Participatory evaluation of sorghum technologies in the marginal dryland zones of Wag-lasta, Ethiopia

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Abstract: Despite dryland areas are diverse in agro-ecology; technological recommendations are summative and based on researchers’ on-station genetic traits, which deprived the farmers’ preference, the economic and technical efficiencies. Participatory sorghum technologies evaluation was thus initiated to compare dryland sorghum technologies (Misikir and Girana-1) against the local practice in a wider scale, comprising 450 farmers from marginal districts of Wag-lasta. The agronomic, economic and preference data were collected and analysed in descriptive statistic, ANOVA, partial budgeting and weighted ranking matrix. The combined result indicated that Misikir, Girana-1 and the local sorghum provided mean grain yields of 2.9, 1.6 and 1.5 ton ha⁻¹, respectively. Accordingly, Misikir technology has 81.3% and 93.3% yield advantage over Girana-1 and the local, respectively. The marginal rate of return (MRR) of Misikir is 477.6% but insignificant for Girana-1 by the cost higher than the local practice. The weighted ranking matrix also shows that Misikir was preferred by its earliness, seed setting performance, grain and biomass yields. Dissemination of Misikir technology is thus safely recommended. The finding further revealed that technological recommendations using on-station plot trials is dwarfing the adoption rates since farmers would hesitate to uptake as if they did not evaluate the technologies on their local context. The paper concludes that scale wide farmers’ participation is vital in
future experiments for sustainable and demand-driven technology development and diffusion on top of providing feedback to the concerned agricultural scientists.

Subjects: Botany; Plant & Animal Ecology; Soil Sciences; Nutrition

Keywords: Drylands; economic efficiency; participatory evaluation; scale wide; technology

1. Introduction
Sorghum (Sorghum bicolor) grows over a wide range of latitudes from 0° to 45° North and South of the equator (International Crop Research Institute for the Semi-arid Tropics [ICRISAT], 1991). Because of its drought resistance, sorghum is the crop of far excellence for dry regions and areas with unreliable rainfall. It is one of the important indigenous food crops and is only second to tef among cereals in the dryland areas of Ethiopia (Geremew et al., 2004). As sorghum is growing under a wide range of environmental conditions, the range of both biotic and abiotic production constraints are diverse, resulting in very poor performance under farmers’ circumstances (Asmiro, Ademe, Lijalem, & Tsega, 2016). The average national yield of 2.4 ton ha\(^{-1}\) is by far very low compared to 3–6 ton ha\(^{-1}\) achieved using improved sorghum technologies (Central Statistical Agency [CSA], 2015). In northeast Ethiopian dryland zones, where sorghum is the major food crop, its average productivity ranges from 1.5 ton ha\(^{-1}\) up to zero in severe moisture deficit seasons, which is by far lower than the national average (Central Statistical Agency [CSA, 2017]). Because of the low amount, uneven distribution and erratic nature of the rainfall on top of fewer improved technologies fitting to diverse growing conditions and lower utilization rates, crop production is seriously affected in these areas (Ademe, Asmiro, Lijalem, & Tsega, 2018).

The major constraints of farmers in using improved technologies are weak linkages between farmers and research as well as limited use of extension and research results. One can still witness the persistence of subsistence agriculture with an ever more dynamic and competitive environment. This entails the risk of the existence of wider gaps between the performance of research and farm averages (Amede, Assefa, & Stroud, 2004). With the aim of addressing these problems, several dryland sorghum technologies were developed and released nationally having special merits. Sekota Dry Land Agricultural Research Centre has been undertaking adaptation trials on these technologies in Wag-lasta marginal areas and released two improved varieties (Misikir and Girana-1) with their production package for wider production domain (Asmiro et al., 2016). However, the trial was on-station at plot level and the evaluation was designed and managed by researchers merely. The recommendation was provided purely on the bases of biological standpoints, devoid of farmers’ involvement, economic efficiency, societal acceptability, and technological applicability. These factors are of course, the building blocks for wider technology diffusion in general and demand-driven knowledge tracking in particular.

Over 70% of new technologies developed for marginal dryland areas have failed to take root among farmers and remain confined to research stations. Further intensification of extension services has not also shown great promise in improving the situation (Sanghi, 1987). An increasing number of scientists, therefore, have recognized that there is a need to modify research methodologies in order to make it more sensitive to local conditions (Ashby, 1986). In recent years, agricultural researchers started working with low-income farmers in hard environmental conditions. These environments tend to be highly fragile, characterized by combinations of low and unreliable rainfall, poor and easily degradable soils, hilly topographies, lack of economic and social infrastructures (Kojo, 1956). As a result, technologies generated on research stations have not performed well under farm conditions and have not been widely adopted (Matlon, 1984).

According to Ogwal-Kasimiro, Wakulira, Kiyini, Mwebaze, and Yiga (2012), to circumvent these problems and to achieve better results, responsive adaptive research trials should be established with actively participating farmers in the technology development process.

Moisture stressed areas in Ethiopia are grouped into seven agro-ecologies and covers 66% of the total area of the country entails diverse potential to different sorghum technologies (Geremew et al.,
2. Materials and methods

2.1. Description of the study area

The study was conducted at three districts (viz., Ziquala, Abergele and Lalibela) in Northeastern marginal drylands of Ethiopia for three consecutive production years (2015/16–2018/19). More specifically, Ziquala district is geographically located at 12°48’N and 38°47’E latitude and longitude, respectively (Asmiro et al., 2016). The district has an altitude of 1462 masl. Its annual average rainfall and temperature are 255 mm and 22°C, respectively (Dereje, 2004). Abergele district is also located at 13°20’N and 38°58’E latitude and longitude, respectively. Its altitude ranges from 1150 to 2500 masl, with the annual mean temperature and rainfall of 23-43°C and 250–750 mm, displaying semi-arid nature of the district (Ademe et al., 2018). Lalibela district is located at 12°55’559”N latitude and 38°42’293”E longitude at an altitude of 2400 masl having mean annual temperature and rainfall of 26.2°C and 895.2 mm, respectively (Woreda Office of Agricultural Development [WoA, 2015]).

The districts’ rainfall is unimodal, short and erratic that extends not more than 2 months per year, usually from the end of June to the end of August. Hence, the districts’ crop production usually fails due to low soil fertility and high moisture stress, almost every year (Ademe et al., 2018).

2.2. Sampling, experimental design and farmers’ participation

Two-stage sampling technique was employed to select the participant farmers. In the first stage, three districts were purposively picked to denote sorghum production areas in marginal drylands of northeastern Ethiopia. In the second stage, 50 farmers who had 0.25 ha clustered farmland on average were randomly selected from each district to host the experiment. In combination, 450 (75 female) farmers in the 3 years were involved for the scale wide participatory on-farm evaluation. Host farmers in each district were organized into farmers’ research and extension groups (FREGs) in order to ease the participatory evaluation. The group members were selected with the consultation of local agricultural experts and key informants, conversant to the areas to represent different social segments (to have diverse spectrum of age, sex and wealth status). Each group had a chairman and secretary to facilitate FREG tasks in collaboration with researchers and extension workers. A timely action plan and meeting schedule were set out by the group members to evaluate the technologies following the main
physiological growth stages. Before launching the experiment, researchers organized operational platform to create awareness and to identify responsible stakeholders in the experiment. Then, memorandum of understanding (MoU) was signed between stakeholders to part duties in the whole trial course. Farmers thus provided training on basic agronomic practices and technology packages for 2 days comprising the theoretical and practical components. Training provision, technical backstopping and data collection were managed by the researchers while farmers undertook the experiment (Table 1).

The experiment was conducted using two improved sorghum technologies¹ (Girana-1 and Misikir) and adjacent to them local cultivar under traditional production practice for comparison. The treatments were laid on three un-replicated simple block considering farmers as replications. The improved technologies were planted in a row at 10 kg ha⁻¹ seed rate along with 100 and 50 kg ha⁻¹ diammonium phosphate (DAP) and Urea, respectively. All the required management practices were done as per the recommendation. The study was carried out for three consecutive years in order to minimize the risk of seasonal variation as well as to increase farmers’ confidence in the provided technologies. Finally, field days were held involving concerned stakeholders to evaluate and endorse the performances of different technologies to the wider community.

2.3. Data collection and analysis

Both quantitative and qualitative data were collected from farmers using a checklist as well as focus group discussions. The quantitative data (days to maturity, grain and biomass yield) were collected at the plot level. The qualitative data (socioeconomic parameters: profitability and acceptability) were also collected. On the other hand, secondary data were collected from different published and unpublished (working reports from districts) sources to triangulate and support the quantitative results. The collected data were analysed using descriptive statistics such as mean, frequency and percentage points. Besides, different methods as suggested by Yadav, Kamboj, and Garg (2004) were used to analyse the technological gaps, extension gaps and the technological index among treatments using the following formulas:

\[
\text{Technology gap} = \frac{\text{Improved yield} - \text{Farmers yield}}{\text{Farmers yield}} \times 100
\]

\[
\text{Extension gap} = \frac{\text{Potential yield} - \text{Improved yield}}{\text{Potential yield}} \times 100
\]

\[
\text{Technology index} = \frac{\text{Technology gap}}{\text{Potential yield}} \times 100
\]

Data from the treatments (Misikir, Girana-1 and Local) were subjected twice to the analysis of variance (ANOVA) followed by Tukey’s honestly significant difference (HSD) test (SPSS, 2007). The

| Table 1. Duties and responsibilities of main stakeholders in the scale wide evaluation of sorghum technologies |
|------------------------------------------------------------|
| **Researcher** | • Preparing manuals and provide training for farmers and DAs  
                 • Confirm clustered farms and provide the seed on time  
                 • Provide technical back up for farmers and experts  
                 • Organizing field days with district Agriculture Offices |
| **Agricultural experts** | • Participate in workshops and trainings  
                           • Provide technical support in site and farmer selection  
                           • Monitor the activities and participate in field days |
| **SMSs** | • Selecting participant farmers and measure their farm using GPS  
           • Provide technical support in technology application  
           • Provide information to researchers on disease outbreaks |
| **DAs** | • Selecting participant farmers and measure their farm using GPS  
           • Provide technical support in technology application  
           • Provide information to researchers on disease outbreaks |
| **Farmers** | • Prepare fertilizers and farmland to the required optimum level  
              • Planting on time, managing weed and harvest on time  
              • Keeping seed quality to give back to the source center  
              • Exchange the seed to interested farmers in any arrangement |
ANOVA table is constructed to illustrate the effects of treatments and other factors like experimental errors on the parameter values under consideration. The post hoc analysis (Tukey-HSD) carried out to compare the means of every pair of treatments in the study districts (i.e., identifying which technology has significantly larger mean as compared to other technology). The first of which was depending on agronomic records as explanatory variables and the second was depending on the indicative scores as explanatory variables. The coefficient of determination ($R^2$) and the Tukey’s test (HSD) have been applied to significant variables in both analyses. The data of the indicative scores of sites for the three agronomic records were standardized and the sample variance ($S^2$) was calculated by the following formula:

$$S^2 = \frac{\sum (x_i - \bar{x})^2}{n - 1}$$

where $S^2$ is sample variance, $\Sigma$ is sum, $x_i$ is the term in data set (indicative scores of sampling sites), $\bar{x}$ is sample mean, and $n$ is sample size.

The results of ANOVA ($R^2$, $F$, $P$) and the sample variance ($S^2$) have been taken to express the impact of the agronomic records and their order of importance, on the different treatments of the trial area (Alaa & Mahgoub, 2019).

Economic data (production costs and benefits) were collected to compare the cost-effectiveness of treatments. The costs of the whole package components such as improved seed, fertilizer and management practices were collected for each district in Ethiopian Birr (ETB). Yield obtained from each treatment was adjusted by 10%, and also the selling price of grain and biomass yield at the farm gate was taken. The average labour cost for improved practice (row planting and weeding) was expressed in person day, where one person day was assumed to be 8 hours of work. Finally, the economic advantage (efficiency) of each technology was calculated in the marginal rate of return (MRR) using the following formula:

$$MRR = \frac{\Delta NB}{\Delta TVC} \times 100$$

where MRR = marginal rate of return, $\Delta NB = $ change in net benefits and $\Delta TVC = $ change in total variable input costs (CIMMYT, 1998).

To make the partial budget more useful, administering sensitivity analysis was worthwhile. Therefore, it was managed by computing the worst, most likely, and best-case scenarios of the cost-benefit sides of treatments. The worst, most likely and best case figures can be computed using a general error factor rate of 10%, or by adjusting the item that most likely to fluctuate. This is because farmers deal with market uncertainties, or not knowing weather the prices will increase or decrease by tomorrow. The sensitivity analysis hence will relax farmers’ forced decision-making built on the imperfect market information. Thus, combining partial budget and sensitivity analysis was robust enough to handle the efficiency questions of farmers on the technology package (Ademe et al., 2018).

Group discussion with FREG members, field visit and field days were used to evaluate the technologies. Farmers’ reaction to each technology was asked using focus group discussions (FGDs) by assigning literate farmers in each group to lead the evaluation since most participant farmers were unable to read and write. Host farmers, therefore, brainstormed to identify their main evaluation criteria to be considered in selecting best sorghum technology under the local context. Five preference parameters (viz., grain yield, earliness, seed setting performance, stalk yield and marketability in descending order) were identified and weighted on the bases of their significance. Farmers were ranking the accredited preference criteria pair-wisely and then considered the rank as weight. The scores given by farmers to each variety were multiplied by the respective weight. Products were aggregated for each variety for final selection (1, 2, 3; 1 = the best) (Russell, 1997).
Moreover, Spearman’s rank correlation was used to see the degree of coincidence between farmers’ preference rank with the actual value of measured attributes (Ferdous, Datta, Anal, Anwar, & Khan, 2016). The correlation coefficient is defined as:

\[ r_s = 1 - \frac{6 \sum d^2}{n(n^2 - 1)} \]

where \( d \) = difference in the ranks assigned to the same phenomenon and \( n \) = number of phenomena ranked.

Finally, extension activities like diagnostic field visits and field days were undertaken to create awareness about the technology in general and the variety in particular, which can benefit the farmers in the long run (Feder, 2002).

3. Results and discussion

3.1. Yield and yield component performance

The local sorghum variety under farmers’ customary practice gave a mean grain yield of 1.5 ton ha\(^{-1}\). On the other hand, the improved sorghum technologies, Misikir and Girana-1 provided mean grain yields of 2.9 and 1.6 ton ha\(^{-1}\), respectively (Table 2). The result thus revealed that, Misikir and Girana-1 improved sorghum technologies have an overall yield advantage of 93.3% and 6.6% respectively, over farmers’ variety under the existing practice in all sites. Sorghum productivity problem in dryland area thus could be overwhelmed by adopting efficient package practices on top of using improved varieties. Likewise, the higher technological index in Misikir technology provided evidence that necessitates a wider scope of further improvements in sorghum production (Yadav et al., 2004). The ANOVA result in Table 3, shows that statistically significant difference between treatments in grain yield, stalk yield and days to maturity across locations (\( p < 5\% \)). Moreover, Tukey-HSD test in Table 4, indicates that among treatments, Misikir was best performing technology in grain yield, stalk yield and days to maturity (\( p < 10\% \)).

3.2. Partial budget analysis

Expenditures which were similar to treatments were not taken and analysed (citrus paribus), hence given the prevailing farm gate prices, the benefit-cost ratio was computed for grain and stalk yield on a hectare basis. The total variable cost of farmers’ practice was lower than that of improved technology. The use of improved production package for Misikir technology thus provided a higher net benefit of ETB 20 802.8 ha\(^{-1}\), followed by the farmers’ practice with the net benefit of ETB 12 292.4 ha\(^{-1}\) (Table 5). The marginal rate of return (MRR) of Misikir technology was thus 477.6%. This implies that for every ETB 1.00 invested in improved technology (changing from local practice to Misikir technology), farmers can expect to recover the ETB 1.00 and obtain an additional ETB 4.78.

The economic return of Girana-1 technology is not promising thus it is rejected from further analysis due to lower net benefit than Misikir and local practice at similar and higher total variable cost, respectively. The process of rejecting dominated treatments from the further analysis is called dominance analysis (Ademe et al., 2018).

The sensitivity analysis is a change in the net benefit and the return on marginal capital as revenue and input prices vary by 10% above and/or below their values. Thus, a 10% change in the revenue of Misikir sorghum technology influenced the net benefit by 24.2%. Whereas, a 10% change in the total input price influenced its net benefit by less than 10%. The return of marginal capital always beats 100%, which indicates an investment in Misikir sorghum technology will be gainful. Generally, the sensitivity analysis result showed that if the price of output becomes constant and the price of inputs increase by 1023.8%, the technology has a positive return.
3.3. Farmers\' preference for different sorghum technologies

Due to their homogeneous sociocultural entities, farmers across location identified five preference parameters in common to select their best sorghum technology. The comparison result of the weighted ranking matrix thus revealed that a technology which has lower aggregated product was peaked as a primary choice. As a result, farmers preferred Misikir, local and Girana-1 technology treatments as the best, fair and worst, respectively, in all parameters (Table 6).
Spearman’s rank correlation coefficient was calculated to see the degree of coincidence between farmers’ preference rank and the actual value of measured agronomic attributes. Therefore, the degree of coincidence between farmers’ preference rank and actual values rank for grain yield, biomass yield and earliness attributes were 100%, 100% and 100% respectively (Table 7). At the end of the trial, field days were organized involving model farmers, development agents, farmers from the trial areas, experts and administrative officials. A total of 750 (200 females) participants visited the trial in different sites and applauded Misikir technology for its grain and stalk yield as well as earliness traits than the rest of treatments.

4. Conclusion
The study was basically focused on the participatory evaluation of sorghum technologies on a wider scale to create demand-driven technology diffusion in the north-eastern drylands of Ethiopia. Two improved sorghum technologies (Misikir and Girana-1) along with the local sorghum variety under farmers’ practice were evaluated at 450 farmers’ field. The result thus revealed that the mean grain yield of Misikir sorghum technology significantly out-yielded Girana-1 sorghum technology as well as the local variety under farmers’ practice. The Tukey–HSD test also indicated that among treatments, Misikir was best performing technology in grain yield, biomass yield and days to maturity in all locations. The MRR result similarly indicated that among treatments, investing in Girana-1 improved sorghum technology was not promising due to its lowest net benefit at the higher and even equal variable input costs. The farmers’ preference ranking matrix also shows that Misikir, the local and Girana-1 technologies were preferred as first, second and third choices, respectively, by the overall preference parameters. The agronomic (ANOVA), economic (partial budget) and the weighted ranking matrix result thus indicated that farmers have preferred and perceived the higher yield potential and profitability of Misikir technology. As a result, Misikir improved sorghum technology is recommended for further dissemination in the marginal drylands of Wag-lasta. This finding tells that recommendations based on researchers’ plot level on-station trial, deprived of economic profitability evaluation as well as limited or even zero farmers’ participation leads to meagre technological adaptation and/or complete rejection. Therefore, suppliers (i.e. researchers) should deliver a basket of choice of improved varieties developed through active and scale wide farmers’ involvement for the needy to pick one, two, or

| Table 5. Partial budget and sensitivity analysis of different treatments |
|---------------------------------------------------------------|
| **Cost/Benefit items**                  | **Misikir** | **Girana-1** | **Local** |
| Adjusted mean grain yield (ton ha$^{-1}$) | 2.61        | 1.44         | 1.35      |
| Adjusted stalk yield (ton ha$^{-1}$)      | 2.88        | 2.43         | 2.34      |
| Gross benefits (ETB/ha)                   | 22,834.8    | 13,321.8     | 12,542.4  |
| Costs of seed (ETB/ha)                    | 150         | 150          | 250.0     |
| Cost of fertilizer (ETB/ha)               | 1250        | 1250         | 0.00      |
| Labor cost for the package (ETB/ha)       | 632         | 632          | 0.00      |
| Total costs that vary (ETB/ha)            | 2032        | 2032         | 250.0     |
| Net benefits (ETB/ha)                     | 20,802.8    | 11,289.8     | 12,292.4  |
| MRR                                         | 477.6       | D            |
| Sensitivity analysis (%)                   | 1023.8      |              |

Price of fertilizer (NPS and Urea) in ETB/kg = 12.5
1USD = 27.94 ETB

Cost of improved [local] seed in ETB/kg = 15 (12.5)
ETB = Ethiopian birr

Price of grain yield in ETB/kg = 7.8

Average labour pay in man/day = 72

Price of stalk in ETB/kg = 0.86

D = dominated
all depending on their context (Table 5). Backup studies should take the farmers’ preference parameters and the feedback into account for future variety and/or technology development activities.

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Note
1 Technology in this study stands for full package practice comprising the recommended production components (viz., improved variety, suggested seed and fertilizer rates, inter and intra row spacing, land preparation and weeding at optimum level).

### Table 6. Summary of farmers’ preference ranking among sorghum technologies

| Weighted parameters          | Misikir | Girana-1 | Local |
|------------------------------|---------|----------|-------|
| Seed setting performance     | Score   | Weight   | Score *weight |
| Score                        | 1.00    | 3.00     | 3.00 |
| Weight                       | 3.00    | 3.00     | 3.00 |
| Score *weight                | 3.00    | 9.00     | 6.00 |
| Earliness                    | Score   | Weight   | Score *weight |
| Score                        | 1.00    | 3.00     | 2.00 |
| Weight                       | 2.00    | 2.00     | 2.00 |
| Score *weight                | 2.00    | 6.00     | 4.00 |
| Grain yield                  | Score   | Weight   | Score *weight |
| Score                        | 1.00    | 2.00     | 3.00 |
| Weight                       | 1.00    | 1.00     | 1.00 |
| Score *weight                | 1.00    | 2.00     | 3.00 |
| Stalk yield                  | Score   | Weight   | Score *weight |
| Score                        | 1.00    | 2.00     | 3.00 |
| Weight                       | 4.00    | 4.00     | 4.00 |
| Score *weight                | 4.00    | 8.00     | 12.0  |
| Marketability                | Score   | Weight   | Score *weight |
| Score                        | 2.00    | 3.00     | 1.00 |
| Weight                       | 5.00    | 5.00     | 5.00 |
| Score *weight                | 10.0    | 15.0     | 5.00  |
| $\sum(s \times w)$           | 22.0    | 40.0     | 30.0  |
| Rank                         | 1.00    | 3.00     | 2.00  |

Ranks: 1 = Best; 2 = fair; 3 = worst. The score multiplied by the weight to provide the overall preference of technologies.

### Table 7. Correlation of farmers’ preference rank and the actual measured traits rank

| Grains yield rank | Biomass yield rank | Earliness rank |
|------------------|-------------------|----------------|
| Misikir          | Actual Farmers d² | (1-1)^2        | (1)        |
| Girana-1         | 2                  | (2-2)^2        | (2)        |
| Local            | 3                  | (3-3)^2        | (3)        |
| Actual Farmers   | 1                  | 1              | 1          |
| d²               | (1-1)^2            | (2-2)^2        | (3-3)^2    |
| r_s = 1 (100%)   | r_s = 1 (100%)     | r_s = 1 (100%) |

Where $r_s$ = correlation coefficient $d²$ = difference in the ranks assigned to the same phenomenon and n = number of phenomena ranked.
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