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Research paper

Large scale evaluation of the improved tef (*Eragrostis tef*) technologies

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Tef is the most important staple crop in Ethiopia. Despite its importance and increasing demand in local and global markets, tef production and productivity have remained low. Therefore this experiment was implemented to assess farmer technology preferences and to create wider demand for the availability of high yielding improved tef varieties. The improved variety of Kora with its associated recommended management practices was used and compared with the local tef growing practice in the 2019 growing season on 65 farmers' farm lands. All the necessary data were collected and estimated using descriptive statistics. The result showed that the variety of Kora provided a higher average grain yield of 2682.4 kg ha^{-1} and resulted in a yield advantage of approximately 76.9% higher grain yield over the local variety under farmer's practices. The result further showed that in the study areas a higher technological index of 41.6% was recorded. Participant farmers were agreed that the variety Kora had longer panicle length, resistance to lodging, resistance to waterlogging, longer in plant height, higher in grain, and straw yield compared to their local variety and even the previously introduced varieties. The improved variety drew a lot of attention from farmers because of its high yielding potential, white seed colour, good straw yield, and lodging resistance. The result indicated that promoting the improved tef Kora variety at a large scale, along with the recommended management practices, could increase farmers' access to improved variety seed and extension services.

Key words: farmer preference, teff, kora variety, promotion, scaling up, technology gap

INTRODUCTION

Tef [*Eragrostis tef* (Zucc) Trotter] is Ethiopia's most important staple crop and a versatile cereal crop when it comes to adapting to a variety of agro-climatic and soil conditions (Plaza et al., 2009). Tef is a staple food crop in Ethiopia and Eritrea, where millions of people depend on it (Tefera and Belay, 2006). It's also grown in Northern Kenya, South Africa, the United States, Canada, Australia, the Netherlands, and Yemen for small-scale gluten-free grain production (Tefera and Belay, 2006). Tef is a lower-risk crop than other cereals because it can withstand adverse weather conditions. Tef grows best between 1800 and 2100 meters above sea level, 750-1000 millimetres of annual rainfall, and a temperature range of 10 to 27 degrees Celsius (Chamberlin and Schmidt, 2012). Tef is a gluten-free, high-protein grain with a nutty flavor. Tef has a protein content that is similar to other grains, ranging from 7 to 11 percent (Bultosa, 2007). Minerals such as calcium, iron, potassium, and zinc are also available in Tef. Tef grain has a carbohydrate content of around 73 percent (Bultosa and Taylor, 2004). Tef straw is the staple diet of all ruminant classes, where it is regarded as a nutritious fodder comparable to good natural pasture and far preferred to other cereal straw, especially during the dry season (Gebrehiwot and Mohammed, 1987; Tefera and Belay, 2006). Straw yield has now equaled grain yield in importance for farmers (Mengistu and Mekonnen, 2012). Tef straw is often used as a mulch and in the construction of house walls when mixed with clay (Ketema, 1997; Refera, 2001). Tef has the highest value in terms of production and consumption, and its trade surplus is second only to coffee in terms of value (Minten et al., 2013). The tef production area continues to expand, and the number of farmers producing tef is increasing. Tef was grown by approximately 6.8 million farmers in 2018, compared to 4.4 million farmers in 2001/2002 (CSA, 2018). Similarly, the tef area planted increased from 1.8 million hectares in 1997 to more than 3 million hectares in 2018 (CSA, 2018). The largest tef-producing regions in the country are Oromia and Amhara, which together accounted for 87.5 percent of national tef production volume and 85.4 percent of the cultivated area during the 2017/2018 cropping season. Amhara region is the second-highest producer with a 38.6% share of volume of production and average productivity of 1.8 tons ha^{-1} (CSA, 2018). Despite its growing importance and demand in local and international markets, tef production and productivity have remained low, at 1.8 tons ha^{-1} (CSA, 2018), far below the crop's potential of 3.2 tons ha^{-1} (Assefa et al., 2017). The low tef yield appears to be due to a lack of understanding about potential avenues for increasing tef productivity, as well as botany issues. Tef research has gotten little national and global attention, owing to its regional significance in Ethiopia (Berhane et al., 2011). While there has been researching on improved tef varieties since the mid-1950s, investments have been limited, and only a small number of improved varieties *i.e.,* about 44 varieties have been released by the national research system (MoA, 2018). Agronomic constraints, such as lodging, low use of modern inputs, and high post-harvest losses, also contribute to low tef yields (Berhane et al., 2011; Habtegebrial et al., 2007; Tesfay and Gebresamuel, 2016). The use of outdated and low-yielding local landraces, as well as the lack of high-yielder, improved varieties (Dadi et al., 2005) and the limited use of inorganic chemical fertilizers (Asfaw et al., 2011), also contributed to the lower level of productivity. The availability and accessibility of improved seeds are key factors in the adoption of improved varieties (Abera, 2008; Asfaw et al., 2012; ICARDA, 2008). Limited or no participation of the end-user farmers during the early stages of technology generation and adaption period was the other most important factor that accounted for the low level of adoption. Farmers were merely passive beneficiaries of the agricultural technology production and verification processes, which were initiated and implemented solely by researchers. Farmers are more knowledgeable of their issues than outsiders, and therefore are in a stronger position to analyze and recognize the technologies that best serve their current circumstances, which is one of the reasons for promoting farmer participation in the research process. Farmers who are more knowledgeable about improved genotypes are more likely to embrace new cultivars since they are better informed about the genotypes' benefits. According to (Bekele et al. (2008) and Asfaw et al. (2011), knowledge of the existing varieties was among the important factors which determined agricultural technology adoption. In most situations, technology exposure is not haphazard, and technology knowledge is a necessary precondition for adoption (Dadi et al., 2004; Diagne and Demont, 2007). Many previous studies found that farmers who took part in on-farm experiments, demonstrations, farmer study groups, and field visit events were more likely to implement improved agricultural technology than those who did not (Asfaw et al., 2011; Chandio and Yuansheng, 2018; Dadi et al., 2005; Krishnan and Patnam, 2014; Verkaart et al., 2017). Farmers' participation would improve the validity of research findings in the field and the acceptability of the technology produced. This experiment is, therefore, initiated to evaluate and promote the improved Kora tef variety and to assess the perception of farmers about the variety.

MATERIALS AND METHODS

Description of the study area

The study was done in the low land areas of Ensaro and Efratana gidim districts of the North Shewa zone Amhara region in the Meher season of 2019. The districts were selected purposively based on tef growing potential. Ensaro was located between 9^0 49'59.99'' North and 39^0 00' 0.00" East while it was 9^0 29'59.99'' North and 39^0 39' 59.99" East for Efratana gidim district. The areas have a unimodal rainfall pattern, with annual average rainfall ranging from 943 to 1199 mm and annual average temperatures ranging from 17.6 to 23 degrees Celsius. The altitude ranges between 1263 and 3000 meters above sea level for both locations. The study area's production system is classified as a mixed crop-livestock agricultural system; in which smallholder farmers produce both crops and livestock. Sorghum, tef, and mung bean are some of the most common crops grown in the area.

Materials and research approach

The improved variety of Kora was used for this research. This variety was released in 2014 by the Ethiopian Institute of Agricultural Research, Debre Zeit Agricultural Research Center (MoA, 2014). The variety is a white-seeded high-yielding potential variety resulting on average 2.5-3.2 tons ha^{-1} on research station and it ranged from 1.8-2.8 tons ha^{-1} under farmers' fields (Assefa et al., 2017; MoA, 2014). A 20 kg seed rate was used, along with 100 kg P_2O_5 inorganic fertilizer and 40 kg ha^{-1} nitrogen fertilizer. About 300 kg of improved seed was delivered to 65 farmers and about 17.5 ha of land were covered. The experiment was implemented in a participatory approach. To enhance farmer participation, two farmers' research and extension groups (FREG) were established in both locations, each with 27 members. All participating farmers, FREG participants, and experts received training on the agronomic practices, which included both theoretical and practical portions, before the start of the trial. Finally, at the end of the field trial, model farmers, development agents, experts, and farmers from the experimental sites gathered for field days. Field day events are valuable because they provide a platform for interaction between farmers and extension personnel, as well as among farmers themselves, for the exchange of new knowledge and experience (Charity and Tegha, 2014; Heiniger et al., 2002; Oswald, 2005).

Data collected

A checklist and focus group conversations were used to gather qualitative and quantitative data from experimental plots and participant farmers (FGDs). Secondary information was gathered from a variety of published and unpublished sources. All agronomic data, including grain and biomass yields, were collected via quadrants in an 'X' pattern from randomly selected farmlands. FREG members were asked to see how they felt about the improved variety and what they preferred. Farmers brainstormed to determine their key variety evaluation criteria to consider when evaluating improved tef varieties in the sense of their area. Farmers evaluated tillering capability, disease resistance, and adaptation to the environment, panicle length, stalk strength, plant height, grain yield, and straw yield.

Method of data analysis

The data were analyzed using simple descriptive statistics like frequency, percentages, mean, and standard deviation, as well as a narrative summary. To see whether the improved variety's mean biomass and grain yield were significantly varied from the local variety under the existing farmers' practice, an Independent Sample T-test was employed. Yield advantage of the improved Kora variety with its associated management practice over the farmers' local variety under the existing situation was analyzed by using the formula:

Yield advantage of the improved technology = {(Yi-Yj)/Yj} x 100 ………………….. 1

Where: Y_i: average yield of the improved variety, Y_j: average yield of the local variety

Furthermore, the technological gap, extension gaps, and the technological index were estimated to evaluate the productivity impact of the improved variety with its associated management practices and to estimate the yield loss as a result of using the local variety with farmers' traditional management practices using the following formulas suggested by Samui et al. (2000).

TG= Yi-Yj 2
EG= PYi-Yi 3
TI= (TG/PYi) x 100 4

Where: TG: technological gap, EG: extension gap, PY_i: potential yield of the improved technology, TI: technological index..

RESULTS AND DISCUSSION

Yield performance of the improved tef technology on farmers' field

In both locations, the result from an analysis of variance showed that a significant variation of grain yield at P<0.05 was found between the local and the improved varieties. In Efratana gidim and Ensaro districts, respectively, the variety Kora produced a significantly higher mean grain yield of 2682.4 and 2013.3 kg ha^{-1}. The improved variety returned a higher grain yield in Efratana gidim district than Ensaro might probably be attributed to agro-ecological variations, environmental differences, soil type, and the farming system. The use of improved production technologies that included high-yielding variety (Kora) of tef with its recommended agronomic practice resulted in 76.9% and 79.4% higher grain yield over the local variety with farmer's practices in Efratana gidim and Ensaro districts, respectively. The current findings were found to be consistent with those of (Birhanu et al., 2020), who recorded an average yield of 2868 kg ha^{-1} from the same variety in North-Western Ethiopia. Feed shortage is a major issue for farmers in the low lands of the study areas, where the sorghum and tef production systems predominate. In both locations, the improved tef variety yielded more biomass than the local tef variety (Table 1). The improved Kora variety in the Ensaro district produced a higher biomass yield (8194.2 kg ha-1), while the local variety in the same district yielded a lower biomass yield of 5280 kg ha^{-1}. As a result, the improved variety outperformed the local variety by 23-55.2 percent in terms of total biomass yield. When compared to the findings of (Birhanu et al., 2020), who reported an average biomass yield of 11700 kg ha^{-1} from the same variety, this result was relatively lower.

Technological gap, extension gap, technology index, and its wide-scale implication

Table 2 presents the information on the technological gap, extension gap, and technological index. The result showed that the variety of Kora in conjunction with the recommended agronomic practices resulted in a higher technology gap, a higher extension gap, and also a higher technological index in both locations. The technological gap is the result of comparing the improved variety's demonstrated yields to the yield obtained from the local variety. The result indicated that the technological gap was found at 1165.7 kg ha^{-1} for Efratana gidim and 891.1 kg ha^{-1} in the Ensaro district. These technological gaps could be narrowed down using the improved tef varieties based on the recommendation. Farmers' decisions on whether and how to implement modern technology, on the other hand, are influenced by the complex relationship between the technology's characteristics and a variety of conditions and circumstances (Biagini et al., 2014; Loevinsohn et al., 2012). The availability and accessibility of improved seeds are key factors in the adoption of improved varieties (Asfaw et al., 2012; Abera, 2008; ICARDA, 2008). One of the most significant sources of innovation is improved seed, which is also one of the most cost-effective and productive agricultural inputs (Messrs et al., 2007). Through a combination of improved technologies and improved farmer cultivation practices, small-scale farmers in Ethiopia can produce higher yields from seeds of improved varieties. The use of improved seeds, according to ATA (2011), increases productivity by 50 percent.

In the Ensaro district, the extension gap calculated from the difference between the potential yield and farmer's demonstrated yield of the improved variety was 786.7 kg ha^{-1}, while in the Efratana gidim district, it was 117.6 kg ha^{-1}. This result appeared to corroborate with the results of (Chandio and Yuansheng, 2018; Krishnan and Patnam, 2014; Verkaart et al., 2017), who proposed that extension agents in Ethiopia assisted in the diffusion of vital information to farmers in the early stages of adoption. The technological index indicates the level of feasibility of the introduced technology in the farmer's field. The lower the technology index value, the more feasible the technology is. In both locations, a higher technological index of 41.6% and 31.8% were recorded in the Efratana gidim and Ensaro districts, respectively. Similar findings were also reported by Mihiretu and Abebaw, (2020) in tef. These higher results of technological and extension gap indicated that there is still room to improve its productivity and to transform the sector easily by using the existing improved varieties with its associated recommended agronomic managements. The current study's findings suggest that concentrated efforts are needed to educate and motivate farmers to adopt improved production technologies to close the extension gap. In Ethiopia, about 3,023,283.5 million hectares of land were covered by tef and, approximately 6.8 million farmers were engaged in growing the crop in the 2017/18 growing season (CSA, 2018). To determine the nationwide effects, let if the technological and extension gaps were narrowing down by 25% through creating better access to improved technologies and availing proper extension services. The average technological gap

Table 1. Mean grain and biomass yield of the demonstrated tef varieties

	District	Local variety (n=3)		Kora variety (n=3)		
		Mean	Std.	Mean	Std.	t-test
Grain yield (kg ha^{-1})	Efratana gidim	1516.7	505.56	2682.4	238.76	3.611^{**}
	Ensaro	1122.2	205.94	2013.3	317.58	4.078^{**}
Biomass yield (kg ha^{-1})	Efratana gidim	5987.9	408.26	7364.9	1141.39	1.968^{ns}
	Ensaro	5280.0	360.00	8194.2	1279.62	3.797^{**}

**. Mean difference is significant at p<0.05, ns= nonsignificant

Table 2. Effect of improved production technologies on the technological gap, extension gap, and technology index

District	Technological gap (kg ha^{-1})	Extension gap (kg ha^{-1})	Technological index (%)
Ensaro	891.1	786.7	31.8
Efratana gidim	1165.7	117.6	41.6

Note: The potential yield for the improved Kora variety was 2800 kg ha^{-1} (MoA, 2014) calculation revealed that a 25% increase in tef production in the study areas would result in a 257 kg ha^{-1} increase and a 14.3% increase in the current national volume of tef production. This finding appeared to be in line with Benson et al. (2018).

Farmer preference

In recent years, participatory research has become increasingly relevant in public agricultural research. The degree to which a technology dissemination process is participatory and ensures the participation of all stakeholders, especially the poorest members of society, are frequently used to assess its effectiveness (Binswanger-Mkhize et al., 2009). The basic planning tasks, performing on-farm trials, and evaluating the planning and trials are all focused on "learning by doing," with researchers, extension staff, and farmers participating. As a result, the aim of participating farmers and other actors in the research system is to optimize yield while also improving actors' participation in selecting technologies that meet their preferences for long-term technology diffusion. The farmers' tef selection requirements were presented in Table 3. Farmers chose varieties based on tillering ability, plant height, panicle length, lodging resistance, seed color, and straw yield. Seed color was the overarching selection criteria stated by the participant farmers during the interview. For market purposes, white to very white seed color is preferred, while brown seed color is preferred for home use. In tef, lodging is the most important significant production constraint. Tef has tall, slender stems that are easily lodged by the wind or rain. The result showed that in all variety evaluation parameters, except in the tillering capacity that more than half of the participants prefer the local variety; all participant farmers during the field evaluation preferred the improved Kora variety over the local variety. All participant farmers were agreed that the variety Kora had longer panicle length, resistance to lodging, resistance to waterlogging, longer in plant height, higher in grain, and straw yield compared to their local variety and even the previously introduced improved varieties. This result is in agreement with that of actual grain and biomass yield obtained from the field trials. Due to its high yielding ability, extremely white seed color, and better straw yield, the variety attracted a lot of interest from farmers. All of the participant farmers during the field visit agreed that the variety, Kora, outperforms their local seed stock. Most importantly, all the participant farmers finally agreed to continue growing the variety Kora instead of their local cultivar.

Table 3. Farmers variety evaluation parameters

Variety evaluation parameters	Kora variety (%)	Local variety (%)
Longer panicle length	100	0
Resistance to lodging	100	0
Resistance to waterlogging	100	0
Strong stalk and longer in plant height	100	0
Have a higher tillering capacity	41.6	58.4
Have higher straw yield	100	0
Have higher grain yield	100	0
Seed color (whiteness)	100	0
Preferred to grow by next year	100	0

Women participation, access to improved agricultural technologies, and extension services

In many developing countries, including Ethiopia, women, whom make up half of the population and play a critical role in the rural economy, face greater challenges to productive assets than men (Patil and Babu, 2018; Raney et al., 2011). Although many attempts have been made to achieve more sustainable development by mainstreaming gender-related issues in the agriculture sector, male and female farmers in Ethiopia have significantly different production efficiency. In Ethiopia, agricultural productivity gaps between male and female-headed households range from 33 to 67 percent, owing to gender disparity in productive resource endowment and inadequate access to agricultural extension services, as stated in many previous findings (See for example Aguilar et al., 2015; Challa and Mahendran, 2015; Gezimu et al., 2019; Tiruneh et al., 2001). In the study areas including in tef production women are actively involved in most of the farm activities.

Figure 1. Mr. Tesfaye Fitihawok from Efratana gidim district in his Kora variety of farmland

Figure 2. FREG members in Ensaro district during field evaluation during the flowering stage

Figure 3. Mrs. Abosetugn G/Meskel from Ensaro district

Land preparation during planting and weeding of tef was mainly operated by women. Efforts have been made during the trial's implementation period to increase women's involvement in enhanced seed and agricultural extension services. From the total 528 participant farmers in training, farmer research and extension group, field day events, and farmers who were directly addressed through the provision of the improved seed of the variety Kora, 93 of them were women accounted for 17.6%, which we consider it as being very low. The farmer, who was seen in front of the camera in Figure 3, was among the most influential women who were growing the improved variety. She lives in Woko fikreselam kebele of Ensaro district. She explained that her husband was refusing to grow the improved variety because of fear of risks. He was incredulous about the new technology but I strongly argue with him and after all, he agrees with me and decides to participate in the current study, she said. As she reflected during the field visit now her husband thanks her and all the family members were very happy about the decision they made and having participated in the study. As seen in the figure she was very happy with her decision and looks very shiny, makes all the participants funny during the field visit.

Field days and large scale promotion

At the maturity stage of the trial, highly active farmer's field days were held in both locations to bring together farmers and other stakeholders in the agricultural value chain to raise awareness on the best performance of the improved tef technologies. Model farmers, agricultural extension experts, representatives from local NGOs, and higher officials attended the field days, which were organized by the Research Center in collaboration with the respective Agricultural Offices. Field visits, knowledge sharing, and in-depth discussions on the demonstrated technologies were all part of the field day schedule. Over 311 out of which 55 female farmers and experts attended the field day event.

Participants during the field visit gave an eye witness and applauded the improved variety for its good growing performance. It attracted a lot of attention from farmers because of its high yielding ability, relatively white seed color, and better straw yield. Straw yield is no less important than grain yield for the farmers. They also preferred the improved Kora variety as it was resistant to waterlogging, resistant to lodging explained by its strong stalk, its good panicle length, and its longer plant height. Finally, participant farmers during the field event were confirmed that all of them were deciding to grow the variety by next year.

CONCLUSION

The result revealed that the improved variety of Kora with its associated recommended management practices on average yielded a significantly higher grain yield of 2682.4 kg ha^{-1} and resulting in a 79.4% higher grain yield over the farmer's practices. The findings also revealed that the study area had a higher technological index of 41.6 percent, suggesting that there is potential to boost its productivity and to transform the sector by using the improved tef varieties with its associated recommended management practices. Further, participants during the field visit also give an eye witness and applaud the improved variety for its good growing performance. The improved variety attracted a lot of attention from farmers for its high yielding ability, white seed color, better straw yield, and lodging resistance. According to the findings of this study, concentrated efforts are needed to educate and encourage farmers to adopt improved production technologies to narrow down the extension gap using the improved tef technologies.

AUTHOR CONTRIBUTIONS

Yehuala Kassa developed the concept and the final proposal for the research project and established the experiment. Also, Yehuala Kassa was involved in designing the experiment, conducted field experiments, collected the data, performed the statistical analysis, and drafted and finalized the manuscript. Shumet Chakle, Teklemariam Ayele, Beneberu Teferra and Awlachew Ayfokiru read and revised the manuscript. All authors read and approved the final manuscript.

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COMPETING INTERESTS

The authors declare that they have no competing interests.

ETHICS APPROVAL

Not applicable.

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