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On-farm evaluation and pre-scaling up of improved finger millet technologies under rainfed condition in Western Oromia, Ethiopia: A case of East Wollega Zone, Ethiopia

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The average yield of finger millet is low in Ethiopia, specifically in Western Oromia due to different production constraints such as limited availability of improved varieties, lack of formal seed delivery system, and limited adoption of the available technologies. To this, BARC in collaboration with AGP-II conducted the pre-scale up and popularized full packaged improved finger millet varieties in cluster approach at East Wollega zone, Western Oromia, on 22 ha in 2019 rainy season. Three districts (Boneya Boshe, Wayu Tuka, and Gida Ayana) were selected and a total of 6 clusters were established. Pre-scaling up of the crop conducted on 22 ha of land and 78 farmers were included in the cluster. Finger millet seed, Gudatu variety was produced at Wayu Tuka district, Bako-09 was produced at Gida Ayana and Gute variety at Boneya Boshe district. Based on the attained yield, a total of 51.74 tons of improved seeds of finger millet varieties were obtained, of which 22.15 tons were Gute variety, 17.38 tons Gudetu, and the rest 12.21 tons were Bako-09. The average yield obtained from the Gute variety was 2.22 t ha^{-1} followed by Bako-09 variety (2.04 t ha^{-1}) and the least for Gudetu variety (1.74 t ha^{-1}). Overall, the varieties showed better performance than local cultivars produced by the majority of the farmers in terms of yield, disease tolerance and other traits. Therefore, scaling-out of the varieties with full production packages should be carried out in the area and for similar agro-ecological operations.

Key words: District, cluster-based, farmers', finger millet, variety.

INTRODUCTION

In spite of significant achievements in the agricultural sector, the problem of food nutrition and security remains a key challenging development and health issue in Ethiopia. Many reports have shown that the country is also experiencing unfavorable climate change whereby several parts of the country are suffering from drought, erratic rainfall patterns, poor soil fertility and poor farming technologies (FAO, 2018; Dessi, 2018; Mohamed, 2017; Endalew et al., 2015) that is worsening food security situation in the country. Besides, the population of the country is estimated to reach 190.9 million by 2050 (Population Reference Bureau, 2018). Hence, to meet future food demand requires the use of crops tolerant to harsh environment and expansion of intensification of the

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present production that ensures sustainable food availability at the household level.

Finger millet is one of the crops underutilized, but remains the main important plant genetic resource that could play a crucial role in dietary needs and income sources for millions of poor farmers in places like Ethiopia and other less developed countries (Asfaw et al., 2018; Kassahun and Solomon, 2017; Birhanu, 2015). Its adaptability to a wide range of environments with minimal input requirements, short growing season, productivity on marginal land where other crops cannot perform and withstanding significant soil acidity make finger millet important cereal crops for future human use (Soumya et al., 2016; Upadhyaya et al., 2007). Nutritionally, its calcium content is 10 times greater than wheat, maize, or brown rice and 3 times higher than milk (Kumar et al., 2016; Bora, 2013), and also important in the diets of children, pregnant and breast-feeding women (Swati et al., 2017; Kumar et al., 2016; Chandra et al., 2016). Ethiopia is among the major finger millet growing countries in eastern Africa followed by Kenya (Asfaw et al., 2018). The Ethiopian Central Statistical Authority data from 1995-2017/18 showed that the area devoted to finger millet cultivation and its production is generally increasing. For instance, in the 2017/18 rainy season, the total land area of about 10,232,582 ha (80.71%) was under cereals, of which finger millet covered about 456,057.31 ha (4.5 %) and 10,308,23.15 tones grain yields (CSA, 2018). Regionally, Oromia contributes 20.6% of the total cultivable land and 21.3% of total production in the country. Specifically, the east Wollega Zone has a good potential in Bonaeya Boshe, Wayu Tuka, Diga and Gida-Ayana districts. According to the International Livestock Research Institute-System wide Livestock Programme (ILRI-SLP)-Crop Residue project survey conducted in 5 districts of east Wollega zone, finger millet took a rank of 1-3 in terms of area coverage. In the area, it is widely used as bread combined with maize flour, injera mixed with tef and also used as porridge, cake, traditional breakfast called "*chacabsa*", soup for babies as well as for adults and distilled spirit locally known as *Areke*.

Despite these benefits, the recent national average yield is only about 2.2 t ha^{-1}. This yield is even below the regional (Oromia) average grain yield of 2.3 t ha^{-1} (CSA, 2018), regardless of reported yield potential in the range of 4-5.0 t ha^{-1} (Kebede et al., 2019; Mulatu et al., 1995). Even though many biotic and abiotic factors can contribute to this big yield gaps, shortage of improved varieties, disease damage (blast), and lack of formal seed delivery systems are among the foremost factors contributing to the low productivity of this crop (Birhanu, 2015; Tefera and Adane, 2013).

Generation, popularizing, evaluating and dissemination of improved finger millet varieties with its full package management technologies through cluster-based approach are amongst the strategies to uplift productivity of the crop. Besides dissemination of varieties; training and field days in the process are other benefits in raising the capacity and knowledge of the participated farmers and other stakeholders. Besides, advisory services during supervision and follow-up of the disseminated technologies creates awareness for large number of farmers in the area. Moreover, various sources showed that cluster-based scaling up of the improved technologies are very important in creating multiple impacts and address large number of farmers in the area (Asfaw et al., 2018; Tefera and Adane, 2013). To this, Bako Agricultural Research Center has conducted a multi-location variety development and released 11 finger millet varieties so far for western Oromia and similar locations (Variety Registration, 2018). Most of the released varieties are not reachable by the farmers. Nevertheless, growers in Western Oromia produce local variety and traditionally use broadcasting sowing methods using 25-30 kg ha^{-1} seeds and mainly once hand weeding. This is also among the major factors limiting the productivity of this crop in the Western Oromia.

Since inter-row spacing and optimum planting density manipulate the final yield of finger millet, it is important to keep using recommended agronomic practices. Previous researches on finger millet plant population studies indicated that most vigorous finger millet was observed when planted at 20-40 cm spacing and 10-15kg ha seed rate (Getahun et al., 2016; Tekle, 2014; Hailu et al., 2015). In addition field managements like weeding, second urea application, and harvesting are difficult in broadcasting sowing methods of finger millet. Further, when the plant density exceeds an optimum level, competition among plants for light, nutrients, spacing and water become sever, and consequently plant growth slows and the yield decreases (Hay and Wolker, 1989). Thus, once a new crop technology is verified and selected by the end-users, evaluating, scaling-up and popularization of the technologies are the next steps to generate demands and awareness towards the technologies. Therefore, this activity was conducted with the objectives of scaling-up and popularizing the finger millet production technology to create multiple impacts and address a large number of farmers in the area.

MATERIALS AND METHODS

Description of the locations

The activity was conducted during the main rainy season of 2019 in the east Wollega zone in three districts namely Boneya Boshe, Wayu Tuka and Gida Ayana that are selected as representativeness in terms of agricultural production particularly on their finger millet production potential. The areas are located in sub-humid Western Ethiopia and have variable climatic conditions with a rainfall pattern of unimodal and maximum precipitation being received in July to beginning of September. In general, the rainfall is erratic; onset is irregular, its amount and distribution are unpredictable. The

Table 1. Agro-ecologies of the districts.

District	Altitude (m)	Temperature (°c)	Rainfall (mm)	Soil type
Bilo Boshe	1501-2700	25-33	850-1250	Loam, clay loam and sandy loam
Gida Ayena	800-2195	15-27	900-1400	Red loam nitiosols
Wayu Tuka	1450-3300	12-32	1400-2400	Sandy (35%), clay loam (60%) and others (5%)

Table 2. Summary of Number and name of clusters, variety used, area covered & number of farmers participated in the implementation of the program.

District	Total area covered (ha)	№ of cluster	Name of cluster/s	Number of farmers	Varieties used
Boneya Boshe	10.00	2	Ejersa Gute and Jawis	40	Gute
Gida Ayena	6.00	1	Homi	8	Bako-09
Wayu Tuka	10.00	3	GA, GB and GBd	30	Gudetu
Grand total	26.00	6		78	

GA = Gida Abako, GB = Gida Basaka and GBd = Gute Badiya. The name of the kebele was used as the clusters name.

farming system of the area is a mixed crop-livestock agriculture and is one of the most important finger millet growing belts in western Oromia, and cultivation of maize, pepper, soybean, coffee (at Gida Ayena), and livestock farming are the major means of livelihood of the rural community (Dagnachew et al., 2018; Zerihun and Hailu, 2017). The agro-ecologies of the districts are indicated according to Table 1.

Site selection and establishment of cluster

Three districts were selected based on their potential and accessibility for supervision, monitoring and evaluation. At Boneya Boshe district, two kebeles, namely, Ejersa Gute and Jawis were selected whereas, at Wayu Tuka district, three kebeles (Gida Abako, Gida Basaka, and Gute Badiya) were addressed. In Gida Ayena, only one potential Kebele was selected (Table 2). Participant farmers were selected based on willingness, gender composition, and capacity and capability to properly execute the planned activity. One cluster that comprises 3-6 ha was established in each kebele. One cluster has 8-20 farmers depending on the number of clusters per district who contribute at least 0.25 ha of land. A total of six clusters were established.

Finally, pre-scaling up of the crop was conducted on 26 ha of land, 10 ha at Boneya Boshe, 6 ha at Gida Ayena, and 10 ha at Wayu Tuka, where a total of 78 farmers (57 male and 21 female) were included in the cluster (Table 2).

Input preparation and field management

Three improved finger millet varieties viz. Gudatu, Bako-09 and Gute were planted on selected farmers' fields based on the adaptation agro-ecology of each variety. Accordingly, at Biloboshe district, Gute, Wayu Tuka Gudetu, and Gida Ayana Bako-09 varieties were planted (Table 2). The varieties were evaluated and released by BARC and recommended for western Oromia agro-ecological zones. To this, Gute, Gudetu and Bako-09 variety was released in 2009, 2014 and 2017 respectively. The finger millet variety (Gute) can be grown in a range of 1200-1900 m above sea level and requires an annual rainfall of 1000-1900 mm with uniform distribution in its growing periods. It needs 140-153 days to maturity and is characterized by erect growth habit. Its yield potential varies between 20 to 35 t ha^{-1} at the research field and 20-32 t ha^{-1} at the farmers' field. Bako-09 finger millet is the second variety used in the implementation of the program, having a brown seed color and characterized by erect growth habit, and medium in height (about 89 cm). This variety can be grown in a range of 1400-2300 m above sea level and requires an annual rainfall of 1200-1300 mm with uniform distribution in its growing periods. It needs 146 days to maturity; its yield potential varies between 2.34 to 2.98 t ha^{-1} at research field, and 2.3 and 2.57 t ha^{-1} at farmers field (Kebede et al., 2020). The third variety, Gudetu can be grown in a range of 1400-1900 m above sea level and it requires an annual rainfall of 1200-1300 mm. It requires 145-150 days to maturity, having a light brown seed color. It has yield potential ranges from 2.1-2.3 t ha^{-1} at research field and 2.0-2.1 t ha^{-1} at farmers' field (Kebede et al., 2016). These cultivars perform better if planted during late of May to mid-June.

The varieties were planted with inter-row spacing of 40 cm at 15 kg ha^{-1} seeding rates across the districts. The recommended blended NPS fertilizer for the East Wollega zone was applied at 100 kg ha^{-1}, while 90 kg urea fertilizer rate (Fufa et al., 2017) was used similarly for all clusters which were applied half at the time of planting and the rest half applied at tillering growth stage. However, all recommended NPS was applied at planting. To control weed, 2, 4-D, herbicide was used. All selected farmers have applied these recommended packages for finger millet production. Fields were managed by participant farmers with close supervision of researchers and Development Agents (Das). All other agronomic practices were carried out in a similar fashion on all fields as per the recommendation for the finger millet in the area.

Roles and responsibilities of stakeholders during Implementation

Agricultural Growth Program (AGP-II) is one of the leading stakeholders and has a lion share in providing resource like financing to the program for training, fertilizers, herbicide and insecticides to control termite's infestation. The second stakeholder, Bako Agricultural Research Center (BARC) is the nuclear and mandate center in supplying improved finger millet seeds' for

Table 3. Training participants on finger millet production packages at Boneya Boshe, Gida Ayena, and Wayu Tuka in the 2019 rainy season.

District	Farmers		Development agents		Other agricultural experts		Total
	Male	Female	Male	Female	Male	Female	
Boneya Boshe	30	10	2	2	5	-	49
Gida Ayena	6	2	2	-	5	-	15
Wayu Tuka	21	9	3	3	4	1	41
Total	57	21	7	5	14	1	105

Table 4. Summary of clusters covered & yield performance of finger millet varieties in the area.

District	No. of cluster	№ of farmers	Varieties used	Area covered (ha)	Harvested GY (t)	Average GY (t ha^{-1})
Boneya Boshe	2	40	Gute	10.00	22.15	2.22
Gida Ayena	1	8	Bako-09	6.00	12.21	2.04
Wayu Tuka	3	30	Gudetu	10.00	17.38	1.74
Grand total	6	78		26.00	51.74	2.00

participated farmers. Additionally, researchers of the center had provided training for the stakeholders. Moreover, BARC has an immense contribution in periodic monitoring and evaluation of farmer's field and played a great role in close supervision, and organizing farmers' field day. Farmers are another stakeholder in allocating land and performing required agronomic practices. Besides, farmers implemented advice obtained from researchers and DAs synchronized with their own indigenous knowledge and also played a key role in farmers' field days. The district of Agricultural and Natural Resource experts are also involved in selecting participant farmers and fields. The experts of the district agricultural office and other concerned bodies (like the district head) participated during periodic monitoring and evaluation together with BARC, and leading role in supervising DA's, as well as the field activities. Further, they smoothen the process of the input distribution and follow up day-to-day activities.

RESULTS AND DISCUSSION

Stakeholders' capacity building

Before planting, both theoretical and practical training with clear objectives were given to participant farmers, development agents, and extension, cooperative and union experts before the commencement of actual work (Table 3). The training was mainly focused on cluster-based finger millet production system, constraints and opportunities in finger millet production in the area, agronomic practices (land preparation, method of sowing and seeding rates, type of fertilizer used, its rates, and time of application, variety to be used, and weeding and insect pest control), pre-harvest and post-harvest managements, marketing, and value chain approaches. The training helped farmers in improving their knowledge, skills, and attitudes towards the importance of this crop in the livelihoods of the rural community.

Field days

A field day was organized and a total of 90 farmers, 15 development agents, 20 experts from the district, and 25 researchers participated on organized field days by Bako Agricultural Research Center with the collaboration of AGP-II. The field day program was covered and transmitted by Oromia Broadcasting Network Television (OBN) as well as Ethiopian Broadcasting Television (ETV) and radio to disseminate the technologies for the wider community. Lastly, a discussion was performed to grasp farmers' and other participants' reaction on the strength and limitation of the planted finger millet varieties and agronomic packages used during the processes in the production. During discussion, the farmers indicated that timely distribution of seeds with enough amounts is important in disseminating the technologies/varieties. They also raised the issue of varieties with seed color (white, brown and black type finger millet). Those distributed and planted varieties were all brown seed type. So, the farmers requested to supply with white and black type seed of finger millets. The white type is mainly used to make *injer* and porridge. The researchers from BARC took the assignments to address the issue of white and black seed color to be scaling-up in the future.

Yield performance of the improved finger millet varieties across districts

As depicted in Table 4, a total of six clusters and 78 farmers from three districts were covered and produced improved seeds on 26 ha. As a result, a total of 51.74 tons of improved seeds of finger millet varieties were obtained, of which 22.15 tons were Gute variety, 17.38

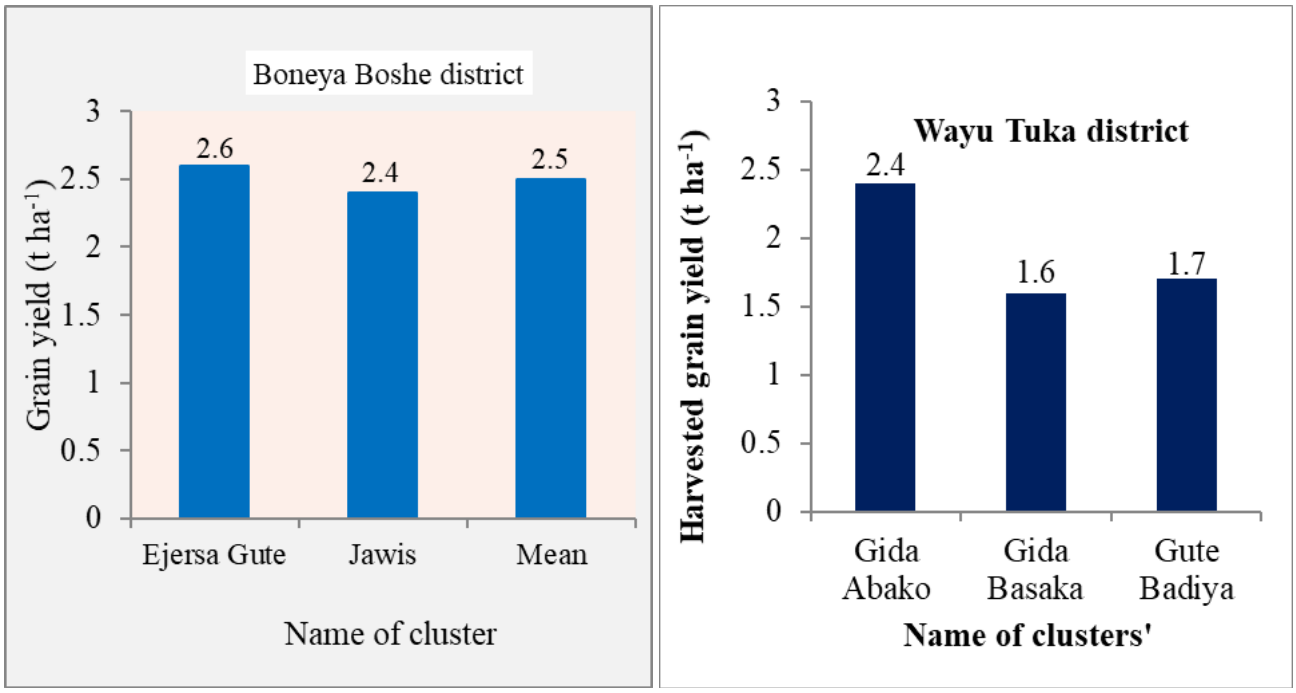

Figure 1. Mean yield of finger millet variety per cluster at Boneya Boshe (a) and Wayu Tuka (b) districts.

tons Gudetu, and the rest 12.21 tons were Bako-09. The overall average yield of varieties revealed that the higher yield of 2.22 t ha^{-1} followed by 2.04 t ha^{-1} was attained from Gute and Bako-09 varieties, correspondingly. On the contrary, minimum average yield (1.74 t ha^{-1}) was recorded from Gudetu variety at Wayu Tuka district. However, the obtained yield is still below the potential productivity of the varieties. For instance, the potential yield of Bako-09 variety can produce 2.98 t ha^{-1} at the research field and 2.4-2.6 t ha^{-1} on farmers' field. But Gudetu variety can give 2.3 and 2.1 t ha^{-1} at research and on-farm field, correspondingly. On the other hand, Gute variety can produce 3.5 t ha^{-1} at research and 2.0-2.1 t ha^{-1} on farmers' field. Overall, the varieties showed better performance than local cultivars produced by the majority of the farmers in terms of yield and other parameters, and hence, selected by the farmers for further dissemination and multiplication in the area. Similarly, Asfaw et al. (2018) reported that improved finger millet varieties showed better performance and gave higher yields than local varieties produced by majority of the farmers. Another author, Geleta (2019) showed that the adapted released finger millet varieties are the best varieties for yielding ability and tolerant to diseases.

Mean yield performance of improved finger millet varieties on farmers' field

The yield of improved finger millet varieties despite varietal differences was also varied among clusters to the same districts. For instance, in the Boneya Boshe district, the average yield of Gute variety at the Ejersa Gute cluster was 2.6 t ha^{-1} (Figure 1 (a)). In Jawis clusters, however, the yield accounted for 2.4 t ha^{-1} from the same variety. Similarly, a high variable amount of yield was observed among farmers in the same cluster that planted one variety of finger millet. To this, the attained yield from Gute variety per farmer ranges between 1.4 to 2.8 t ha^{-1} at Jawis cluster (Figure 2) while at Ejersa Gute Cluster, the yield harvested from the same variety ranges from 1.6 to 2.6 t ha^{-1}.

In the same fashion at Wayu Tuka district, high yield differences were observed among clusters' that produced a similar variety of finger millet (Figure 1b). In the district, a total of three clusters namely Gida Abako, Gute Badiya, and Gida Basaka were established and Gudetu finger millet variety was planted on a total of 10 ha. Each cluster consists of 10 farmers and a total of 30 farmers were addressed.

The highest yield of 2.4 t ha^{-1} was achieved at Gida Abako cluster. Conversely, minimum yield (1.6 t ha^{-1}) was recorded at Gida Basak clusters. Likewise, high yield variation was observed between farmers field that produced similar variety in the same cluster. According to harvested yield per farmer, the yield obtained ranges between 1.1 to 3.2 t ha^{-1} (Figure 3). On the other hand, at Gida Ayena district, only one cluster (Homi) was established and Bako-09 variety was produced on a total of 6 ha that comprise eight farmers. From this variety, average yield of 2.04 t ha^{-1} was recorded. However, the yield attained form this variety on farmers' fields showed

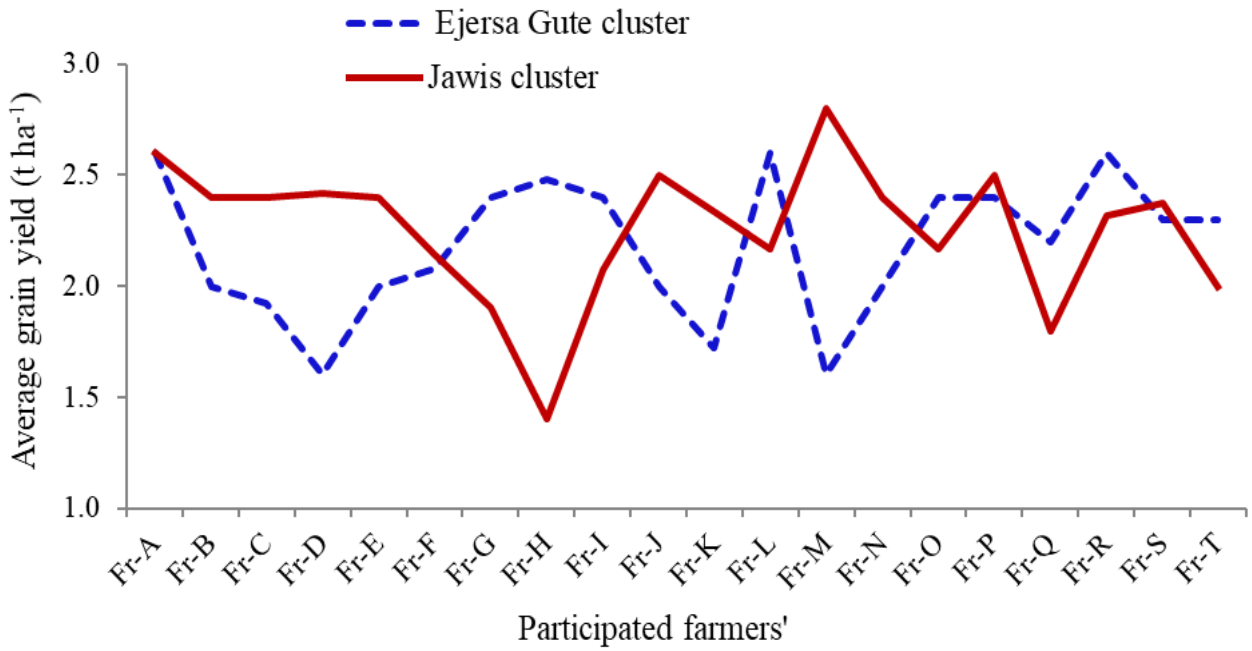

Figure 2. Yield of finger millet variety on farmers' field at Boneya Boshe districts.

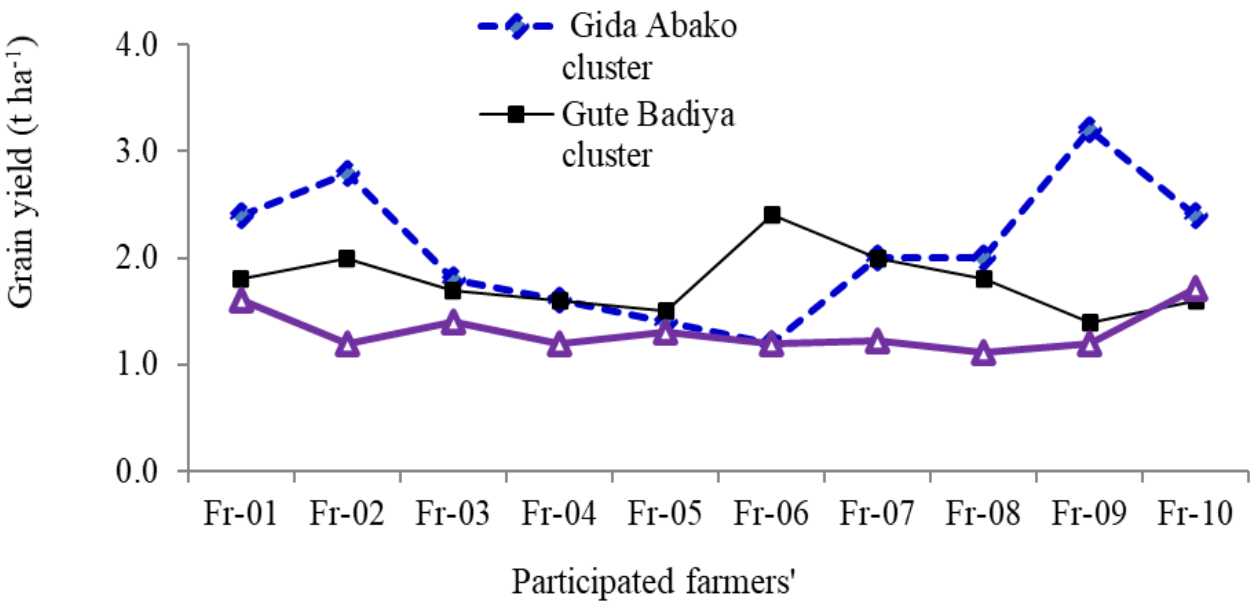

Figure 3. Yield of finger millet variety on farmers' field at Wayu Tuka district (Fr-01 to Fr-10 indicates the name of farmers).

variation and ranges from 1.7 to 2.6 t ha^{-1} (Figure 4).

This yield difference among farmers in the same cluster that planted similar variety might be due to variabilities among farmers field in soil fertility status and the different levels of farmland utilization intensity and the ability of some farmers to apply inputs (farmyard manure, crop residues, organic or inorganic fertilizers) to some fields over time (Tittonell et al., 2012; Penny, 1996). Similarly, research reports indicated that the heterogeneity of farmers' field contributed to a great extent in yield variations of crops with similar varieties and nutrient application in the soil during planting (Hailu et al., 2018; Tolera et al., 2015; Vanlauwe et al., 2014; Schmidt et al., 2002). This indicates the call for site-based crop

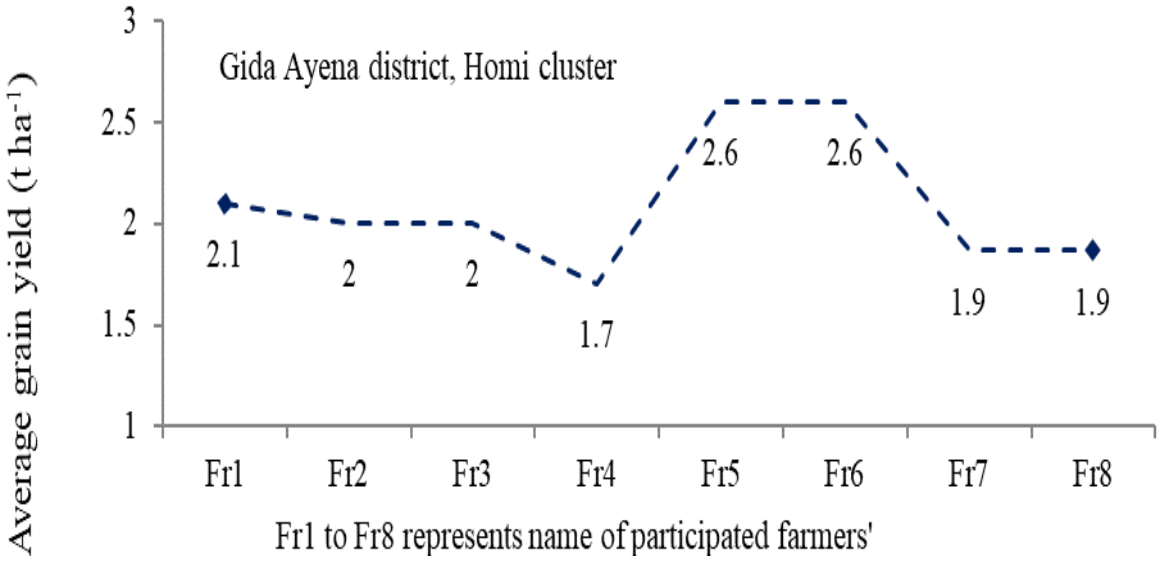

Figure 4. Yield of finger millet variety on farmers' field at Gida Ayena district.

management (variety development, fertilizer application rate, and type, herbicide, etc.) for finger millet production in the future.

Conclusion

Despite the huge yield potential and area under finger millet production in eastern Wollega zone, western Oromia, its current productivity is far below the yield of research fields and its yield potential. Limited availability of improved seed, lack of improved crop recommendation technologies, and formal seed delivery systems are the foremost constraints that contribute to low productivity of this crop in the area. On the other hand, the amount and distribution of appropriate improved finger millet varieties, chemicals, its utilization, and threshing problem across the zones highly influenced the productivity and importance of this crop at farmers' level (not considerably attended to as other crops). To this, BARC in collaboration with AGP-II conducted the pre-scale up and popularized full packaged improved finger millet varieties in cluster approach at east Wollega zone, western Oromia, on 22 ha in 2019 rainy season. Based on attained yield, Gute variety gave the maximum yield of 2.22 t ha^{-1} at Bilo Boshe district followed by Bako-09 variety (2.04 t ha^{-1}) at Gida Ayena whereas, Gudetu variety gave the least yield (1.74 t ha^{-1}) at Wayu Tuka district. Thus, scaling-up of the varieties with full production packages should be carried out by zonal/district extension agents for similar agro-ecological areas through establishing and strengthening seed producer Cooperatives. There is also an enormous potential (favorable weather, potential areas, varieties, etc.) for the western Oromia to produce surplus finger millet grain for food self-sufficiency by strengthening the farmers capacity through technology dissemination preferable by cluster approach.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Asfaw Z, Fekede G, Mideksa B (2018). Pre-scaling up of improved finger millet technologies: The case of Daro Lebu and Habro districts of west Hararghe, Oromia, Ethiopia. International Journal of Agricultural Education and Extension 4(2):131-139.

Birhanu A (2015). Trends, Growth and Instability of finger millet production in Ethiopia. Journal of Agriculture and Environmental Science 4(2):78-81.

Bora P (2013). Nutritional Properties of different millet types and their selected products. A thesis presented to the University of Guelph in partial fulfillment of requirements for a master degree in food science. International Journal of Agricultural Education and Extension 4(2):131-139.

Central Statistical Agency (CSA) (2018). Agricultural Sample survey Volume I: Report on area and production of major crops (private peasant holdings, Meher season). Statistical Bulletin 586. April 2018, Addis Ababa, Ethiopia.

Chandra D, Chandra S, Pallavi, Sharma AK (2016). Review of Finger millet [*Eleusine coracana* (L.) Gaertn]: A power house of health benefiting nutrients. Journal of Food Science and Human wellness 5(3):149-155.

Dagnachew L, Tesfaye A, Tilahun G, Dereje W, Tafa J, Tesfaye L, Teha M, Kamil A, Tilahun G, Shure S (eds.) (2018). Participatory identification of agricultural production constraints: The case of Oromia, Harari and Dire Dawa city Administration. Work shop proceedings, 23-24 November 2017, Addis Ababa, Ethiopia.

Dessi A (2018). Cereal crops research achievements and challenges in Ethiopia. International Journal of Research studies of Agricultural Science 4(6):23-29.

Endalew B, Mequanent M, Samuel T (2015). Assessment of Food

Security situation in Ethiopia. Asian Journal of Agricultural Research 9(2):55-68.
Food and Agriculture Organization (FAO) (2018). The state of food security and nutrition in the world 2018: building climate resilience for food security and nutrition. Food & Agriculture Organization.
Fufa A, Dagnachew L, Megersa K, Zerihun A, Megersa D, Gudeta B, Kebede D, Girma Ch, Hailu F (2017). Yield improvement of finger millet due to blended fertilizers at Bako and Gute, East Wollega Zone, Ethiopia: In Proceedings of Oromia Agricultural Research Institute Workshop on Review of the completed Research Activities of crop research Directorate held at Batu Fish and Aquatic Life Research center, 4-8 Semptember 2017. pp. 176-181.
Getahun D, Tigist A, Bekele A (2016). Influence of row spacing and seed rate on yield and yield components of finger millet at Assosa Zone in Benshangul Gumuze Region of Ethiopia. Journal of Biology, Agriculture and Healthcare 6(5):42-45.
Geleta N (2019). Adaptation study of released Finger millet Varieties in Western Oromia, Ethiopia. Journal of Biology, Agriculture and Healthcare 9(11):63-68.
Hailu F, Fufa A, Megersa D, Gudeta B (2018). Effects of NPS Fertilizer Rates on Yield and Yield Traits of Maize Varieties at Bako, Western Ethiopia. In: Oromia Agricultural research institute workshop proceeding on Adaptation and Generation of agricultural technologies, 25-27 June 2018, Adama, Ethiopia pp. 213-222.
Hailu F, Dagnachew L, Girma M, Kebede D, Kasa M, Geleta G, Chemeda B, Megersa K (2015). Effects of seeding rate on the grain yield and yield components of finger millet in East Wollega Zone, Ethiopia: In Proceedings of Oromia Agricultural Research Institute Workshop on Review of the completed Research Activities of crop research Directorate held at Ademi Tulu Agricultural research center, 17-21 November 2015. pp. 62-66.
Hay RKM, Wolker AJ (1989). An Introduction to the Physiology of Crop Yield. Cambridge Journal 26(3):292.
Kassahun T, Solomon M (2017). Phenotypic characterization of Ethiopian finger millet accessions for their agronomically important traits. ACTA Universitatis Sapientiae, Journal of Agriculture and Enviromental Science 9(1):107-118.
Kebede D, Dagnachew L, Megersa D, Chemada B, Girma M, Geleta G, Gudeta B (2019). Genotype by environment interaction and grain yield stability of Ethiopian black seeded finger millet genotypes. Journal of African Crop Science 27(2):281-294.
Kebede D, Dagnachew L, Girma M, Kasa M, Geleta G, Chemada B, Hailu F, Girma Ch, Gudeta B (2016). Registration of “Gudetu Finger millet (*Eleusine coracana* sub spp. Coracana) variety. East African Journal of Science 10(1):71-72.
Kebede D, Dagnachew L, Kasa M, Girma M, Girma Ch, Megersa D, Megersa K, Chemada B, Hailu F, Geleta G, Fufa A, Gudeta B (2020). The Release and Registration of Bako-09 Finger millet variety. Ethiopian Journal of Crop Science 8(2):101-105.
Kumar A, Metwal M, Kaur S, Gupta AK, Puranik S, Singh S, Gupta S, Babu BK, Sood S, Yadav R (2016). Nutraceutical value of finger millet and their improvement using Omics approaches. Journal of Frontiers in Plant Science 7:934.
Mohamed AA (2017). Food security situation in Ethiopia: A review study. International Journal of Health Economics and Policy 2(3):86-96.
Mulatu T, Debclo A, Gutema Z, Degu E (1995). Finger millet [*Eleusine coracana* (L.) Gaertn]: A potential crop in Ethiopia Pp.124-132. In Proceeding of Workshop Organized to Re-establish Sorghum and Millet in Eastern and Centeral Africa. 6-9 November 1995, Kampala, Uganda.
Penny DC (1996). Yield and nutrient mapping for site specific fertilizer management. Communications in Soil Science and Plant Analysis 27(5/8):1265-1279.
Population Reference Bureau (2018). World population data sheet of 2018. Available at https://www.prb.org/wpcontent/.
Schmidt JP, DeJoia AJ, Ferguson RB, Taylor RK, Young RK, Havlin JL (2002). Corn yield response to nitrogen at multiple in-field locations. Agronomy Journal 94(4):798-806.
Soumya R, Karunkar S, Vivek K (2016). Millet grain processing, utilization and its role in health promotion: A review. International Journal of Nutrition and Food Science 5(5):318-329.
Tefera M, Adane M (2013). A survey on the status and constraints of finger millet production in Metekel zone, North Western Ethiopia. Direct Research Journal of Agriculture and Food Science 1(5):67-72.
Tekle Y (2014). Determination of inter row spacing and seed rate on productivity of finger millet [*Eleusine Coracana* (L.) Gaertn], at Jinka, Southren Ethiopia. International Journal of Research in Agricultural Sciences 1(3):172-176.
Tittonell P, Muriuki A, Klapwijk CJ, Shepherd KD, Coe R, Vanlauwe B (2012). Soil Heterogeneity and Soil Fertility Gradients in Smallholder Farmers of the East African Highlands. Soil Science Society of American Journal 77(2):525-538.
Tolera A, Ernest S, Tolessa D, Dagne W, Hae Koo K (2015). Sensor-Based In-Season Prediction for Quality Protein Maize Varieties on farmers field around Bako-Tibe, Western Ethiopia. American-Eurasian Journal of Agriculture and Environmental Science 15(8):1557.
Upadhyaya HD, Gowda CL, Gopal R (2007). Morphological diversity in finger millet germplasm introduced from Southern and eastern Africa. Journal of SAT Agricultural Research 3(1):1-3.
Vanlauwe B, Coyne D, Gockowski J, Hauser S, Huising J, Masso C, Nziguheba G, Schut M, Van Asten P (2014). Sustainable intensification and the African smallholder farmer, Current Opinion in Environmental Sustainability 8:15-22.
Variety Registration (2018). Crop variety registers for plant variety release. Protection and Quality control Directorate of Ethiopia, № 21, Addis Ababa.
Zerihun A, Hailu F (2017). Effects of Nitrogen rates and time of application on the yield of maize: Rainfall variability influenced time of N application. International Journal of Agronomy pp. 1-10.