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Good Agricultural Practices for Tapping Yield Potential of Teff Crop in Ethiopia: A Review

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Abstract

Teff (*Eragrostis* teff) is a warm-season annual cereal, characterized by a large crown, many tillers and a shallow diverse root system is one of the underutilized crops that can contribute to food security and crop diversification. Currently, Ethiopia is the largest teff-producing country and the only country to have adopted teff as a staple crop. Many studies revealed that row planting and transplanting teff seedlings have a higher yield than the traditional broadcast method. The research report showed that the average row planting yield was 2.8 tons per ha, which was 75 per cent higher than produced with traditional methods (1.6 tons per ha) and 5.1 tons per ha gained on transplanting 20 days of seedling, which is the highest of all. Row planting and transplanting by hand is also associated with unavoidable drudgery and requires great labor hours (70 to 100 hr/ha) making it costly and unlikely for adoption in larger plots. Therefore, this review article presents different possible options to overcome the problem incurred in teff tillage practices, sowing/ transplanting techniques and also options to adopt other methods/techniques practiced in similar crops.

Keywords : Teff, Agronomic practices, planting, Transplanting techniques, Yield potential, Good agricultural practices

Teff (*Eragrostis* teff (Zucc.) Trotter) is a fascinating, ancient, small grain with high nutrients, which is popularly called as 'Williums love grass', 'teff' and 'bunch grass'. It is said to have originated in Ethiopia between 4000 and 1000 BC (Tadesse, 1969; Costanza, *et al.,* 1979 and Seyfu, 1997). Teff crop plays a vital role in food security, nutrition and income generation for resource-poor farmers and consumers in developing countries, especially in East Africa (Gina, Solomon, Kebebew, 2018).

Teff is a member of the Poaceae family, subfamily Eragrostidae and the genus Eragrostis with a diploid chromosome number of 2n=40. There are 350 species in this genus of which 54 are found in Ethiopia and 14 are endemic to Ethiopia (Alganesh, 2013). Teff is a warm-season annual grass, characterized by a large crown, many tillers and a shallow diverse root system. It is a staple food grain in Ethiopia but is used as a forage crop in other countries like Australia, South Africa, and the United States (Fikadu *et al*., 2018). Nutritionally, teff grain is considered to have an excellent amino acid composition, higher lysine levels, gluten-free and excellent iron content as compared to other cereal crops (ATA, 2013).

The traditional method of production without balanced inputs, poor agronomic practices and unavailability of suitable farm implements threatens the cultivation of Teff crop. According to Korinna (2013), lodging is considered as the major bottleneck affecting productivity in teff. However, past research revealed that agronomic measures and new cultivation systems

may help to reduce lodging, such as row planting by hand or machine instead of broadcasting at row distances of 20 to 25 cm or transplanting at 10 to 15 cm between plants within the row seems to alleviate lodging (Tareke Berhe *et al*., 2010).

Further, reduced tillage frequency, reduced seed rate, row planting, teff seedling transplanting methods and drip irrigated teff production have been a significant difference in teff biomass and grain yield when compared with traditional methods of production (Wubishet & Kolhe, 2023 and Tareke Berhe *et al*., 2010). Therefore, present article addresses a compressive review of different possible options to alleviate the problem incurred in teff tillage practices, row planting and teff seedling transplanting techniques. Also address the possible agronomic techniques experienced on other cereals; which can be adapted to teff cultivation.

Importance of Teff Crop

Teff grains are the world's tiniest grain, measuring 1-1.7 mm in length and 0.6-1 mm in diameter, with an average seed weight of 0.3-0.4g for 1000 seeds and 150 grains required to equal one grain of wheat (Lacey *et al.,* 2005 and Bultosa, 2007). The word teff is derived from the Amharic (Ethiopian national language) word 'teffa' which means 'lost', due to the small size of the grain. Teff grains can be white, light tan to deep brown or reddish-brown purple (Gamboa, 2008). Teff has a mellow, nutty flavor with a hint of molasses sweetness. The white teff has a chestnut flavor, while the darker types have an earthier hazelnut flavor. It is a shallow-rooted annual tufted grass, 25 - 135 cm high with slender culms and long, narrow, smooth leaves. Its inflorescence is a loose or compact panicle with 11 - 63 cm in length (Dawit and Hirut, 1995). Teff is resistant to extreme water conditions, as it can grow under both drought and waterlogged conditions (Minten *et al.,* 2013). Combined with its low vulnerability to pests and diseases, it is considered a low-risk crop (Minten *et al.,* 2013 and Fufa *et al*., 2011).

Teff is one of the most important staple crops in Ethiopia consumed by over 70 million people. Its importance is beyond being a staple food as it is connected to the socio-cultural heritage of the society (Siyum and Ummal, 2020). Teff is nutritional worth and health advantages and its quality value as a gluten-free grain can be used to avoid celiac disease when used as a substitute for wheat (Hopman *et al*., 2008) and piqued attention throughout the world (Baye, 14). According to Akansha *et al.* (2018), 100g teff grains contain 11.0 per cent of protein, 2.5 per cent fat, 70.2 per cent carbohydrate, 3.0 per cent fiber, 10.5 per cent moisture, 2.8 per cent ash, calcium (165.2 mg), iron (15.7 mg), copper (2.6 mg), magnesium (3.8 mg), phosphorous (425.4 mg), potassium (380.0 mg) and sodium (15.9 mg). It has a higher nutritional content than other cereal grains, containing all necessary amino acid composition, notably lysine and greater mineral content; mostly iron, calcium, phosphorous and copper (Melaku Umeta *et al*., 1996). It is likely to remain a favorite crop of the Ethiopian population and the crop is also gaining popularity as a healthy food in the Western world. The straw is the preferred feed for animals and is used for reinforcing mud for plastering wooden walls to build houses (Geta, 2020).

Teff Production in Ethiopia

Ethiopian farmers have been using traditional tillage implements called 'Maresha' (traditional animal-drawn plowing implement), using these implements' farmer plough their land up to ten times at the start of the rainy season (Friew and Lake, 2011). After repeated plowing, most of the husbandry planted teff by broadcasting method with a higher seed rate of 25-50 kg per ha, which results in increased plant density, hence rendering the crop prone to lodging and leading to low yields. High plant population forms insect build-up, nutrients and sunlight competition. It creates inconvenience for weeding and pest control measures and is difficult for cultivation. Lodging is one of the causes of low productivity of the crop and the yield loss associated with it is estimated to be as high as 30 per cent (Tareke Berhe *et al*., 2010; Friew & Lake, 2011 and Seyfu, 1993; 1997).

In Ethiopia, teff is known to be a rainfed crop and is produced only once a year, which demands protective irrigation to increase productivity (Yenesew *et al*., 2015). It is a labor-intensive crop and also productivity depends on timely and efficient pre-harvest and post-harvest operations. Most of the farmers in the country usually prepare their land using human power or draught (Geta, 2020). Indeed, Ethiopia is the largest Teff producer in the world. According to CSA (2018) report, teff accounts for 24 per cent of the grain area, followed by maize at 17 per cent and sorghum at 15 per cent (Table 1 and 2). The two major teff-producing regions are Oromia and Amhara and collectively, the two regions covered 85.5 per cent of the teff area and 87.8 per cent of the teff production.

Table 1

Production, plantation and yield of tef and other cereals crops in Ethiopia

Crops	Plantation Area, ha	Total plantation (%)	Yield ton/ha
Grain	12,574,107	100	–
Maize	2,135,571	17	3.675
Sorghum	1,881,970	15	2.525
Tef	3,017,914	24	1.664

Source: Ethiopia Statistics (2018), *: all numbers rounded, averaged yield

Despite its versatility in adapting to extreme environmental conditions, the productivity of teff is low in Ethiopia at 1.664 tons per ha as compared to 3.675 tons per ha for maize and 2.525 tons per ha for sorghum (CSA, 2017).

The national average grain yield of teff is in the order of 800 kg ha^{-1} (Tulema *et al*., 2008 and Kolhe, 2011) which is low compared to other crops, such as wheat and rice. These indigenous practices are laborious and result in low productivity of Teff (Friew and Lake, 2011). These low yield levels can be attributed to different production constraints; such as susceptibility to lodging, moisture stress and poor pre and post-harvest agronomic practices (Asargew *et al*., 2014) and also lack of improved agronomic practices such as tillage and sowing methods and appropriate agricultural technologies.

Teff crop is the most important crop in Ethiopia compared to other cereals (Fig. 1a), hence found Teff cultivation area and yield is in increasing trend over the years (Fig. 1), but the productivity per unit area is the lowest (Fig. 1b) when compared to others crops such as Maize, Sorghum and Wheat (Fig. 1c). Most agricultural researchers believe that the low productivity is mainly attributed to a lack of improved agronomic practices and appropriate agricultural technologies (Fig. 2) the improved tillage oxen-pulled

Table 2

Regional level tef production, plantation and yield in Ethiopia

Region	Total teff plantation		Total production of teff		Yield ton / ha
	ha	%	ton	%	
Tigray	167,584	5.5	2,410,116	4.8	1.438
Amhara	1,137,844	37.7	19,328,573	38.5	1.699
Oromia	1,441,030	47.8	24,737,963	49.3	1.717
SNNPR	246,099	8.2	3,412,547	6.8	1.387
Benishangul-Gumuz	24,433	0.8	303,184	0.6	1.241
Others	924	0.03	12,014	0.02	-
Total	3,017,914	100	50,204.400	100	

Source : Ethiopia Statistics (2018)

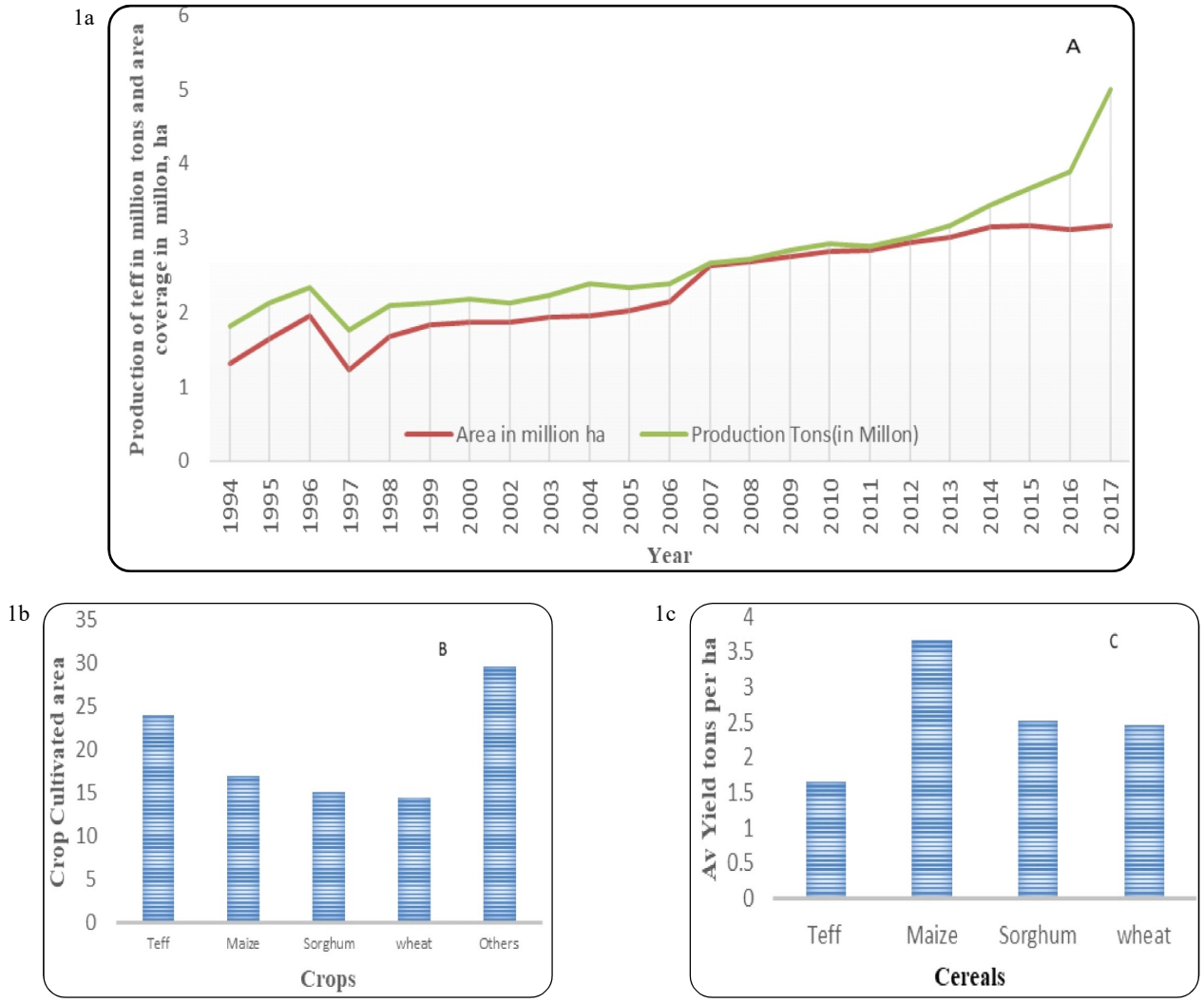

Fig. 1 : Teff production, Area coverage in terms of year (A), Percentage share of teff (B), teff productivity (yield) comparing with maize, sorghum and wheat, (C) (adapted from CSA 1994 - 2017 data)

Fig. 2 : Improved animal-drawn moldboard plow (left side) and farmers taking training on how to use the implement (right side) at Melkassa Agricultural Research Center (*Source*: Unpublished 2018 progress report)

moldboard plow (modified by the Agricultural Mechanization Research group at the Melkassa Agricultural Research Center) reduces the tillage requirement by 50 per cent due to its complete inversion or turning of the furrow slice that results in the inhibition of weed germination and growth. They reported that using this improved implement a yield increase of up to 12 per cent was observed. However, this implementation cannot reach the farmer's hand due to poor research extension systems and the cost of the implementation as well (Friew and Lake, 2011).

Sowing Techniques and Practices

Broadcasting Teff Seeds

After tilling a land repeatedly, farmer has established a teff crop by broadcast sowing method. Broadcasting is a traditional method commonly used for teff sowing in Ethiopia due to its small grain size. The current average seed rate used for broadcasting is around 30-50 kg per ha (Tareke which is much higher than the recommended rate 2.5-5 kg per ha (ATA, 2013). It is clear that broadcasting with a high seed rate results in increased plant density as shown in Fig. 9. Hence, rendering the crop prone to lodging and leading to low yields. A high plant population also creates insect build-up, nutrients and sunlight competition.

Row Planting Teff Seeds

In the past, a few researchers and organizations conducted trials to test the row planting of teff in different parts of the country and confirmed that it is most meritorious in increasing teff productivity and production (ATA, 2013 and Berhe *et al*., 2014). According to the ATA report (2013), Improved Teff Seeds, Reduced Seed Rates and Row Planting (TIRR) technique, teff productivity and production significantly increases throughout the country. They reported that the TIRR technique employed farmers and two additional family members (mostly women and children) using empty plastic bottles or similar small containers for pouring / drilling the seed and fertilizer manually (furrows are opened by animal-drawn traditional plough just before planting) not only reduced seed rate but also gained a significant yield difference than broadcasting method.

Indeed, manual row planting by hand results in uneven inter and intra-row distribution of seeds (bunching and gaps in the field). The seeds are drilled at a higher seed rate than recommended due to small seed size. In addition, row planting by hand is also associated with unavoidable drudgery and requires more labor hours (70 to 100 hr/ha) making it costly. Therefore, the adoption of row planting can be costlier than broadcasting. It may require 30 per cent more labor than broadcasting due to the lack of a mechanized row planter (ATA, 2013). It is reported, that the average TIRR yield was 2.8 tons per ha which was 75 per cent higher than produced with traditional methods, *i.e.,* 1.6 tons per ha. Many research outputs revealed that tilling the land more than three times is not necessary and doesn't have a significant effect on the yield component of the teff crop. In this regard, another research has conducted efforts to minimize the repeated tillage practices done by the farmers. Araya *et al.* (2012) stated that enhanced teff yield using a reduced tillage system and better water conservation management practices have a significant effect on the yield of teff crop.

Transplanted Teff Seedling

In recent attempts few researchers explained that the yield of the transplanted teff has given 3,400-5,100 kg per ha. This shows the new approach has a four fold increase in yield (Berhe *et al*., 2011; Zewdie, 2010 and Tareke *et al.,* 2013). Zewdie (2010) reported that the main effect of transplanting is increasing the tiller number, producing strong and fertile tiller culms and increasing the number of productive tillers, which increases the number of seeds per panicle giving individual plants wider space to show their potential and the use of complete fertilizers. This method requiers less seed, but requires more labor as compared to row seeding and broadcasting.

Zewdie, 2010 reported that row transplanting technique obtained higher grain (around 51qt per ha) as compared to the conventional broadcasting method (10qt per ha) in the off-season under irrigation at Debrezeit Research Center (DRC). This result shows that it is possible to produce teff using irrigation facilities instead of producing teff once per year in

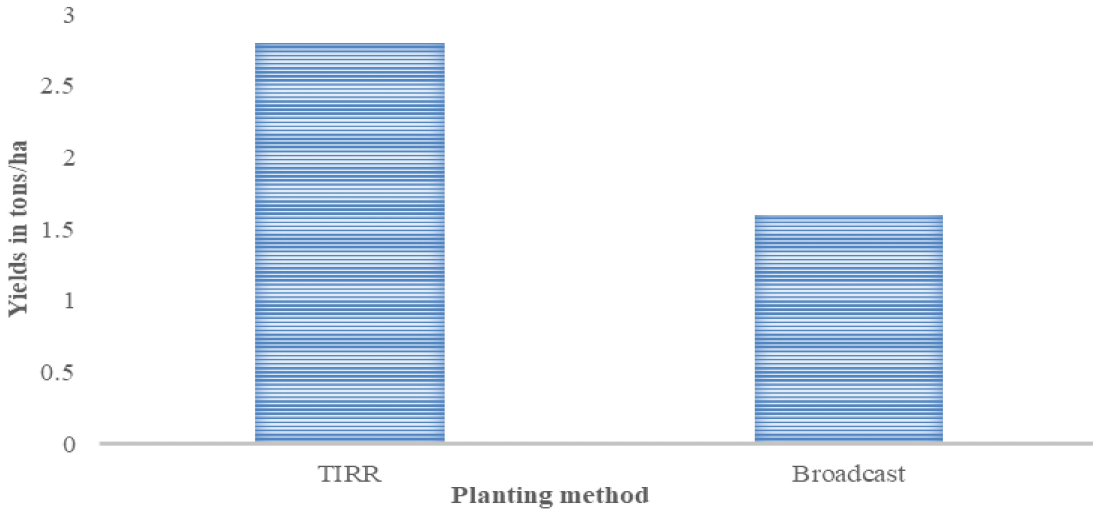

Fig. 3 : Comparison of TIRR planting method and Broadcast method (Adapted from ATA, 2013 report)

the rainy season only. There are also some scientists reported that by transplanting the teff seedling, land management and especially weeding can be done more readily and the incidence of lodging is reduced as a result increased the quality and quantity of teff yields obtained (Chanyalew and Assefa, 2013).

Recently teff farmers stopped practicing it because of low yield with high labour cost and it should be conducted with mechanical means to reduce the cost of production, the drudgery of the farmer, health risks for farm laborers. However, there are different transplanting techniques available worldwide on a crop like rice, which can be adopted for teff crops easily.

Ethiopian Institute of Agricultural Research (EIAR), especially, the Melkassa Agricultural Research Center, have started to introduce row planting technologies and developed different teff seed row seeders as shown in Fig. 4.

Fig. 4 : Different prototypes of teff seed drills developed at Melkassa Agricultural Research Center: Manually operated, 12-row plastic bottle teff seed drill (left side), Front pack scoop type six row teff seeder(middle), Backpack scoop type six-row teff seeder(right side)

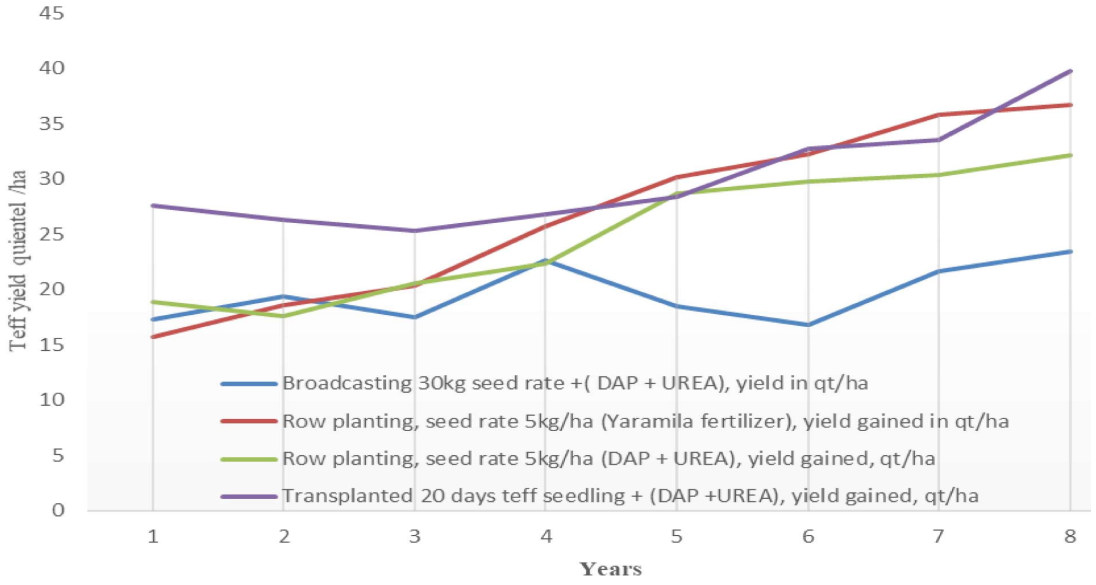

Fig. 5 : Comparison of different teff planting methods (Adapted from: Zewdie *et al.*; 2010, Berhe *et al*.; 2011, ATA, 2013; Zewdie *et al.,* 2010, Tareke B, Zewdie G, Sue E, Hailu A, 2013)

A study on comparision of different planting methods on productivity of teff crop (Fig. 5) revealed that the yield performance of the transplanting technique excelled the rest of the techniques followed. The second good performance next to transplanting was row planting with new fertilizer Yaramilla while the lowest increment was seen in the broadcasting method (Zewdie *et al*. 2010; Berhe *et al*., 2011; ATA, 2013; Zewdie *et al.,* 2010 and Tareke *et al*., 2013).

Berhe *et al* (2009 & 2011) reported that more than 3 tons yield per ha was obtained using transplanting techniques, when manually transplanted in rows 20 cm apart with 15 cm between hills. Three seedlings per hill were used in transplants (Fig. 6).

Tareke Berhe *et al.,* 2013 studied different planting methods used to identify the best teff planting techniques with traditional broadcasting of 30kg seed with recommended dose fertilizer (RDF), broadcasting with reduced seed rate (*i.e.,* 5 kg teff seed used) with RDF, row planting with reduced seed rate *i.e.,* 5 kg with RDF and transplanting with 0.4 kg seed RDF. The transplanting method excelled from all techniques.

Fig. 6 : Tiller potential of transplanted tef seedling (sample taken from the trials at Melkassa Research Center, 2018)

Manual Transplanting

Manual transplanting does not require costly machines and is most suited for labor-surplus areas and small teff fields.

According to Madusanka's report (2011), this technique has some limitations namely Transplanting by hand is tedious and time-consuming (up to 30 man-days ha^{-1}), Planting laborers can suffer from back-pain problems (health risk), Difficult to get enough labor at peak periods to transplant on time, Difficult to maintain optimum spacing and uniform plant density,

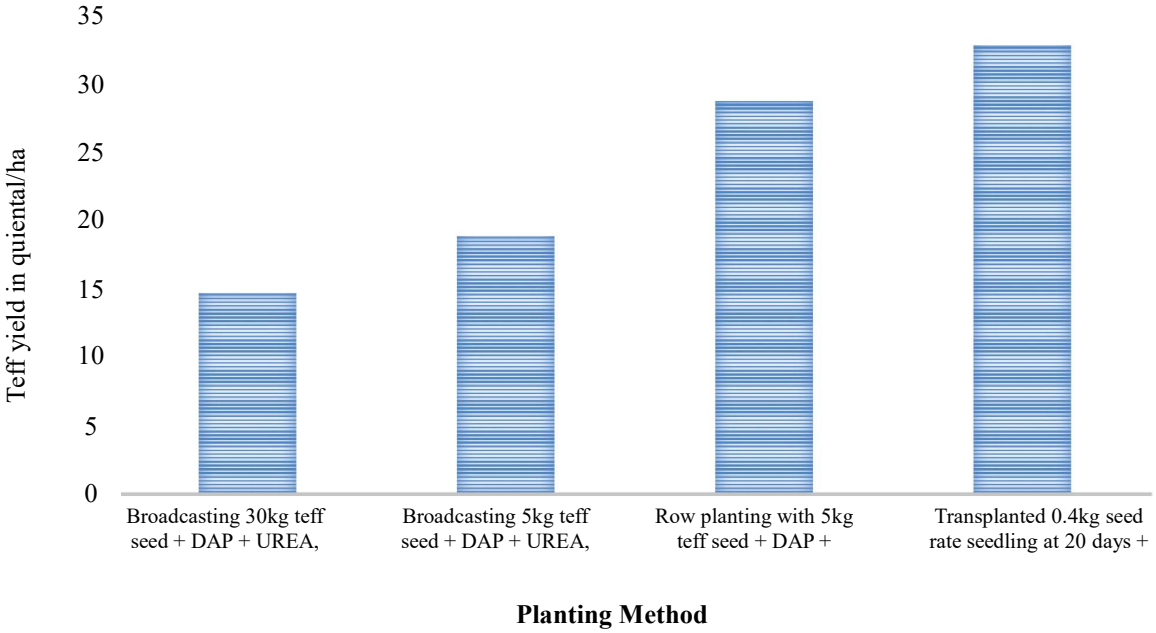

Fig. 7 : Different planting methods compared with Teff yields such as: Broadcasting at 30 kg seed ha^{-1}; broadcasting at 5 kg seed ha^{-1}; row planting at 5 kg seed ha^{-1} and transplanting young seedlings 20 days old at 0.4 kg seed rate ha^{-1} (Adapted from: Tareke Berhe *et al.,* 2013)

Fig. 8 : Teff transplanting manually at DZARC (*Source*: Tareke Berhe *et al*., 2013)

Fig. 9 : Teff broadcasting, lodged (left) and transplanting manually (right) at DZARC (*Source*: Berhe *et al.*, 2013)

especially with random transplanting and contract labor and Low plant density with contract transplanting on an area basis, which resulted in lower yields.

The high productivity obtained, witnessed in the above-mentioned research activities; shows that the potential yield for teff has not been yet sufficiently exploited, especially with the application of improved agronomic practices, reducing tillage frequencies, using improved implements, transplanting methods and irrigation facilities.

Mechanically Operated Machines

The walking-behind type engine-operated transplanters are light enough to operate by one operator and the self-propelled type transplanters carry one or more labor to operate and add mats to trays. Engine-operated transplanters manufactured by China,

Fig. 10 : Manually operated, hand-cranked rice transplanter walking backward type (left) and walking forward type (right)

Fig. 11 : Walking behind (left) and Self-propelled paddy transplanter (middle), Self-Propelled at Operation (right side) (*Source* : Dixit and Khan, 2011)

Japan, South Korea, India and other industrialized countries are designed to transplant rice crops and few are suitable for Teff crop based on field conditions.

Teff is an indigenous crop in Ethiopia, growing with traditional practice is uneconomical. Based on crop Potentialty and importance, researchers tried to improve teff production system. Recently teff row planting and transplanting have shown a significant advantage over the traditional method, but costing high on labours, hence machnical transplanting is practicable, that will reduce farmer's drudgery, reduce time and cost on large area planting and it has some great opportunities to boost teff productivity and production in total.

References

Agricultural Transformation Agency, 2013, Working strategy for strengthening Ethiopia's Teff Value Chain. Retrieved Nov. 6, 2018, from http://www.ata.gov.et/download/working-strategy-for-strengthening-ethiopias-tef-value-chain.

ALGANESH, T., 2013, Genetic resources of Teff in Ethiopia, achievement and prospects of Teff improvement proceeding, pp. : 15 - 20.

ASARGEW, F., BITEW, Y., ASFAW, M., LIBEN, M. AND GETAHUN, M., 2014, Row spacing and fertilizer rate on yield and yield components of teff [Eragrostis tef (Zucc.) Trotter] under transplanting planting method. *Journal of Biology and Agricultural Health Care,* **4** : 133 - 136.

TULEMA BALESH, JENS, B. A., FRED, H. J. AND BERNARD, V., 2008, The prospects of reduced tillage in tef (Eragrostis tef Zucc.) in Gare Arera, West Shawa Zone of Oromiya, Ethiopia. *Soil and Tillage Research,* **99** : 58 - 65.

KOLHE, K. P., 2011, Testing and ergonomically evaluation of tractor mounted and self-propelled coconut climber. *Intl. Journal of Engineering and Technology,* **3** (9) : 357 - 362.

BERHE, T., 2011, MOA/ATA'S teff value chain program: 2011 achievements and plans for 2012.

BERHE, T., 2009, Recent developments in tef, Ethiopia's most important cereal and gift of the world. CIIFAD Forum Seminar, Addis Abeba, Ethiopia.

BERHE, T., GEBRETSADIK, Z., EDWARDS, S. AND ARAYA, H., 2011, Boosting Teff Productivity using improved agronomic practices and appropriate fertilizer. In K. Assefa, T. Solomon, & Z. Chanyalew (Ed.), Achievements and Prospects of Teff Improvement. Proceedings of the Second International Workshop, pp. : 133 - 140. Debreziet.

BULTOSA, G., 2007, Physicochemical characteristics of grain and flour in 13 teff [Eragrostis teff (Zucc.) Trotter] grain varities. *J. Appl. Sci. Res.,* **3** (12) : 2042 - 2051.

CHANYALEW, S. AND ASSEFA, K., 2013, The agronomy of teff. Paper presented at the 'Improved evidence towards better policies for the teff value chain' conference, 10 October 2013, Addis Ababa, Ethiopia.

COSTANZA, S. H., DEWT, J. M. J. AND HALRAN, J. R., 1979, Literature review and numerical taxonomy of eragrostis teff (teff). Economic Botany. **33** : 413 - 424.

CSA (Central Statistical Agency), 2015, Agricultural sample survey 2015/16. Report on area production of crops (private peasant holdings, Meher Season). *The FDRE statistical bulletin,* Vol. 578, Addis Ababa, Ethiopia, pp. : 123.

CSA (Central Statistical Agency), 2017, Agricultural sample survey: Area and production of major crops, *Meher Season.* Vol. I. Addis Ababa, Ethiopia.

DAWIT TADESSE AND HIRUT KEBEDE, 1995, Germplasm collection, conservation and characterization of teff. Plant genetic resources centre/Ethiopia. *Internal Report*. Addis Abeba, Ethiopia.

FIKADU, ASMIRO, A., WEDU TSEGA, D., DERSEH AND ENDALEW, 2018, A review on economics of teff in Ethiopia. *Open Access Biostatistics & Bioinformatics,* **2** (3) : 15 - 20.

FRIEW KELEMU AND LAIKE KEBEDE, 2011, Some experience with mechanization. Achievements and Prospects of Teff Improvement. *Proceedings of the Second International Workshop Debrejet.* pp. : 161 - 168.

FUFA, B. B., BEHTE, R., SIMONS AND BERHE, T., 2011, Teff diagnostic report: Strengthening the teff value chain in Ethiopia. Addis Ababa, Ethiopia.

GAMBOA ARGUEDAS, P. AND EKRIS, V., 2008, Teff survey on the nutritional and health aspects of Teff (Eragrostis teff).

GETA, KIDANEMARIAM, 2020, Theoretical and experimental investigation of threshing mechanism for Teff (Eragrostistef (Zucc.) Trotter) based on its Engineering (Physical and Mechanical) Properties, pp. : 24 - 30.

GINA, CANNAROZZI, SOLOMON., CHANYALEW AND KEBEBEW, ASSEFA., 2018, Technology generation to dissemination: lessons learned from the tef improvement project. https://doi.org/10.1007/s10681-018-2115-5

HOPMAN, G. D., DEKKING, E. H. A., BLOKLAND, M. L. J., WUISMAN, M. C., ZUIJDERDUIN, W. M., KONING, F. AND SCHWEIZER, J. J., 2008, Teff in the diet of celiac patients in the Netherlands. *Scandinavian Journal of Gastroenterology.* **43** : 277 - 282.

LACEY, T., 2005, Eragrostis tef is a specialized niche crop. Government of West Australia. Department of Agriculture. Farm note No. 42/2005.

MELAKU UMETA AND PARKER, M. L. 1996. 'Microscopic studies of the major macro' components of seeds, dough and injera from teff (Eragrostis tef). SINET: An Ethiopian journal of science., **19** : 141 - 148.

MINTEN, B., S. TAMERU. E. ENGIDA, AND T. KUMA., 2013, 'Ethiopia's value chains on the move. The case of Teff.' ESSP II working paper 52. International Food Policy Research Institute (IFPRI). Addis Ababa, Ethiopia.

SEYFU, K., 1997, Teff Eragrostis teff (Zucc.) Trotter, Promoting the conservation and use of underutilized and neglected crops. 12, Institute of Plant Genetics and Crop Plant Research, Gatersleben /International Plant Genetic Resources Institute, Rome, Italy.

SIYUM, T. AND UMMAL, S., 2020, Development and Implementation of efficient and cost multipurpose agricultural equipment for teff plantations for small-scale farmers in rural communities. *International Journal of Mechanical and Production Engineering Research and Development* (IJMPERD). **10** (1) : 719 - 730.

TADESSE, EBBA, 1969, Teff ([Eragrostisteff]: the cultivation, usage and some of the known diseases and insect pests, part1. Debre zeit agricultual experiment station. addis ababa univesity, College of Agriculture, Die Dawa, Ethiopia.

TAREKE, B., ZEWDIE, G., SUE, E. AND HAILU, A., 2013, Boosting teff productivity using improved agronomic practices and appropriate fertilizer. In : Zerihun Tadele (eds.) Achievements and Prospects of teff Improvement; Proceedings of the second international workshop, November 7-9, 2011, Debre Zeit, Ethiopia. Ethiopian Institute of Agricultural Research, Addis Ababa, Ethiopia; Institute of Plant Sciences, University of Bern, Switzerland. Printed at Stampfli AG, 3001 Bern, Switzerl, pp. : 143.

Wubishet, A., Kishor Purushottam Kolhe., 2023, Assessing the biomass potential of plate scraps of adama science and technology university: A step towards generating biogas for kitchen use. *Journal of East China University of Science and Technology,* **65** (2) : 649 - 663.

ZEWDIE, G. T., 2010, Final Report on off -Season Teff productivity increasing trials using drip irrigation. Crops Production Program Coordinator Sasakawa Global, 2000. Addis Ababa, Ethiopia.

Yenesew Mengiste Yihun, 2015, Agricultural water productivity optimization for Irrigated Teff (eragrostic tef) in a Water Scarce Semi-Arid Region of Ethiopia. *Ph.D. Thesis* submitted in fulfillment of the requirements of the Academic Board of Wageningen University and the Academic Board of the UNESCO-IHE Institute for Water Education, pp. : 10 - 66.