https://doi.org/ 10.33472/AFJBS.6.5.2024. 961-975

African Journal of Biological Sciences

Review of Teff Crop Agronomic Practices and Properties in Ethiopia

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Article History
Volume 6, Issue 5, Apr 2024
Received: 22 Apr 2024
Accepted: 29 Apr 2024
doi: ***10.33472/AFJBS.6.5.2024. 961-975***

Abstract

This paper provides a comprehensive review ofcereal crops like rice, and wheat: plantation, agronomic practices, their properties, and adoptingsimilar transplanting techniques for teff cropsin Ethiopia. The review encompasses the selection of algorithms, data requirements, and optimization strategies, offering insights into advancements, challenges, and theoretical foundations. This review highlights the available transplanting mechanism of Agronomic practices and properties, focusing on techniques and algorithms that enhance seedling performance, and growth and accurately predict output production needs. It emphasizes the effectiveness of advanced transplanting technology for increasing the teff crop productivity. Additionally, the review offers valuable insights for future research directions and practical adaption of transplanting technology for teff crops in Ethiopia. This comprehensive assessment serves as a beacon for teff-producing community methods for teff seedling plantations, to refine their traditional sowing procedures, enhance efficiency, and reduce planting interruptions. A prominent highlight is the importance of transplantingpractice and utility, which play a pivotal role in cereal crop plantation. The main goal of the present research is to aware the teff producing farmer’s community regarding the importance of mechanization, and the need for advanced transplanting technology. In the present work emphasizes the studies of available cereal transplanting techniques, agronomic practices, their properties, andthe adaption of similar transplanting techniques for teff crops. And also thoroughly examined the available transplanting mechanisms and techniques of the various cereal crops globally. Furthermore; the techniques of studying mechanical and physical properties of crop seedlings are investigated. The findings of this research will be very helpful to the marginal and low land holding farmer’s community of Ethiopia to increase their teff crop yield.

Article Highlights:

- Agricultural Mechanization optimizes teff crop planting efficiency and reliability.
- Real-world case studies validate cost and time reductions, improving teff sowing performance.
- Challenges in data management and ethical mechanization implementation require careful consideration.

Keywords: Tef, agronomic practices, seedling, transplanter, physical and mechanical properties

1. Introduction

Tef is one of the staple food crops of Ethiopians community, believed to be originated, domesticated and diversified in the country. It is cultivated in a wide range of environments and performs better than other cereals under adverse climatic and soil conditions. While its demand and the price of tef grain increases at alarming rate, its productivity level is low, to tackle this; it should be applied yield increasing promising agricultural engineering technologies and it should be expanded the production areas from rainfed into water stressed regions using irrigation structures through a detail research. To do this, tef crop has encouraging useful traits than other cereals;like maize and wheat. According to Kebebew *et.al*. (2011, 2013), some of these beneficial traits are; Broad agro-ecological adaptation and it may grow over a wide range of agro-climatic conditions from sea level up to 3000 meters above sea level on a variety of soil types (i.e. from light sandy to heavy clay soils of variable fertility). In addition, its versatile property to resilience to moisture stresses with reasonable tolerance to both drought and water logging, and low-risk, therefore, it is reliable crop to the Ethiopian peasants. Furthermore, they elaborate that tef crop is particularly used as a catch crop in replacement cultures for failures of early sown long-season crops; such as maize and sorghum due to drought or other causes.Ethiopian farmers have been using traditional tillage implements called Maresha, using this implements farmer's plow their land five up to ten times at the start of rainy season. Some even reported up to twelve times in vertisols (Friew and Lake, 2011). After repeated plowing, most of tef husbandry planted tef by broadcasting method with higher seed rate 25– 50kg ha^{-1} which results in increased plant density, hence renders the crop prone to lodging and lead to low yields. High plant population forms insect build-up, nutrients and sunlight competition. It creates inconvenience for weeding and pest control, difficult for cultivation, irregular placement of seeds, and suboptimum plant density. However, past research revealed that agronomic measures and new cultivation systems may help to reduce lodging. Row planting by hand (or machine) 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). Lodging is one of the causes for low productivity of the crop and, the yield loss associated with it is estimated to be as high as 30% (Tareke Berhe *et al*., 2010, Friew and Lake, 2011, Seyfu, 1993; 1997, Teklu and Tefera, 2005). Therefore, cognizant of the problem incurred to tef production, different method of agronomic practices investigated by different researchers. Many of them reported as reduced seed rate, row planting, tef seedling transplanting methods, and drip irrigated tef production have been a significant difference on tef biomass and grain yield, when compared with traditional methods of production (Teklu, 2005, Tareke Berhe *et al*., 2010). The researchers use manual method of transplanting techniques on small plots to exploit the potential of tef seedling transplanting methods, and have got significant result on tef yield. However; those researches not used mechanical transplanter due to unavailability of suitable technology. Mechanical transplanting proved beneficial in saving of 66% cost of transplanting and required only 7% of time for transplanting as compared with manual transplanting (Sharma *et al*., 2002). In addition, they didn't explain the details mechanism of tef transplanting techniques like. mechanized transplanting that are different from hand transplanting, usually seedling boxes. Moreover; they were not clearly stated the way to grow tef seedling (mat preparation), i.e. seedling growing media and selection process not clearly mentioned. Also; physical and mechanical properties of tef seedling, and optimum irrigation level (i.e. water requirement for transplanted tef seedling vs. stage of maturity) not deeply studied. However, this paper mainly focusses a detail studies to address those gaps related to tef crops from available literature. Therefore, the objective of the present paper is to avail transplanting techniques and similar mechanisms used for other cereals, which wouldapplyto Tef seedling. And; also find a suitable and efficient tef transplanter with minimum (affordable) cost to boost tef productivity. Furthermore, the new tef transplanter will help to look into new methods of tef production in irrigated areas.

2. Literature Review

2.1. Tef Production in Ethiopia

Tef is a gluten-free crop, which makes it suitable for patients with celiac disease (Dekking *et al*., 2005). It is likely to remain a favorite crop of the Ethiopian population and the crop is also gaining popularity as a health 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 (Fekede *et al*., 2015, Geta K., 2020). In Ethiopia, from the cereals, tef is known to be a rainfed crop and is produced only once in a year, therefore, increasing the production of the tef crop irrigation has become an important factor (Yenesew *et al*., 2015). It is a labor-intensive crop; each activity (pre-harvest and post-harvest) is mostly done by traditional practice. It is obvious that the productivity of agriculture is strongly related among other factors, the timely and efficient pre-harvest and post-harvest operations. Most of the farmers in the country usually prepare their land either using human power or draught (Geta K., 2020).Indeed, Ethiopia is the largest Tef producer in the world. According to CSA (2018), report tef accounts for 24% of the grain area, followed by maize at 17% and sorghum at 15% (Table 1 and Table 2). Two major tef-producing regions in Ethiopia are Oromia and Amhara, and collectively, these two regions account for 85.5% of the tef area and 87.8% of the tef production.

Table 1. Production, plantation and yield of tef and other cereals crops in Ethiopia

Crop	Area in ha	Yield in ton / ha
Grain crops	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.

Table 2. Regional level Tef Production, plantation and yield in Ethiopia

Tef production area)	Area in ha (% total area)	Production in ton (% of TP#)	Yield** (ton / ha)
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), *: all numbers rounded, #TP: total production, **: averaged yield.

3. Research Methodology

The study is planned to study the available transplanting techniques and mechanisms for the different cereal crops like rice, wheat, etc from the available literature. and the agronomics practices followed by the farmers of Ethiopia planting teff by visiting the farmer's farm. Also; it is observed that the practices followed by the farmers for planting of teff seedling are very throbbing and laborious. Therefore; it is decided to study the physical and mechanical properties of the seedlings, the date of seedling for transplanting, seedling mat growing materials, design a model to determine the values of operational parameters for transplanting of the seedlings in irrigation schemes, and compare it with the other cereal crops. And to select the best possible mechanisms of transplanting for the teff crop. The overall research methodology for the research undertaken is shown in Figure1 as below;

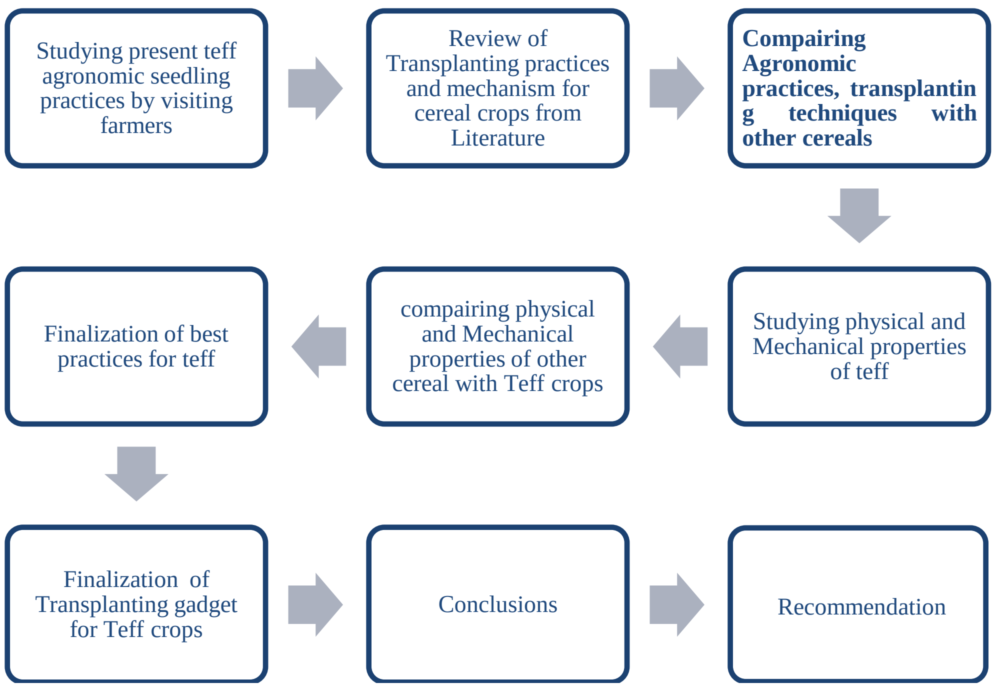


Figure. 1 Overall Research Frameworkof Agronomic practices, properties, and transplanting techniques for Tef crop

3.Tef Crop Establishment and Agronomic Practices

Tef farmers usually prepare their land either using human or draught animal or rarely used mechanical powered implements. The majority of tef farmers have been using traditional tillage implements called Maresha, using this implements farmer's plow their land five up to ten times at the start of rainy season. Some even reported up to twelve times in vertisols (Friew and Lake, 2011; Tarekegn *et al*., 1996). However, on seedbed preparation, many research outputs revealed that tilling the land more than three times is not necessary and don't have significant effect on the yield component of the tef crop (Haftamu G. *et al*., 2009). In this regards another research has conducted efforts to minimize the repeated tillage practices done by tef farmers. Araya *et al*

(2012) stated that enhanced tef yield using reduced tillage system and better water conservation management practices have significant effect on the yield of tef crop. After preparation of a good seedbed farmer has established tef crop by broadcasting sowing method with high plant density. The national average grain yield of tefis in the order of 800 kg ha^{-1} (Tulema *et al*., 2005) which is low as compared to other crops, such as wheat and rice. This 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).Most of agricultural researcher believed that the low productivity is mainly attributed by lack of improved agronomic practices and appropriate agricultural technologies (Friew and Lake, 2011). According to Zewdie *et al*., (2010) reports row planting and transplanting method may improve the productivity of tef. Since the seeds are sown and seedling are transplanted in rows uniformly, it makes easy for performing subsequent operations; like weeding, applying crop protection chemicals and harvesting. Transplanting is assumed to have the benefits of escaping dry spells occurring in any particular season and enhancing productivity under dry land areas. In addition, it reduces the seed rate; it required only 2-2.5kg seed to cover a hectare of land (Tareke *et al*., 2013, Fetene and Kolhe 2021). They mentioned in their research that row planting by hand (or machine) at row distances of 20 to 25 cm or transplanting at 10 to 15 cm between plants within the row seems to alleviate lodging. Lodging is one of the causes for low productivity of the crop and, the yield loss associated with it is estimated to be as high as 30% (Seyifu, 1997). It has been argued that more efficient agronomic management could double the yield of tef crop (Mueller *et al*., 2012, Kolhe, 2015).Now a day's concerned bodies including Ethiopian Institute of Agricultural Research, (EIAR) have started to introduce row planting technologies to the wider farming community. In past the few researchers and organizations conducted trials to test row planting of tef in different parts of the country, and confirmed that it is most meritorious in increasing tef productivity and production (ATA, 2013; Berhe *et al*., 2014). ATA report (2013) stated that as a result The Institute for Rehabilitation and Research (TIRR)technique had been demonstrated and massive rural people mobilizations were conducted all over the country during 2012 to 2014 cropping season, tef productivity and production significantly increases throughout the country. They reported that the TIRR technique employed a 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 result 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, mainly due to the nature of very small size of the tef seed. In addition, row planting 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, the adoption of the row planting, in fact can be costlier than the broadcasting. It may require 30% more labor than the broadcasting due to lack of the mechanized row planter (ATA, 2013). Even though it is difficult to practice, 2.2 million farmers were participated and used TIRR methods, which was one-third of the total number of tef farmers in Ethiopia, on 1.1 million ha practiced, and the average TIRR yield was 2.8-ton ha^{-1}, which was 75% higher than produced with traditional methods, i.e.1.6-ton ha^{-1} (ATA, 2013).

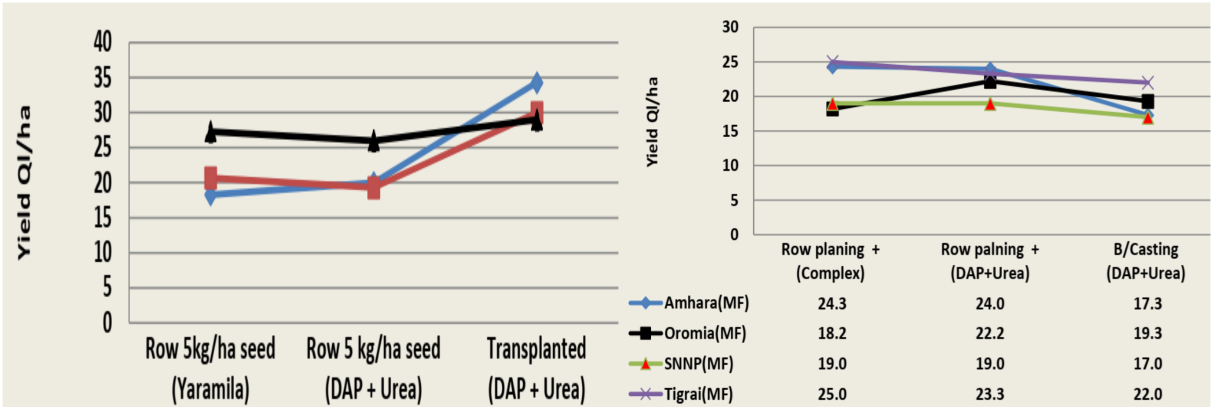


Figure 2. Planting Method and Complete Fertilizer on Yield at Model Farmer Field(left)andon FTC (right) (Source: Berhe, 2011).

There is also another promising agronomic practice called the Transplanting method. This includes the available published information related to tef seedling transplanting method researchers call 'new agronomic practices'. Therefore, in recent attemptssome tef researchers explained, that the yield of the transplanted tef has given 3,400-5,100kg ha^{-1}. This shows the new approach (Transplanting method) has a fourfold increase in yield (Berhe *et at*., 2011; Zewdie, 2010). 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 increasesthe number of seeds per panicle (Ref fig 2-3). As he stated, the best results came from wider spacing, giving individual plants wider space to show their potential and the use of complete fertilizers. Transplanting is commonly practiced as a method of weed control for wet soil. Since the seedlings are vigor the weed will help for control. While requiring less seed, transplanting requires much more labor as compared to row seeding and broadcasting.


Figure 3. Tiller potential of transplanted tef seedling (Source: Zewdie, 2010, Berhe, et al., 2011).
After recognizing of the advantages, it was practiced on tef crop for the first time in 2008/2009 at Debreziet Agricultural Research Center, and promising results were obtained. According to Berhe *et al* (2011) the field experiment with plot sizes of 20m^2 was conducted and reported that tef seedlings were grown in pots for two weeks and then manually transplanted in rows 20 cm apart with 15 cm between hills. Three seedlings per hill were used in transplanting and around 3ton ha^{-1} obtained using tef seedling transplanting techniques as depicted in Figure 4-5.

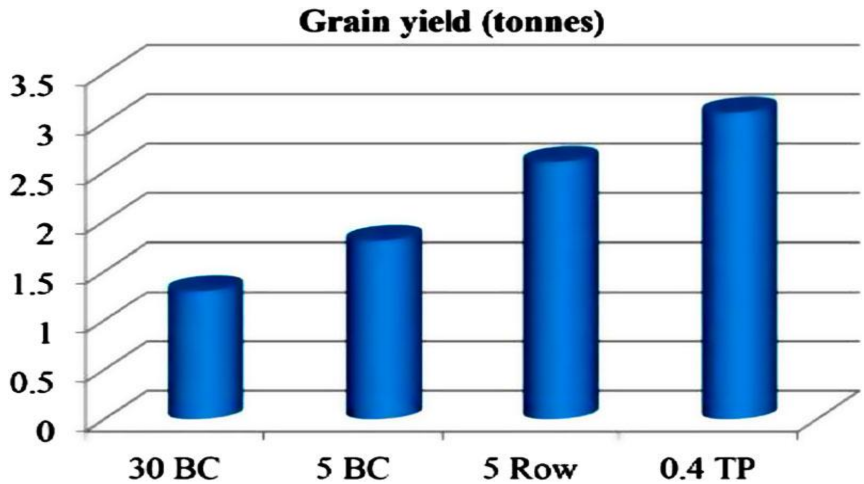


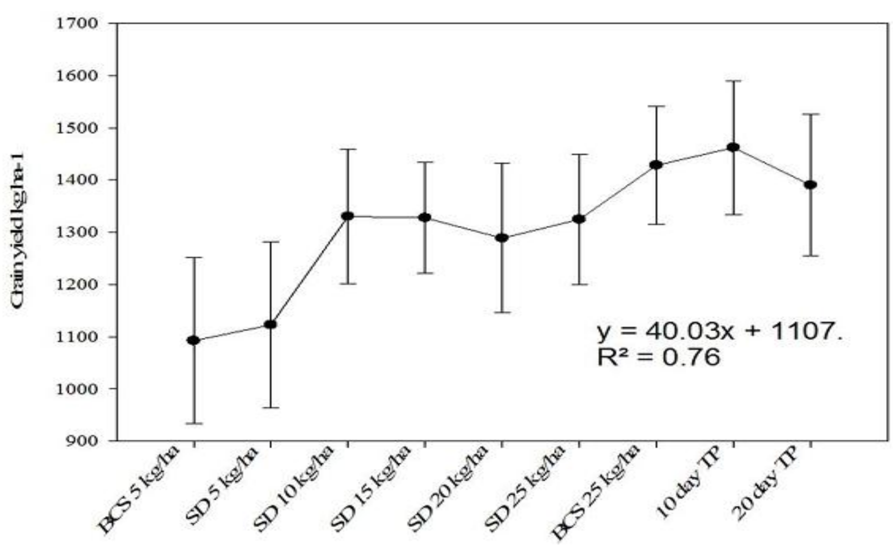
Figure 4. Average tef yields (ton ha^{-1}) with different planting methods and different seed rates, ranging from 30 kg to 0.4 kg seed ha^{-1}, in the 2012/2013 season. Broadcasting at 30 kg seed ha^{-1}; broadcasting at 5 kg seed ha^{-1}; row planting (direct-seeding) at 5 kg seed ha^{-1}; and transplanting young seedlings at 0.4 kg seed ha^{-1} (Source: Berhe, *et al*., 2011).

Figure 5. Tef transplanting manually at DZARC (Source: Berhe, *et al*., 2011)

Another preliminary work was conducted in the off-season under irrigation in Debrezeit Research Center (DRC), the preliminary results showed that tef seedling transplanted technique in rows obtained higher grain (around 51q ha^{-1}) as compared to the conventional broadcasting method(10q ha^{-1}) and row planting (28q ha^{-1}) (Tarekegne *et al*., 2010; Zewdie, 2010). There also another scientist reported that by row planting or transplanting the 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 tef yields obtained (Berhe *et al*., 2014;Wubishetand Kolhe. 2022).

Figure 6. Tef broadcasting, lodged (left) and transplanting manually (right) at DZARC (Source: Berhe, *et al*., 2011)

That high productivity obtained, witnessed in the above-mentioned research activities; shows that the potential yield for tef has not been yet sufficiently exploited, especially with the application of agricultural machinery and irrigation. Even if this manual transplanting method shows a significant advantage over the other two techniques in terms of yield, however, it is a time and resource-intensive technique (Refer to fig 6- 7).It is expensive and labor-intensive, and high labor charges result ina high cost of production, difficult timeliness operation, and serious backache for the farmer which limits the size of the field that can be transplanted. Recently tef farmers stopped practicing it because of the unavailability of tef seedling transplanter (Zerihun, 2016). Therefore, the applicability of the transplanting method on the crop needs further investigation, and it should be conducted with mechanical means to reduce the cost of production, the drudgery of the farmer, health risks for farm laborers, and also start season tef production on irrigated schemes with mechanical means to overcome tef as only rainfed crop.



*BSC=Broadcast seed; SD= Seed drill; TP=transplant.

Figure 7. Tef grain yields as a function of transplanting time and sowing method over the years and locations (source Sisay G. *et'al*.)

4. Physical and Mechanical Properties of Tef Seedling

Plants are rheological materials whose properties follow non-Newtonian laws as derived from their behavior in terms of plasticity and elasticity (Miu, 2016). The physical and mechanical properties of seedlings are important to design a transplanter. The mechanical properties will be compression, tension, Young's modulus, shearing stress, bending stress, and frictional characteristics of the seedling. The physical properties are stalk (stem) diameter, height, weight, maturity, moisture content, and cellular structure. The study of mechanical properties is needed for textural analysis and a better understanding of product quality. The machine may result in reduced work efficiency and higher seedling damage if designed without considering these criteria.The physical properties can influence the mechanical properties such as the tensile strength, shear stress, and flexural rigidity of the stem (resistance to lodging) (Geta, 2020, Kolhe 2009, 2015). Some physical properties of the cereal crop stem at the maturity stage have been investigated and reported by several researchers; however,there is little information available for the crop stem and none for the seedlings.According to Smith *et al* (1994),the Moisture content of the crop will be determined by oven-dry method at a temperature of 103°C for 24 hr. The bulk density will be found by the weight-volume method under natural filling conditions. The bulk density of the crop could be determined by weighing the crop packed in a container of known volume. The crop will be densely packed by gently tapping the container to allow the settling of the crop in the container (Ndirika *et al*., 2006). Also according to Geta (2020), it is possible to measure the physical properties of tef stem with a Micro Meter and Vernier Caliper, as the mechanical properties like tensile test with UTM, and shear (cutting force) test with a Texture Analyzer. Turbhatmath (2010) studied the physical and mechanical properties of 6th, 7th, and 8th-week onion seedlings suitable for the development of seedling transplanter. As he stated the average weight, bulb diameter, height, and compressive strength were directly proportional to the age of the seedlings. The six-week seedlings were thin and very light in weight i.e. 1.12 g and the seven-weekseedlings' weights were nonuniform. The seven and eight-weekseedlingshave higher compressive strength hence they were suitable for transplanter and the diameter of this seedling was found suitable for transplanting with transplanter.Nazari *et al* (2008) also studied the physical and mechanical properties of alfalfa stem, the experiments were conducted at a moisture content of 10%, 20%, 40%, and 80% w.b. They found that the average bending stress value varied from 9.71 to 47.49 MPa and the average Young's modulus ranged from 0.79 to 3.99 GPa. They stated that bending stress decreased as the moisture content increased. That is the value of the bending stress at low moisture content was obtained approximately 3 times higher than at high moisture content. Young's modulus in bending also decreased as the moisture content and diameter of stalks increased.

The bending and shearing properties of sunflower stalkswere studied by the average bending stress value varied from 21.98 to 59.19 MPa. Young's modulus in bending also decreased as the moisture content and diameter of stalks increased. The average Young's modulus varied between 0.86 and 3.33 GPa. The shear stress and the shear energy increased with increasing moisture content. Values of the shear stress and energy also increased from top to bottom of stalks due to the structural heterogeneity. The maximum shear stress and shear energy were found to be 11.04 MPa and 938.33 mJ, respectively, both occurring at the bottom region with the moisture content of 37.16% (Shahbazi and Nazari, 2012). According toCrook and Ennos (1994) lodging susceptibility in cereals depends on three factors: first, the size and dynamics of the forces to which the plant is subjected; second, the bending strength of the shoot and its resistance to buckling; and third, the anchorage strength of the root system. Flexural rigidity (E x I) is not stem strength but is a measure of the stem's ability to bend.
It is dependent on the geometry of the stem (stem radius and stem wall width) but is not dependent on the material component of the stem.Geta (2020) reported that testing equipment and empirical formulas determined the physical and mechanical properties of four tefvarieties

stem at three segments at (the bottom, middle, and upper position) maturity stage to design tef thresher. He reported that most of the *tef* varieties have very small thicknesses of stem and their diameter decreases from the bottom towards the upper position with minimum difference. The measured shear stresses were 8.5Mpa, 10.2Mpa, 6.30Mpa, and 5.10Mpa for Local, Guduru, Kora, and Quncho tefvarieties, respectively. Also, he explained that in Modulus of elasticity, the varieties have maximum and minimum values of elasticity 0.13 and 2.6 Gpa at moisture levels of 8.82% and 16.6%, 1.02 and 3.6 Gpa at moisture levelsof 10.32%and 13.79%, 0.85 and3.22 Gpa at moisture levels of 7.65% and 12.72%, 1.28 and 3.88 Gpa at moisture levels of 5.5% and 19.70% at upper and bottom position for Local, Kora, Quncho and Guduru varieties respectively. Moreover, they studied flexural rigidity in four tef varieties. The varieties have maximum and minimum values of flexural rigidity: 1.3 and 26 $kNmm^{-2}$ at moisture levels of 8.82% and 16.6%, 10.18 and 36 $kNmm^{-2}$ at moisture levels of 10.32%and 13.79%, 8.48 and 32.2 $kNmm^{-2}$ at moisture levels of 7.65% and 12.72%, 12.78 and 38.84 $kNmm^{-2}$ at moisture levels of 5.5% and 19.70% at upper and bottom positions for Local, Kora, Quncho and Guduru varieties respectively.

5. Method of Transplanting

In the transplanting method seed is sown in one place and the seedlings after they have grown a little is transplanted to another. This is done to get higher yields and less weeding. According to Madusanka, (2011) report transplanting of seedlings can be mainly categorized into three groups: By hand (manual) as shown in Fig 8, by Manually operated machines (work by manpower),and by Mechanically operated machines (work by engine power)

5.1. Hand Transplanting

This method is good for small fields. Manual transplanting does not require costly machines and is most suited for labor-surplus areas and small rice fields. It can be done in the field with less than optimal leveling and with varying water levels. Seedlings are raised in a wet, dry, or modified mat nursery. Proper nursery management will produce healthy, vigorous seedlings.

Figure 8. Rice Seedling Hand Transplanting

According to Madusanka's (2011)Report this technique has some limitations:

- Transplanting by hand is tedious and time-consuming (up to 30 man-days ha^{-1})
- Planting laborers can suffer from back problems(health risk)
- Difficult to get enough labor at peak periods to transplant on time
- Difficult to maintain optimum spacing and uniform plant density, especially with random transplanting and contract labor

- Low plant density with contract transplanting on an area basis lowers yields
- Risk, in rainfed areas, that seedlings (especially of modern varieties) may get too old before rain falls and the field is ready to be planted.

5.2. Manual Transplanter

Manually operated transplanters are powered by manpower. The operator has to move with the transplanter and power the machine by hand. These machines are small enough to operate manually. Various types of machines exist in the world. These machinesconsist of a seedling tray, forks, handle, and skids as shown in Fig 9. By pressing the handle, the forks pick up the seedlings and plant them in 6 rows. For every stroke of the handle, the seedling tray moves sidewards for uniform picking of seedlings by the forks. The operator has to pull the machine while punching the handle at the desired spacing. The Row to row spacing is 20cm (Madusanka, 2011).

Figure 9. Manually operated, hand-cranked rice transplanter walking backward type (left) and walking forward type(right)

5.3. Mechanically operated machines

Engine-operatedtransplanters are powered by engines as depicted in fig 10. The operator has to move with the transplanter or in some; the operator can sit on it. The walking-behind type engine-operatedtransplanters are light enough to operate by one operator and the self-propelled type transplanters carry one or more laborers to operate and add mats to trays. Engine-operated transplanters manufactured by China, Japan, South Korea, India, and other industrialized countries are designed to transplant rice crops and are suitable for their field conditions.

Figure 10. Walking behind (left) and Self-propelled paddy transplanter, (middle), Self-Propelled at Operation, (right side) (source: Dixit and Khan, 2011).

6. Conclusion and scope for future research

a) Conclusions

From this study following conclusions are made:

1) The plantation of teff has an illustrious key role in fulfilling major pangs of hunger of the Ethiopian population, and distinctive source of income of the community of Ethiopia, but itsfarming practice is stilltraditional.Different stakeholders tried to modernize the way of tef production by adapting various techniques of mechanization. Recently tef row planting and transplanting have shown a significant advantage over traditional practices, but due to theavailability of suitable teff seedlings transplanter farmers didn't practice it.
2) The available transplanting mechanism of cereal crops like; rice can be modified by considering the physical and mechanical properties of teff seedlings. And similar mechanism may be used for teff transplanting.
3) Transplanting techniques have a great advantage in the plantation of tef crops if an appropriate transplanting mechanism is developed for tef crops; that will reduce farmer's drudgery, and time for tef seedling transplant on a wide area, and also it has some great opportunities to boost tef productivity and production in total.

b) Scope for future research

There is anincredible scope for future research on teff transplanting, as the agronomics practices followed by the teff-producing communityare manual by using human labor, hence the mechanical and semi-automatic gadgets may be designed and practiced for the teff crops.

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