OPEN ACCESS

Global Journal of Research in Agriculture & Life Sciences
ISSN: 2583-4576 (Online)
Volume 04 | Issue 02 | March-April | 2024
Journal homepage: https://gjrpublication.com/gjrals/

Research Article

Transfer of Improved Bread Wheat Technologies to Reduce Yield Gaps in Wheat-Based Areas: The Case of North Shewa, Central Highlands Ethiopia

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DOI: 10.5281/zenodo.10813396 **Submission Date: 21 Jan. 2024 | Published Date: 13 March 2024**

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Abstract

Wheat is one of the important staple cereals cultivated in Ethiopia accounting for a significant share in area coverage and production volume. The low productivity of wheat resulted from the challenges of the high levels of pests and lack of disease-tolerant varieties. This study has depicted the importance of a participatory approach to sustainable technology transfer and contributing to reducing yield gaps in wheat farmers production practices. The study was conducted in the central highlands of Ethiopia for the purpose of introducing improve bread wheat varieties and reduce yield gaps and production and productivity improvement. A multidisciplinary team of researchers and other stakeholders was established for effective technology transfer. Twelve bread wheat varieties were demonstrated and three of them were recommended for different production areas based on farmers' preferences, adaptability, and yield performances. Field days were organized to evaluate and popularize the technologies. An average of 46% yield advantage was obtained compared with the farmers' conventional practices. Seed business ideas were also incorporated through community-based seed production and marketing approaches for sustainable technology transfer and to enhance the diffusion of the technologies. As a result, 320 tons of improved seed were produced and sold as certified seed and over four million Birr was obtained for the farmers from the seed business. Participatory approaches accompanied by a multidisciplinary team of different stakeholders and demand-driven technology supplies were useful for the effective transfer of wheat and other agricultural technologies. The provision of training and credit access will improve the capacity of farmers seed producer and marketing cooperatives.

Keywords: Participatory, Seed, Technology, Variety, and Yield-gap.

1. INTRODUCTION

Agricultural technologies were developed to reduce hunger and poverty through productivity enhancements (Pretty, J.N. and Hine, R., 2001). Crop production is the main livelihood and food security improvement farm outputs in Ethiopia. Stimulation of farmer-to-farmer seed exchange enhances the overall productivity of the rural community. Technology outreach requires the involvement of participants to allocate farmlands for new technologies (Pretty *et al*., 2003). Participatory approaches convince and motivate the farmers to change their attitudes toward the new technology and encourage them to be involved in the outreach program.

There are experiences in the sustainable transfer of promising technologies (Pretty *et al*., 2011). This helped the farmers to have a chance to enhance productivity and market participation (Altieri, *et al*., 2012). Transfer of improved bread wheat technologies can benefit the farmers to have a chance access to improved seeds and knowledge. Scaling up in this context means expanding and sustaining successful practices of improved agricultural technologies in different places over time to reach a greater number of users. This brings more quality benefits to more people over a wider geographical area, more quickly, more equitably, and more lasting.

Wheat can be grown at altitudes ranging from 1500 to 3200 but, the most suitable regions fall between 1900 and 2700 masl (Gebremariam *et al*., 1991). Ethiopia is the second wheat producer in Sub-Saharan Africa with a cultivated land of 1.29 million ha (CSA 2014 and Beteselassie *et al*., 2007). Wheat is one of the most important cereals cultivated in Ethiopia. It ranks 4th after teff (*Eragrostis tef*), Maize (*Zea mays*), and Sorghum (*Sorghum bicolor*) in area coverage and 3rd in total production and accounts for more than 14 percent of the total cereal output (CSA, 2011). It is the major crop grown in the central highlands of Ethiopia (Holden *et al*., 2004).

In addition to grain, wheat straw is also an important livestock feed, thatching roofs, and bedding. Wheat is an important commodity, which contributes a major part to achieving the country's agricultural policy objective of food self-sufficiency. Despite its tremendous importance wheat production faced immense production constraints affecting both yield potential and quality. The average yield of wheat is about 2 tons/ha which is below the world's average of 2.9 tons/ha and Germany's national average yield of 10 tons/ha (Altieri, *et al*., 2012 and Feleke and Zegeye 2006).

Low productivity of wheat resulted in the limitations of Low rate (178 kg/ha) of fertilizer application on 29% of the total area of wheat lack of access to improved seed of wheat nearly 3% of the total wheat area was covered with improved seed (Joshi., *et al*, 2011). There are huge yield gaps across the intervention areas as a result the development and transfer of high yielder and diseases-resistant bread wheat technologies were a priority research agenda. The problems mentioned were common in the central highland areas of Ethiopia. The future production improvement depends on the utilization of the improved technologies and the enhancement of the seed supply system.

With this understanding, its improvement program was implemented for various years and many improved varieties have the merit of higher-yielding in both grain and biomass and disease-resistant than farmers' cultivars are released. Many management practices also have been developed. According to the Central Statistics Authority (CSA) of Ethiopia reports, over the last ten years, the trend in wheat production showed no increase during the first seven years and showed a slight increase during the last three years both in the area and total grain yield.

The increase in production during the later years may be attributed to improved farmers' awareness and availability of better-adapted varieties, improved production practices, increased local demand, and better market prices. Therefore, the activity was done to enhance farmers farmers aware of the technologies, to create access to improved seeds, to accelerate the rate of technology dissemination, and to improve farmers and extension linkages to expand the production and productivity of bread wheat using improved varieties together with improved management practices.

2. Material and Methods

Area specification

This activity was implemented in six wheat-producing districts of central highlands areas namely Tarimaber, Bassonawerana, Siyadebirnawayu, MoretinaJiru, Merhabete, and Ensaro. These are characterized by altitudes ranging from 2400 to 2700 m.a.s.l, cortisol, cambisol, and vertisol areas, and are suitable for wheat production. Initially, a total of 12 improved varieties of bread wheat including "Menzie", "Bolo" and "Tsehaye" with the recommended fertilizer rate of 225 and 275 kg. ha^{-1} of DAP and Urea were demonstrated on 15 different farmers' fields using farmers as replication. Based on the evaluation outputs different varieties were recommended for different agroecology based on farmers' preferences, yield results, and agroecology suitability of the varieties.

The host and follower farmers were organized as Farmers Research Groups (FRG) as trial and learner groups. After the variety evaluation and selection, process farmers were agreed on the selected varieties and interested in using them for scaling in large-scale productions implemented for three consecutive years (2015-2017). We used different Media which played an important role in advocating and expressing our ideas and making wider demands of the technologies and market linkages for the produce at a time.

The approaches and methods used

Participatory approaches were the main strategy for the evaluation of the varieties. Through these farmers learn by themselves with the exchange of indigenous knowledge among themselves. A multidisciplinary team comprised of researchers from different disciplines was organized. Improved technologies were introduced based on demands desired by the farmers. Training provision and field day, field clustering, continuous monitoring, and support were implemented. A multidisciplinary team of researchers, farmers groups, and extension workers was established during the implementation periods. Pieces of training was given for participant farmers and stakeholders focused on pest management options, applications of compiled recommended practices, seed production and marketing approach, and market potential of improved seed.

Different stakeholders agreed to share responsibilities with the signing of a memorandum of understanding. Based on the agreements, research was responsible for providing training for farmers and extension workers, timely delivery of the seed for interested farmers, and technical support. Farmers were responsible for covering labor and fertilizer costs and implementing the activities of field management activities by themselves based on the required production practices. Each host farmer was also responsible for transferring improved seed to at least five farmers and they reported the amount of seed delivered to the interested farmers and the list of the farmers who bought or exchanged seed from the host farmers. Extension workers and cooperatives were responsible for facilitating technology dissemination among the farmers.

Seed dissemination

In the implementation periods, a total of 26.68 tons of improved bread wheat seed was disseminated for 482 (73 female) farmers, and 163.38 hectares of land were covered starting from 2014 to 2017 production periods in the districts (Table 1).

Table 1 Seed dissemination, the area covered, and participants.

Area in ha	Seed (tone)	Participant farmers		
		Male	Female	Total
163.38	26.675	359	57	416

Awareness creation

The training was organized and provided for 742(47 female) host farmers and extension workers. This intervention helped bring the farmers and extension workers to a common understanding of the production system and sustainable seed exchange for technology diffusion improvement. In each implementation year, different field days were organized in the implementation areas together with offices of agriculture by inviting different stakeholders including higher officials. The field days were important to strengthen the linkages among the actors and to get organized feedback. During the events, the approach, weaknesses, convenience, and limitations of the technologies and approaches were discussed. In the field days 861 (28 female) farmers, extension workers, and administrative bodies participated. Most of the participants in various events were interested in technology and convinced to strengthen the linkages and approaches. In general, 1603 (75 female) participants were aware of the technology and the approaches through training and field days (Table 2).

Table 2 Event participants

Intervention events	Participants (number)		
	Male	Female	Total
Training	695	47	742
Field days	833	28	861
Total	1528	75	1603

Figure 1 indicated that the research center organized different theoretical training, and technical support on the host farmers' field and organized different field day events were organized in addition to seed delivery based on the agreements set.

Figure 1 Theoretical training, field practices and field days on wheat technology transfer.

Data collection and analysis

Yield data were collected using X-fashion on representative farmers' fields and compared with the districts' annual yield reports. Farmers' opinions and feedback about the approaches and the technologies were collected during the field days and finally, descriptive statistics and qualitative analysis techniques were used to evaluate the results.

3. Results and Discussions

Variety recommendations

From the demonstration activity, different varieties were recommended for different production areas based on farmers' preferences and the agroecology suitability of the production areas for the varieties tested. Based on this 'Menzie' variety for vertisol areas with its selected parameters of adaptability, disease tolerance, and yield, 'Tsehay' variety for light soil and frost-prone areas based on its properties of early maturity and disease tolerant and comparative yield advantage, and 'Bolo' variety was recommended for all areas based on similar characteristics of adaptability and disease tolerant.

Productivity (yield) improvement

The intervention improved the productivity of wheat by an average of 50% in vertisol areas (Moretinajiru and Siyadebir districts) from 2.8 to 4.2 tons per hectare and 36% improvement in non vertisol areas (Bassonawerana and Tarimaber districts) from 2.2 to 3.0 tone ha^{-1} compared with the baseline information and the woredas annual report (Figure 2). The seed production and marketing approach contributed 28% improvement of wheat productivity to overall intervention areas (Northshewa zone Amhara region) based on the (CSA, 2017) annual productivity report (it changed from 2.03 to 2.6 tons ha^{1}) in grain yield and it was better also in biomass yield based on farmers' opinion.

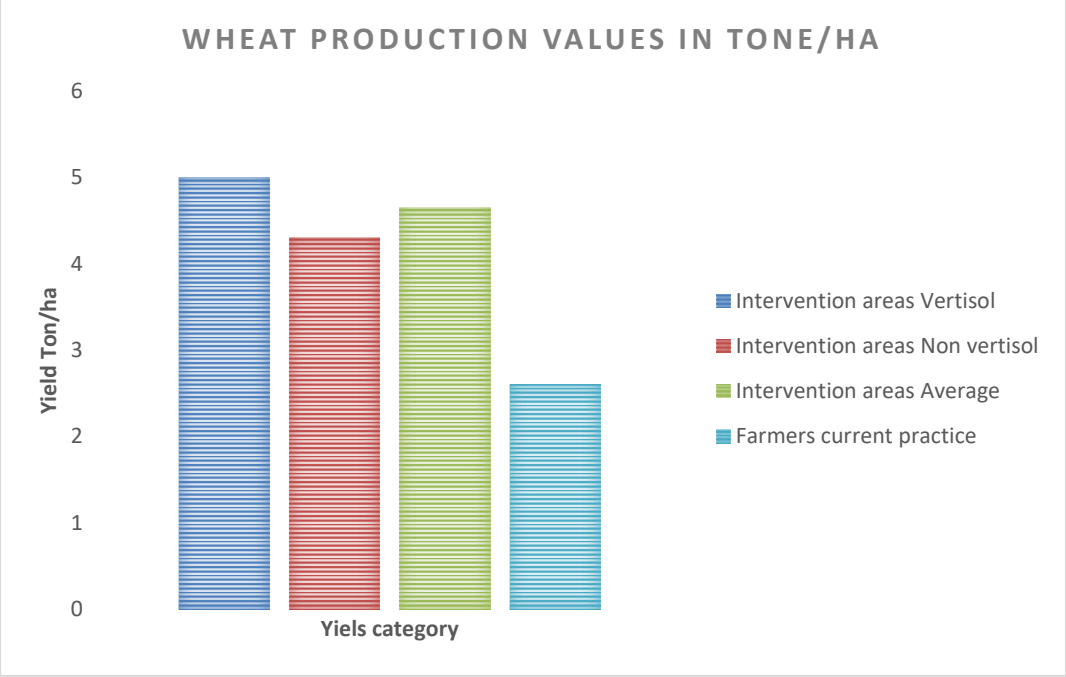

Figure 2 Yield gaps of famers practice and new intervention by production areas.

Institutional linkages for sustainable seed supply system (3Ss)

Technology transfer activities were implemented, and the farmer-to-farmer seed exchange system was performed smoothly. Based on this approach 2410 indirect beneficiary farmers were accessed to improved seed from previous host farmers. This was checked by tracking the primary host farmers and tracing the list of buyers from the host farmers for the first two years. Accordingly, 200 tons of wheat seed was exchanged, and more than 1000 hectares of farmland were expected to be covered by these improved varieties.

Seven seed producer and marketing cooperatives are established in four intervention districts and now they form one seed producer and marketing union. Mortinajiru, Bassonawerana, Siyadebirnawayu, and Ensaro districts each have legalized and licensed seed producers and marketing cooperatives. A sustainable seed supply system (3S's) for these introduced varieties implemented in these districts for other kebeles within and outside the district and other similar areas. The seed varieties are produced and collected by seed producers and marketing cooperatives. The collected seed proceed and cleaned then redistributed by the cooperatives to many interested farmers.

Seed as a business

In addition to the farmer-to-farmer seed exchange system, smallholder farmers produce and sell improved seeds to seed enterprises and different governmental and non-governmental organizations. The produced seed was collected by the cooperatives and sold as a seed used for seed purposes in other similar areas. In 2015 and 2016 production years 105 and 215 tons of seed were collected in the same order and sold to the formal seed system to generate 4,320,000.00 Birr from seed business as well through cooperatives.

Advocacy and media coverage

The activity has been expressed by various local, regional, and national Mass Media of Radios journals, and Televisions which play an important role in making wider demand and market linkages of the technology at a time. Leaflets and broachers were also distributed for sustainable knowledge transfer and production and productivity improvement. The local Media of Amhara and Debre Birhan Fana FM radios gave special emphasis to expressing the efforts and beneficiaries' feedback about the technologies during the field days of scale-up activities. These Media are easily accessed by rural farmers and the information shared via these played vital roles in technology dissemination in various areas across the zone.

Stakeholders' responses and feedback.

During the field days and evaluation events, various stakeholders participated and reflected their feelings about the approaches and performance of the technology. The main actors like farmers, agricultural experts, and cooperative leaders reflect their feelings and future responsibilities for more technology expansions to other beneficiaries. Farmers said, "We are happy with these varieties because the varieties have better performance, and high yielder compared with others we know and local varieties that we used". "We will also expand these varieties and production practices shared in the linkage to those farmers who didn't access it before through farmer-to-farmer seed and knowledge exchange.

Planting bread wheat in a cluster basis is interesting and helps to protect from mixtures of other varieties and crops." Agricultural experts and other stakeholders said "We thank the research center because of its efforts for introducing new technologies to farmers in our areas. We are responsible for transferring these technologies to other farmers in our respective mandate areas to enhance the production and productivity of wheat. We motivate the farmers who participated and learned in this field day to transfer to other farmers. We will continue to encourage the farmers to produce on a cluster basis hence it helped to produce quality seed, and easy for monitoring, management, and harvesting."

Unions and cooperatives ''we have the responsibility to serve the farmers by organizing the produced and strengthening the market linkages of the seed business; we provide improved seeds at a fair price which is released and introduced by the research centers based on the farmers' interest. We replace and produce quality seeds periodically using recently released improved varieties. We have a role to help ourselves and other member and non-member farmers to escape from rust diseases. Since we are organized to manage the challenges of farmers, we are delivering improved varieties that benefit farmers."

Challenges

The prevalence of rust diseases in other varieties may affect these varieties' tolerance in the future. The prevalence of frost in the highland areas required early planting and in some intervention areas, there were weed management problems.

4. Conclusion and Recommendations

Conclusion

Participatory and partnership involvement approaches were important systems to create technology demand in the intervention areas for effective technology transfer. Establishing and strengthening local farmers' institutions improved the capacity of farmers and enhanced the diffusion of new technologies. The partnership involvements improve seed transfer efforts through farmer-to-farmer bread wheat technologies transfer activities. Further enhancement of their capacity through training and technology delivery will improve the overall productivity of the rural community. The outreach activities require concentrated involvement of different approaches to allocating farmlands for improved and newly introduced bread wheat varieties. It helps to convince and motivate the grower farmers to widen the area coverage of the crop and improve the productivity per unit area of farmlands. Training and field day events played vital roles in reflecting the feelings of stakeholders. Farmer's interest in the varieties and institutional linkages with the local institutions create a new opportunity for seed business.

Recommendations

For sustainable improvement of production and productivity of wheat different approaches are required. Demand-driven, participatory, and multi-stakeholder intervention approaches are important for effective technology transfer activities. Seed producer and marketing cooperatives shall be established in other similar areas for successive technology transfer. Capacity building for the existing cooperatives through financial and technical options on credit services and training are very critical concerns. Technical backstopping through training and financial support will be one of the future interventions to sustain the informal seed supply system. It should be provided for the existing cooperatives and member farmers. Seed production and marketing cooperatives shall be established in the other areas. Capacity building for the existing cooperatives through financial and technical options through credit services and training is a very critical concern. The provision of early-generation seeds for established seed producers and marketing cooperatives will sustain the seed business. Creating market linkage for both seed and grains produces effective utilization of the introduced technologies.

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CITATION

Abiro T. (2024). Transfer of Improved Bread Wheat Technologies to Reduce Yield Gaps in Wheat-Based Areas: The Case of North Shewa, Central Highlands Ethiopia. In Global Journal of Research in Agriculture & Life Sciences (Vol. 4, Number 2, pp. 1–6). https://doi.org/10.5281/zenodo.10813396