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Bridging Sorghum Yield Gap Through Up-Scaling Improved Technology in Wag-Himira Zone, Ethiopia

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Abstract. Up-scaling of improved sorghum production practices (Sorghum technology, hereafter) was carried out for three years to bridge the yield gaps in dry-land areas. It was explicitly aimed to create wider technology demand among major stakeholders. Their roles and linkages were also acknowledged to make technology diffusion viable. The new technology was promoted for 264 farmers; planting and related agronomic practices were done as per the package. Results revealed that the new technology had a 116.6% yield advantage over the local sorghum production practice. The technological gaps among the new and local practice were 1400 and 988.7 kg ha^{-1} for grain and straw yields, respectively. The technological index (53.8%) also proved that sorghum production would increase through tamping the extension networks, on top of up-to-date technology usage. despite, 83.6% of the farmers were applied the full technology package, 68.3% of them described as it was tough due to its labor-intensive nature. Labor shortage, lack of experience and technological obscurity of studied farmers were defies for complete technology package use. To bridge sorghum yield gaps sustainably, the new technology should further scale-out to other similar areas via founding robust-enough stakeholder linkage, and demand-driven distribution.
Keywords: sorghum technology; stakeholder linkage; technology gap

INTRODUCTION

Sorghum (*sorghum bicolor (L.) Moench*) is a cereal crop adaptable to a wide range of ecological conditions mainly in hot and warm agro ecological zones (FAOSTAT, 2013). Ethiopia is the 2nd largest sorghum producer in Eastern and Southern Africa next to Sudan in terms of area coverage and production volume (Abady et al., 2017). It is one of the major cereal crops grown in the semi-arid areas of Ethiopia mainly for human consumption, and it ranks 3rd in terms of production area and volume (Gebretsadik et al., 2014). The area coverage of sorghum in Wag-himira zone is estimated 38,909.19 ha with a total producer farmers of 80,533 having an average productivity of 1.42 ton ha^{-1} (Mihiretu et al., 2019). It is by far less than the national average of 2.4 ton ha^{-1}, as well as its yield potential reported to be in the range of 2.5-5.0 ton ha^{-1}. Despite its importance, the yield remains low due to erratic and unreliable rainfall, low soil moisture and fertility, poor management and pests in the dry land areas (Solomon et al., 2021). Apart from moisture deficit, lack of improved varieties with associated production package are major limiting factors leading to poor yield performance under the farmers' condition in the study areas (Mihiretu et al., 2019).

Some agronomic studies discovered that the gap between the actual and potential yields of sorghum would be bridged through the use of improved varieties with improved production package practices (Berhane, 2012; Siyum et al., 2023). Sekota Dry-land Agricultural Research Center, thus undertook a participatory evaluation and recommended the improved sorghum variety named *'Misikir'* with its production package practice (sorghum technology, hereafter) for wider cultivation in the study area. The new sorghum technology was preferred for its early maturing and high yielding potential than the existing method of production. This circumstance therefore dictated us to promote and upscale the new sorghum technology in the marginal arid lowlands of Wag-himira zone to bridge perceived yield gaps. The study was explicitly aimed to create a wider demand on the new sorghum technology through identifying major stakeholders, their roles and linkage to enhance technology multiplication and diffusion in the extension system.

In this study, production package practice is defined as 'planting improved

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sorghum variety in row on well prepared land using recommended seeding and fertilizer rates with an optimum weeding frequency (Mihiretu et al., 2019).

METHODS

Study area and sample selection

The study was conducted in arid lowland woredas of Wag-himira zone, viz., Abergelle and Ziquala for three consecutive production years (2015-2017). The woredas were purposively selected to denote sorghum producing areas in the marginal dry-land zone (Mihiretu et al., 2021). A total of 264 interested farmers (156 in Abergelle and 108 in Ziquala) who had 0.25-0.5 ha of average farmland in cluster were selected to host the promotion. Land size allocation per farmer was made by researchers and development agents (DAs) to make equity in technology access.

Field management and implementation

The researchers organized operational platform to create awareness about the technology, then to share duties and responsibilities among stakeholders (Researcher, Extension workers and Farmers). Researchers and DAs together identified the host farmers and measure the clustered farmland using GPS. Prior to the implementation, farmers and extension workers were provided training on the whole operation and agronomic practices. Planting was in row at 10 kg ha^{-1} seed rate along with 100 and 50 kg ha^{-1} of Di Ammonium Phosphate (DAP) and Urea, respectively. The latter was in split to apply at planting and knee height growth stages (Mihiretu et al., 2019). Weeding and other management practices were done as per the recommendation. Experts and researchers continuously follow up the activity and provided technical backstopping starting from land preparation to harvesting (Tesfahun et al., 2013).

Data collection and analysis

The quantitative grain and stalk yield data were collected using quadrant method. The qualitative perception data about the technology in comparison to the local practice were collected using unstructured open-ended opinion checklist. Field days were held involving stakeholders to endorse the technology to the wider community (Solomon et al, 2021). The quantitative data were analyzed in descriptive statistics, but an independent sample t-test was used to show the statistical yield difference among the two sorghum production practices. Different formulas (Eq. 1, Eq. 2 and Eq. 3) were also used to analyze the technological and extension gaps as well as the technology index between the two sorghum production methods (Yadav *et al.* 2004). In addition, a 5-point Likert rating scale and Tim Willet's perception theory was applied to generalize the farmers' opinion using sum and average scores. The Cronbach's alpha test was checked for internal consistency among the Likert-type items (Mihiretu et al., 2021). Duties and responsibilities of stakeholders was narrated based on the context, while the linkage between farmers-extension-research was described via strengths, weaknesses, opportunities and threats (SWOT) analysis.

$$TG = ITY - FPY \quad \ldots (1)$$
$$EG = PY - ITY \quad \ldots (2)$$
$$TI\ (\%) = (TG/PY) \times 100 \quad \ldots (3)$$

Where, TG: technology gap, ITY: improved technology yield, FPY: farmers practice yield, EG: extension gap, PY: potential yield, TI: technology index

RESULTS AND DISCUSSION

Description of participant farmers

The average age of participant farmers in the pre-scaling up were 42.5 and 38.8 for men and women, respectively with a mean farming experience years of 22.3 and 15.6. Most farmers were thus relatively in active age group and able to realize changes in production across time, which helps to consider the importance of technology and extension advice (Dayakar et al., 2014). About 71.2% were male-headed with an average family size of 4.8, which indicated that they had sufficient labor for full

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technology package application (Table 1). Educational status determines technology use of farmers, hence 43.5% of them attended from read and write to secondary school. Tillage frequency as well as timely planting and weeding determines crop productivity, besides agronomic findings suggested that '3×' plough is an optimum for sorghum production (Mihiretu et al., 2019a). In this regard, 78.4% of farmers were plowed at sufficient level (3×) but the rest were below optimum level (2×). Likewise, 97.4% and 89.8% of the participant farmers planted and weeded the experiment at critical and proposed times. Timely planting and weeding favor fast growth of sorghum as they can increase adequate soil water filtration in the dry land areas (Kinfe and Tesfaye, 2018).

Table 1. Characteristics of participant farmers and their field management, n=264

Variables	Description	%	Means
Age of the farmers? (years)	M (F)	-	42.5 (38.8)
Family size of the household? (number)	-	-	4.8
Farm experience of the farmers? (years)	M (F)	-	22.3 (15.6)
Sex of the household head? (%)	M (F)	71.2 (28.8)	-
Educational level the farmers (%)	Lit. (Illit.)	56.5 (43.5)	-
The training provided sufficient? (%)	Yes (No)	88.5 (11.5)	-
Plowing frequency of the farmland?	3 (2)	78.4 (21.6)	-
Planting was on time? (%)	Yes (No)	97.4 (2.6)	-
Weeding was on critical time? (%)	Yes (No)	89.8 (10.2)	-

Note: M=male, F=female, Lit.=literate, Illit.=illiterate
Source: own survey (2015-17)

Yield performance of sorghum technology

The combined result revealed that the sorghum technology had a yield advantage of 116.6% over the local practice (Table 2). The higher yields was mainly attributed to the use of improved variety, appropriate fertilizer and seed rates, good management practices as well as proper use of moisture conservation structures. This result was in line with the findings of Berhane (2012) who identified that coincident use of soil and water conservation techniques with fertilizer significantly increases sorghum yield. The technological gaps were 1400 and 988.7 kg ha^{-1} for grain and straw yields, respectively. This result discloses the production gaps would be bridged through using the improved varieties with their production packages. The extension gap of 1600 kg ha^{-1}, on the other hand displays that it was impossible to replicate the result obtained by breeders at the research site. The technological index of 53.8% gave an evidence that still there is room for improving sorghum production through firming extension networks plus to the emphasis on area specific recommendations. The technology index indicates the feasibility of evolved technology at the farmer's field, hence the higher technology index depicts the unfeasibility and still a room to improve the new technology at farmers' context (Zewde and Purba, 2022). The same finding by Berhane et al. (2019) revealed that higher technological index in *'Misikir'* sorghum technology provided an evidence that necessitates a wider scope of further improvement in sorghum production.

Perception, demand and constraints of sorghum technology

To generalize farmers' perception on sorghum technology, Tim Willet's perception theory was used by calculating the sum and average score of the Likert scale. According to the theory, if the average score is greater than 3.51, farmers have good perception on the technology. If the average score is 2.51–3.50, farmers have not confidence on the technology. If the average score is below 2.50, farmers have not good perception on that technology (Mihiretu et

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al., 2019). Cronbach's alpha reliability test was also carried out for internal consistency among Likert scale items, thus the statistics table gives alpha coefficient, α = 0.81, elucidates that the questions hired were consistent and reliable. The result thus indicated that large number of farmers had a positive view and perception on the technology in most parameters. But they have no confidence on disease and pest resistance capacity since no disease outbreak in the study years as well as it was very susceptible to birds' attack, respectively (Table 3). In general, the overall average score of 4.25 Likert rate item responses implies that the farmers were perceived and accepted the technology with full confidence.

Table 2. Yield performance of sorghum technology in the arid lowland areas

	Mean yield (kg ha^{-1})					TG	EG	TI
	New	Local	SD	t	Sig.	(kg ha^{-1})	(kg ha^{-1})	(%)
Grain	2600	1200	2.39	3.89	0.002	1400	1600	53.8
Straw	3688.7	2700	6.13	2.04	0.073	988.7		

Note: Potential yield (PY) of new sorghum technology = 4200 kg ha^{-1}
SD: standard deviation, TG: technology gap, EG: extension gap, TI: technology index
Source: field data (2015-2017)

Table 3. The farmers' demand and perception on sorghum technology, n = 264

Parameters	SD	D	N	A	SA	SS	MS
The germination performance is good	-	-	7.3	34.1	58.5	284	4.50
The vegetative performance is good	-	-	2.4	29.3	68.3	293	4.65
Seed setting performance is good			12.2	39.0	48.8	333	4.28
Seed size of the technology is good		2.4	56.1	29.3	12.2	217	3.24
The technology is pest resistant		2.4	58.5	24.4	14.6	220	3.29
The technology is early maturing		14.6	9.8	43.9	31.7	231	3.60
Threshability of the variety is good			2.4	52.8	44.8	283	4.49
Productivity of the variety is good			2.4	36.6	61.0	288	4.57
Seed color of the variety is white			18.5	49.8	31.7	256	3.57
Food quality of the variety is good			22. 6	61.0	16. 4	413	4.00
Average = 4.25							
Cronbach's alpha coefficient α = 0.81							

Note: SD: strongly disagree, D: disagree, N: neutral, A: agree, SA: strongly agree,
SS: sum of scores, MS: mean of scores; values are in percentage points
Source: own survey (2015-17)

As far as demand is concerned, 82.7% were highly interested to use sorghum technology by next year, but the rest refused due to labor shortage. However, 75.4% of farmers informed merits of the technology to other fellow farmers through storytelling and physical invitation to visit the performance. Likewise, 80.2% of participant farmers suggested other eligible neighbor farmers to use the technology and 81.2% of the suggested farmers had positive reaction to implement in the future. Among factors, ease application of technology is playing significant role in technology adoption (Solomon et al., 2021). Accordingly, with researchers and experts' follow up, 83.6% of farmers applied the full package and 68.3% of them defined the package application was tough and labour intensive mainly in sowing and weeding stages (Figure 1a). Therefore,

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the farmers identified labor shortage, lack of experience and technological intricacy as the most important challenges in descending order. Those farmers challenged by labor shortage, were due to lesser family size as well as young and non-eligible household members though they have no doubt on the technology to increase yield and yield components (Figure 1b). During the field days, the visitors said that clustering extension approach was ideal because cluster level dialogues can form partnership among farmers and various public organizations (research, innovation and extension), which was vital to formulate and expedite future policy reform on the conventional extension approach (Mihiretu et al. 2019).

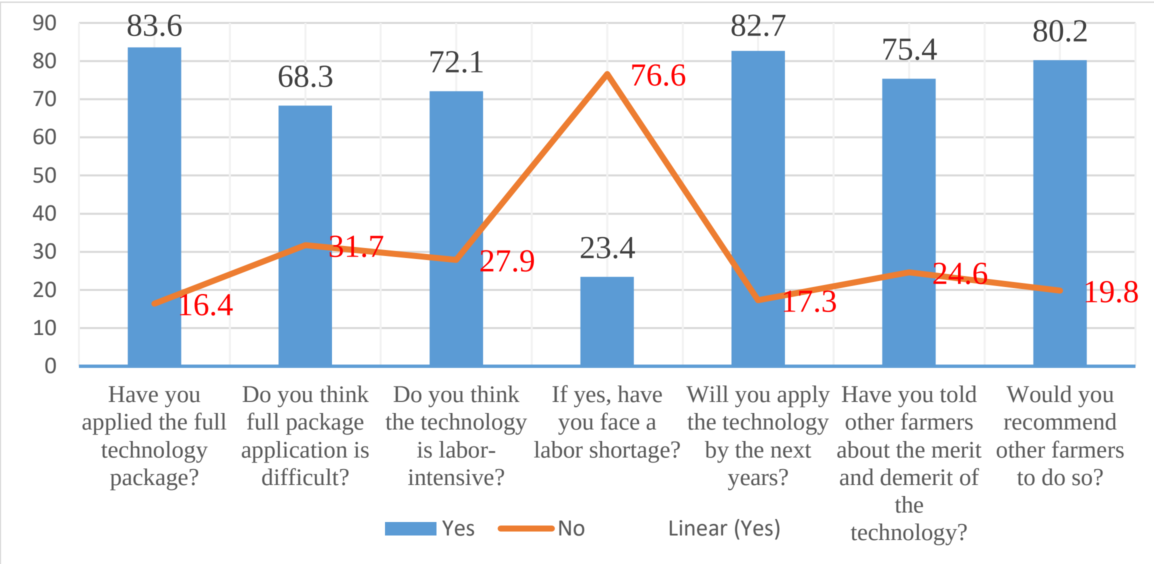

Figure 1a. Farmers' demand and continuity on sorghum technology

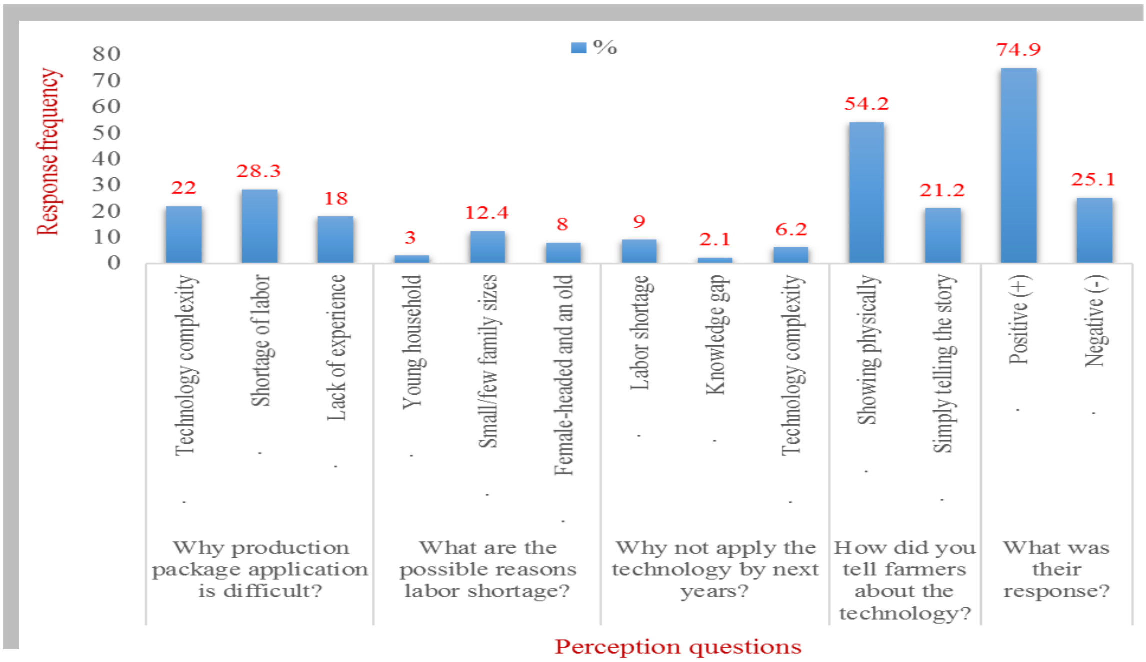

Figure 1b. Practices and constraints of sorghum technology application

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Stakeholder linkage analysis

The proper distribution of duties among stakeholders would consolidate the tripartite linkages of farmers-extension-research (Mihiretu, 2019). The SWOT analysis (Table 4) shows that the major stakeholders and their linkage in technology promotion and diffusion process. To create demand on the new sorghum technology, field days were commenced involving farmers, experts, higher officials and media to promote and assess the technology and the benefits of clustering extension approach. On top of recognition to the new sorghum technology, clustering was appreciated for creating competition among farmers in farm management, as well as ensuring the "eye catching" power to impress the participants.

Table 4. Analysis of stakeholders' linkage in sorghum technology promotion

SWOT analysis		Stakeholders		
		F	E	R
Strengths	▪ Being optimist and have high demand on technology	×		
	▪ Respectable tripartite contact throughout the study process	×	×	×
	▪ Applying the technology in cluster	×		
	▪ Availing inputs and training on time			×
	▪ Organizing field days		×	×
Weaknesses	▪ Inadequate follow up by the nearby stakeholders		×	
	▪ Gap in full package application of the technology	×		
	▪ Seed quality maintaining problem	×		
	▪ Stumpy technical backup to farmers		×	
	▪ Reluctant to weed at optimum level	×		
Opportunities	▪ Presence of NGOs working on technology promotion in the area			
	▪ Technology use becomes focus of the development program			
	▪ Upright information of farmers' about the technology			
	▪ Presence of seed exchange culture of the community in any arrangement (via cash, in kind, free for non-eligible)			
Threats	▪ As an arid-lowland, the area has low and erratic rainfall			
	▪ High temperature in main cropping season			
	▪ High risk of drought occurrences in 3/4 years interval			
	▪ Higher input cost leads to lower willingness to pay			

Note: F, E and R stands for farmers, experts and researchers, respectively

CONCLUSION

The result confirmed that the sorghum technology has a grain and straw yield advantage over the local production practice. This revealed that sorghum production problems could be overcome by adopting improved varieties with their production packages. The extension gap displays that it was impossible to replicate the potential yield at farmers' farmland using improved practices. The technological index also provided evidence that there was a scope for further improvement in sorghum production using technology. Nevertheless, more than half of farmers described package application in general and row sowing in particular as tough due to labor shortage. The authors strongly recommend that sorghum technology should further scale out to similar agro ecologies by establishing seed producing and marketing cooperatives to make the technology diffusion and exchange system. Therefore, to bridge the yield gap between the technology and existing production, there is the need to strengthen the extension network besides emphasizing on

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area specific recommendations. The intervention also provided a lesson for researchers to apprehend production improvement options for future breeding and adaptation programs on the commodity using the current outcome as a springboard.

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