated thousands of years ago before the birth of Christ in Ethiopia (Seyfu ,1997). *Tef* has got both cultural and economic value for Ethiopian farmers with more than six million households' life depending on the production of *tef*. It is a daily staple food for about 57.2 million people of Ethiopia, and this accounts for more than 64% of the total population of the country (ATA, 2013a). In Ethiopia, tef is primarily grown for its grain that is used for preparing injera, which is a staple and very popular food in the national diet of most Ethiopians. It can also be used in many other food products, such as kitta, anebaberro, gruel, and local alcoholic beverages, such as tella and katikala (Seyfu ,1997). According to Patricia and Lisette (2008) tef is rich in energy (353-367 K cal/100 g), fat (2.6%), protein (8 - 15%) and gluten free and also is reported rich in iron, calcium, potassium and phosphorus.

Tef is adapted to a wide range of environments and presently it is cultivated under diverse agro-climatic conditions (Mitiku, 2008). *Tef* has a short growing season with rainfall needs of 450–550 mm, and temperature range of 10–27^{o}C (Nadian *et al.,* 2010). *Tef* is day length sensitive and flowers best during 12 hours of daylight. *Tef* is well adapted to a wide range of soil types. It has the ability to perform well in black soils and, in some cases, in low soil acidities. In addition, have capacity to withstand waterlogged, rainy conditions, often better than other cereal grains except rice (ATA, 2013b). The major *tef* producing regions in Ethiopia are Shewa, Gojam, Gonder, Wellega, Wollo, Keffa and Ilubabor (Shorrocks, 1997). Currently, in Ethiopia out of the total grain crop area, 81.39% (10,358,890.13 hectares) was under cereals. Of them *tef* is first rank in area of production (3.07 M ha) and second ranks in terms of production (5.4 M t) which followed by Maize. But it is productivity (17.56) is very low as compared with productivity of other grain cereal crops yield potential (CSA, 2019).

The low *tef* crop productivity could be due to a complex interaction among the environments, lack of appropriate management practices, biotic and abiotic stresses. Of these, soil fertility problem is one of the major causes of temporal and spatial yield variability (Brhan, 2012). The soil fertility mapping project in Ethiopia reported the deficiency of S, Zn, B and Cu in addition to N and P in major Ethiopian soils (Ethio-SIS, 2014). The broadcasting method that farmer use now days which contributes to the insufficient and poor productivity of *tef*. Now day's row drilling method and transplanting a young *tef* seedling that increases the tiller number, producing strong tiller culms and it increases yield and quality of seeds (Tekalign *et al*., 2001). Therefore, application of other sources of nutrients beyond urea and DAP, especially those containing S, Zn, B and other micro-nutrients, (CSA, 2017) and newly introduced row and transplanting method of sowing could increase *tef* crop productivity (Tareke *et al*., 2011). So, objectives of this study to review the effects of Inorganic fertilizer and sowing methods on yield and yield components of *tef*.

2. EFFECT OF INORGANIC FERTILIZER AND SOWING METHODS ON TEF PRODUCTIO IN ETHIOPIA

2.1. Importance of inorganic nutrient in *tef* crop production

Plants require nitrogen in the largest amounts among the soil nutrients for growth and development. Among the macro nutrients, N is ranked first in limiting sustainable crop production. An adequate supply of N is used properly in conjunction with other soil fertility inputs, can speed up the maturity of crops such as small grains (Tisdale *et al*., 2002). Mulugeta (2003) found that application of high rates of N fertilizer increased the number of fertile panicles of *tef*. Increased N levels dramatically increased grain yield in *tef* due to increase in yield components. Different research findings show that an increase in fertilizer rate increased the total dry matter content in *tef* (Tareke *et al*., 2011). Successive increase in N rates increased dry matter accumulation and straw yield of *tef* (Mulugeta, 2003).

As applied N rates increased, the grain uptake also increased which was also reflected in the plant height, yield and yield components like panicle length, panicle weight, grain yield, straw yield and biomass yield (Legesse , 2004). Selamyihun *et al*. (1999) also reported that nitrogen content (%) in *tef* seed increased with each increment in N fertilizer, while N content (%) in *tef* straw increased only up to the intermediate level of N fertilizer applied. Temesgen (2001) stated that Excess N supply causes higher photosynthetic activity and more vegetative growth accompanied by weak stem, long internode, droopy leaf and increases susceptibility to lodging. Phosphorus is the second most essential element for crop production in order to achieve maximum yields. A good supply of P has been associated with increased root growth and a stiff stalk to resist lodging (Miller and Donahue, 1995). In cereal crops, good P nutrition strengthens structural tissues such as straw or stalks, thus, helping to prevent lodging (Brady and Weil, 2002). According to Legesse (2004), the total P uptake was significantly increased as applied P rate increased but this increase was not at all reflected in an increase in growth, yield and yield components. Alemayehu *et al*. (2006) indicated that the grain yield of *tef* is increased with application of P fertilizer in different soil type.

Sulfur is required in similar amount as that of phosphorus and constitutes 0.2 to 0.5% dry matter accumulation in crop tissue (Ali *et al*., 2008). Sulfur deficiencies are often misdiagnosed as nitrogen problems, leaving growers to wonder why their nitrogen applications are ineffective. In many crops, an acute sulfur deficiency causes the entire plant to turn yellow. In crops like maize and small grains, however, yellow stripes that run parallel to the leaf blade are common. Sulfur deficiency is most frequently observed on very sandy soils with low organic matter content during seasons of excessive rainfall (Brady and Weil, 2002). The most important role in such an increase of grain yield was performed by the number of grains per ear as one of the yield components (Nadian *et al*., 2010). According to Habtegebre'el and Singh (2006) found that combined N and S fertilization increased the dry matter and grain yields of *tef* on average by 1.7 and 0.3 kg ha^{-1}.

Boron is an essential element for better utilization of macro-nutrients by plants and there by greater translocation of photo-assimilates from source to sink during growth period (Ali *et al*., 2013). It is involved in the transport of sugars across cell membranes and in synthesis of cell wall material (Singh *et al*., 2015). Its deficiency results in low grain set, poor seed quality and interferes rapidly with cell division, cell membrane permeability and often results in phenolic compounds accumulating in plant tissue (Shorrocks, 1997). Zinc is an essential element for plants, animals and human beings. Increased risk of Zn deficiency in human beings is attributed to low levels of Zn intake. People in developing countries consuming mostly cereals have low Zn in their diet (Cakmak *et al*., 2001). Tareke *et al*. (2011) explained that *tef* responds highly when treated with Zinc. Populations that depend on *tef* grain and straw, respectively, as major source of Zn. Tef Zn concentration has been reported to be low (Wakjira, 2018).

2.2. Effect of Inorganic Fertilizer on *Tef production*

Different studies in various environments at different years reported that *tef* responds to inorganic fertilizer. Mitiku (2008) stated that application of 69 kg N ha^{-1} was the best to obtain high total biomass yield, straw yield and grain yield. Similarly, Legesse (2004) found that, high yield components were recorded in response to application of 69 kg N ha^{-1}. As applied N rates increased, the grain uptake also increased which was also reflected in the plant height, yield and yield components like panicle length, panicle weight, grain yield, straw yield and biomass yield. The studies carried out at Oromia and Tigray region of Ethiopia showed that application of 69 kg N ha^{-1} increase grain yield of *tef* but not significance difference from application of 46 kg N ha^{-1} at two regions as showed in table 1. Temesgen (2001) also reported that the application of different levels of N fertilizer affected grain, straw and biomass yield significantly on farmer's field where increasing N fertilizer rate consistently increased *Tef* grain yield from 1620 kg ha^{-1} in the control treatment to 1950 kg ha^{-1} in the 69 kg N ha^{-1} rate was applied.

Table1. Effects of Nitrogen on grain yield of *Tef* at Vertisols of Oromia and Tigray

No	Nitrogen (kg ha^{-1})	Grain yield (kg ha^{-1})	
		Oromia (Vertisols)	Tigray (Vertisols)
1	0	2551^{c}	2111.33^{c}
2	23	2809^{bc}	2830.67^{b}
3	46	3055^{a}	3379.67^{a}
4	69	3249^{a}	3443.67^{a}
	LSD	302.92	78.05

Source: [Giday *et al*., 2014; Seifu , 2018.]

Mehreteab (2008) reported that panicle length, plant height, number of nodes, number of effective tillers, lodging index, biomass yield, grain yield and harvest index increased with an increased level of phosphate fertilizer and the optimum grain yield was obtained by applying phosphate fertilizer rate of 46 kg P_2O_5 ha^{-1}. Bereket *et al.* (2014) reported that increasing P rate from 46 to 69 kg P2O5 ha^{-1} increased grain yield of bread wheat by about 6.8%. Alemayehu *et al.* (2006) indicated that the highest grain yield was obtained with the highest P fertilizer rate (80 kg P2O5 ha^{-1}) in most localities of *Vertisols* and the highest grain yield in most localities of *Nitosols* were obtained at 60 kg P2O5 ha^{-1} with interaction of 100 and 60 kg N ha^{-1}, respectively.

According to Habtegebrial and Singh (2006) found that combined N and S fertilization increased the dry matter and grain yields of *tef* on average by 1.7 and 0.3 kg ha^{-1}, compared with the control and S fertilization increased the nitrogen use efficiency of the *tef* crop by 36%. Mulugeta and Shiferaw (2017) Suggested in Ethiopia application of suboptimal levels of mineral fertilizers aggravates the decline in soil fertility. Application of 150 kg NPS (63:25:10.5) + 34.5 kg N ha^{-1} gave highest grain yield. Seifu (2018) reported that the highest grain yield (3228 kg ha^{-1}) of *tef* was obtained at the highest rate of blended (150 kg NPSB ha^{-1}) fertilizer application, while the lowest grain yield of 2503 kg ha^{-1} was recorded from non-treated (control) plot.

According to Fayera *et al*. (2014) the maximum *tef* grain yield was obtained with the highest total nitrogen, phosphorus, potassium and zinc uptake. Application of blended fertilizer gave maximum *tef* yield over NP fertilizer. Application of 100 kg NPSZnB ha^{-1} produced the maximum grain yield (1386.5 kg ha^{-1}) of *tef*, while the lowest grain yield (1085.8 kg ha^{-1}) was obtained under the control treatment (Teshome, 2018). Lemlem (2002) also reported that application of blended fertilizer, DAP and urea significantly increased the N, P, K, Zn, Mg and S concentrations *tef* grains and increased grain yield in Vertisols. Application of blended fertilizer increase tef yield from 12.4 to 39.6 % over the control plots.

2.3. Response of Crops to Sowing Method

2.3.1. Broadcasting

Broadcasting as one of the seed sowing methods, and in combination with reduced cultivation offers the advantage of being up to four times faster than conventional ploughing and drilling and is of particular value for sowing large hectare of winter cereals (Ball, 1996). Under the current farmers' production system, *Tef* seeds are sown on the surface of the soil and left uncovered or sometimes covered very lightly by pulling woody tree branches over the field using oxen (Seyfu ,1997). The broadcasting system with poor quality of seed, poor soil fertility, and seed rate which is 25-50 kg/ha which make the mature plant to lodge i.e. fall over. All these things affected the production of *Tef*. One of the risks associated with higher plant populations is the increased potential for lodging which can impact yield and quality. This may be particularly true under high yield environments like the Red River Valley (Tareke, 2008).

2.3.2. Row planting

In order to avoid uneven stands, improve tillering, improve yield attributing parameters, to reduce lodging and decrease competition among plants, row sowing is preferred although it is tedious, time taking and needs educated person (Hunt, 1999). Row planting of teff seed is considered to be superior compared to the traditional broadcasting method because a reduced seed rate decreases competition between the seedlings for water and nutrients. Moreover, the even distribution of the teff seedlings makes weeding easier and less costly. In research trials, row planting has been shown to increase teff yields up to three times average yields and lowers seed costs, making it seemingly a good value proposition for teff farmers (Berhe *et al*., 2011). According to Tareke (2008) best results came from spacing and row sowing increases tiller number, producing strong and fertile tiller culms, and increase the number of seeds/panicles of *Tef*.

2.3.3. Transplanting Methods

According to Tareke (2008) planting seedlings on a flat bed and transplanting those into the field showed a promising result. For example, it reduces the seed rate from the broadcasting method and in the new method 2-2.5 kg/ha would be enough for a hectare. Moreover, it increases tiller number, producing strong tiller culms and it increases number and quality of seeds. As the researcher explained, the yield of the broadcasting plot was 500-

1200 kg/ha, On the other hand, the transplanted ones gave 3,400-5,100 kg/ha with a fourfold increase in grain yield. In addition, the straw yield also increased from the transplanted grain.

Table 2. Summary benefits and drawbacks planting method of *Tef*

No.	Planting methods	Benefits	Draw backs
1	Broad casting	- Easy sowing method - Low labour cost	- Difficult to control plant population - High cost for seed - High susceptibility to lodging - Low yield capacity
2	Row Sowing	- High grain yield - Reduce cost for seed - Reduce problem of lodging - Easy management practice	- High cost for labour than broad casting
3	Transplanting	- High grain yield - Least cost for seed - Reduce problem of lodging - Easy management practice - Reduce moisture stress - Responsive to fertilizer application - Increased plant height, panicle length and tiller capacity	- Very high labour cost - Complex and difficult to apply seed

Source: [Abraham *et al*., 2016; Chanyalew and Kebede, 2013]

2.4. Effects of sowing method on yield and yield components of Tef

It has been argued recently that low *Tef* productivity is partly caused by the way farmers sow *Tef* seed. Traditionally, farmers broadcast the seed using a rate of 25–50 kg per hectare. According to ATA (2013a) report most of the farmers who employed new *Tef* technologies experienced yield increases across all regions. Row planting and transplanting technologies produced especially high yields, on average increasing yields by 70% from the national average of 12.6 quintals/ha to 20.9 quintals/ha. In Amhara and Oromia transplanting produced the highest yields followed by row planting and broadcasting. In SNNP and Tigray row planting produced the highest average yields of 22 and 21 quintals/ha respectively. Transplanting in SNNP and Tigray produced the second highest average yield, with broadcasting producing the lowest in comparison to the other two technologies.

Table 3. Effect of sowing methods on yield of *Tef* at different region of Ethiopia

No	Treatment	Grain yield(kg/ha)		
		Southern Ethiopia Vertisols	DZARC (Oromia) Vertisols	Shebedino (SNNP) Clay Loam
1	Broad casting	1497^{b}	2011^{b}	995.45^{b}
2	Row Sowing	1992^{a}	2167^{a}	1324.0^{a}
	LSD	0.63	112.6	149.9
	CV	10.63	8.5	19.9

Source: [Abraham *et al*., 2016]

In Tigray for instance broadcasting yields were 17 quintals/ha, a 30% increase over the national average. As planting method was only one component of the Teff technology package, this increase in yield from broadcasting compared to the national average can be attributed to the other components of the package (ATA,2013a). Broad casting practice reduces yields because of the uneven distribution of the seeds, higher competition between plants for inputs (water, light and nutrients), and difficult weeding once the plants have matured (Fufa et al., 2011)

As a solution, it has been proposed to reduce seed rates and to plant seed in rows or to transplant seedlings (as is often done for rice, for example). Reducing the seed rate to between 2.5 and 3 kg per hectare allows for reduced competition between seedlings and optimal tillering of the Tef plants. By row planting or transplanting the seeds, land management and especially weeding can also be done more readily and the incidence of lodging is reduced (Berhe *et al*., 2011). Tareke *et al.* (2011) reported that transplanting sowing method of *tef* increased grain yield by increasing productive tillers and reducing lodging. The significant increase in grain yield in response to using transplanting might be attributed due to less competition for growth resource like water, sunlight and nutrients, better air circulation which reduces the occurrence of insect pest and disease infestation and also uniform plant stands given opportunity to suppress weed growth (Wakjira, 2018).

2.5. Effects of Inorganic fertilizer and sowing Method on yield and yield components of Tef

Many Authors suggested Synthetic fertilizer and sowing Method on *Tef* affects yield and yield components of

Tef in different way and different area. Shiferaw (2012) reported that application of Blended fertilizer in a row sowing gave (3700-4000 kg/ha) grain yield than the rest of the treatments at different site (Table 4).

Table 4. Effects of sowing methods and fertilizer types on grain yield of *tef*

		Grain yield (kg ha $^{-1}$)							
		Oromia (Shewa)				Oromia (Wollega)			
		Denkaka		Ude		Gabate		Kobo	
No	Fertilizer Type	Vertisol		Vertisol		Nitosol		Nitosol	
		B/cast	Row	B/cast	Row	B/cast	Row	B/cast	Row
1	No fertilizer	1583	1419	1150	833	455.67	447.33	418.3	416.33
2	DAP + Urea	3317	3681	3347	3847	3155	3189.33	3122.3	3164
3	Blended	3208	3986	3305	3722	3110.33	3250.67	3025.67	3222.67
	Mean	2703	3029	2601	2801	2295.78	2295.78	2188.78	2267.67

Source: [Refissa 2012; Shiferaw, 2012]

Significantly lower (830-1500 kg/ha) grain yield was recorded under unfertilized conditions in both broadcast and row sowing at both sites. Application of Blended fertilizer increased grain yield by 102-109% at the two sites as compared to the control treatment (broadcast sowing and non-fertilized). Similarly, Refissa (2012) reported that row sowing method and Blended fertilizer increase tef grain yield than the rest of the treatments at different site (Table 4). Tareke *et al*. (2012) who reported that transplanting increased grain yield by increasing productive tillers and reducing lodging. Similar results also reported blended fertilizer increased grain yield of *tef*. Transplanting combined with blended fertilizer increased grain yield by 50% than using DAP or Urea fertilizer, and this increment in grain yield is mainly due to the number of tillers and number of panicles.

3. Conclusions

Tef is the most widely grown cereals in Ethiopia. It is a staple diet of the majority of the population, and it is most widely planted by Ethiopian farmers and also gaining popularity as a health food in the western world. Ethiopia is the center of origin and diversity of *Tef*. Ethiopian farmers have been growing *Tef* for both the grain and straw yeilds. In addition to this, *tef* is excellently adapted to the changing environments in the country, and thereby suffer low production risks. The principal limitation of *Tef* cultivation in Ethiopia is the low productivity due to un balanced and sup optimal use of in organic fertilizer and use of broad casting sowing method. Both sowing method and fertilizer types affected yield of *tef* in Ethiopia. Row sowing reduces seed rate by five times as compared to broadcast sowing and transplanting method reduces seed rate by ten times row sowing method.
Application of different nutrient great role in growth, development as well as in yield and yield components of *Tef* and also nutrient up takes from the soil. Application of different levels of micro primary and secondary nutrients affected growth, yield and yield components of *tef*. But Ethiopian agriculture has emphasized only on N, P and K-fertilizer inputs. The application of micro element such as Sulfur (S), Zinc (Zn), Boron (B) and others not well known in Ethiopia. The proper application of these micro nutrients with good sowing method has increase yield and yield components of *tef*. Types of fertilizer whether it is complete or incomplete, macro or micro how it applied, practice sowing method and spacing all this affect the yield and yield components of *tef*. The best grain yield of *Tef* can be improved through use of blended in organic fertilizer application and transplant or row sowing method. Therefore, the growers, farmers, researchers and all stakeholders' give attentions in use of blended fertilizers that contain Micro and micro nutrients and sowing methods of *tef* to increase the yield.

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