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Participatory Technology Development and Selection with Farmers: Exploring Its Role to Enhance Improved Rice Variety Adoption in Ethiopia

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Abstract
Growing dissatisfaction with agricultural technology adoption rate in resource-constrained farming systems has been observed in recent years. This low adoption rate is partially attributable to gaps in farmer engagement in technology development, where Participatory Technology Development (PTD) is assumed to be a solution. This mix of review and research articles attempts to explore the influence of participatory technology development and selection approaches on rice variety adoption. It uses both primary and secondary data. Direct matrix ranking was used to analyze primary data collected from farmers in an experiment to identify farmers' variety preferences, while the critical review method was used to analyze secondary data. Accordingly, our research results show that when a rice variety is being developed, breeders habitually control all steps of the technology development process, and there is little input from farmers. The levels of farmers' participation in most of the research undertaken by the national rice program were characterized by passive participation, despite the functional participation of farmers also observed in the Variety Verification Trial (VVT) and variety validation trials. This study also reveals that practicing the PVS approach with rice varieties that are assumed to be the best performers in breeders' eyes helps to choose highly acceptable varieties in farmers' eyes under their complex farming system. PVS approach also backed up the limitations of the Conventional Technology Development (CTD) approach used by rice program for so long. Therefore, engaging farmers at the required position and expected level in the cycle of rice breeding stages is suggested as a promising way to accelerate rice variety adoption.

Keywords: Shaga, Conventional Technology Development, Participatory Plant Breeding, Participatory Variety Selection, Adoption, and Farmers

1. Introduction

Agricultural technology is a means to improve farm productivity and thereby enhance smallholder farmers' income, food security, and livelihoods (Wordofa *et al*., 2021) [28]. In developing countries, the lower adoption rate of agricultural technology is attributed to the inability to keep up with productivity improvement with that of population growth (Alemu *et al*., 2017) [1]. Drivers for the lower technology adoption were viewed from three perspectives. Some groups give higher emphasis to the environment in which the technologies are utilized, while another group gives a higher value to the technology itself. The third group capitalized: both groups have considerable influence (Beyene *et al*., 2022) [3].

From the technology point of view, the inability to meet farmers' preferences during the technology development process is considered a prominent contributor to lower adoption (Groote *et al*., 2014) [12]. Lower adoption of the technology is primarily emanated from the technology development approach, termed Conventional Technology Development (CTD). In this approach, farmers' participation in the breeding and variety selection process is very limited. Farmers may participate in the variety selection around the last stage of technology development and release. The Conventional Plant Breeding (CPB) approach is similar to Participatory Plant Breeding (PPB) with three major differences; testing and selection take place on a station rather than on the farm, key decisions are made by the breeders and the process is not implemented in a large number of locations (Ceccarelli & Grando, 2009) [5]. These conditions contribute to poor technology diffusion and adoption (Osiru *et al*., 2010) [19].

Principally, the CTD approach's implementation mainly involves on-station testing, with farmers' opinions only being sought at the very end, frequently even after the variety had been released (Tripp, 1991) [23]. This process could lead to two common mismatches: maintaining varieties that farmers won't want and removing varieties that farmers would have preferred. These mismatches can happen when breeders' selection criteria differ from farmers' selection criteria and when the scenario on-station does not accurately represent the situation on-farm, respectively (Morris & Bellon, 2004) [18]. This leads to low rates of varietal change or replacement. This phenomenon highlights the potential for improvement from a change in approach that incorporates elements of Participatory Plant Breeding (PPB) (Witcombe *et al.*, 1996) [27].

The reality of rice research and development endeavors in Ethiopia may not be different. Despite the availability of numerous improved rice varieties, their adoption level is too low, and the production system is still dominated by the local rice cultivar, X-Jigna. A lower adoption rate of improved rice variety is associated with technology development approaches that undervalue farmers' involvement and preference (Atnaf *et al.,* 2021) [2]. Caryopsis color for Gumara and biomass and cooking quality for Ediget varieties are two examples of the lower adoption result of CTD (Atnaf *et al.,* 2021) [2]. In the technology development procedure, considering as many preferable traits as possible in a single variety was paramount to enhance rice variety adoption and thereby bring expected returns in research investment.

The limitation of the CTD approach's contribution to higher technology adoption necessitates the development of a new approach known as Participatory Technology Development (PTD). It is a form of informal small-scale farming systems research focusing on improving small-scale farmers' production systems to reduce rural poverty. It mainly focuses on disclosing indigenous traditional knowledge to scientific knowledge (Zahumensky, 2014) [29]. Under the PTD and selection approach, Participatory Variety Selection (PVS) or Participatory Variety Evaluation (PVE) appears from three basic premises. The first premise is that a heterogeneous environment requests specific effort for varietal selection rather than centralized breeding. The second premise is that breeders may not be aware of some of the important traits preferred by farmers, while the third premise is that a variety selected on a research station may not perform well under farmer management (Karthikeyan & Pati, 2013) [14].

Although PVS/PVE allows some kind of participation, the approach has its limitations in bringing farmers' participation to the expected level for better adoption. Accordingly, Participatory Plant Breeding (PPB) has been initiated to fill the above-mentioned gaps. PPB allows farmers to participate in major stages of the varietal development process both on the station and the farm (Wakuma, 2017) [26]. Therefore, this article tries to investigate the influence of Participatory Technology Development (PTD) and PVS approaches on the adoption rate of improved rice variety, giving special emphasis to Northwest Ethiopia.

2. Materials and Methods

This article used both primary and secondary data. Primary data were collected from farmers and experts during the implementation of PVS conducted by the researchers from Fogera National Rice Research and Training Center (FNRRTC) to identify farmers' variety preferences. A total of 20 on-farm trials were established in 3 districts of the South Gonder zone in Northwest Ethiopia, namely Libo-kemkeme, Fogera, and Dera. The trials were established aiming to demonstrate the performance of improved rice varieties and to manage farmer variety preferences using their selection criteria. The layout of the trial covers a total area of 1000 m2, where 200 m2 was allocated for each of the rice varieties namely Abay, Erib, Wanzaye, Shaga, and X Jigna in the 2017 cropping season. Out of the 20 sites, PVS was undertaken on a total of three trial sites, one from each district, selected based on performance of the trials.

1. From each site, 10 farmers (five male and five female) in total 30 farmers were selected by development agents to participate in PVS, which was undertaken in the three districts.
2. Orientation has been given to the farmers and development agents about the aims and procedures of rice PVS.
3. A quick visit to the trials has been accomplished by farmers and development agents participating in the PVS to identify selection criteria.
4. Both groups of farmers listed out the variety selection criteria, gave relative weight (for each criterion, and seated scores using a scale (5. very good, 4. good, 3. average, 2. poor, 1. very poor) to each variety referring to the selected criterion. The total score of a given variety is generated as the sum of the multiplication of the relative weight of respective selection criteria with the scale score of a given variety.
5. Facilitators presented each group's PVS result in the face of all members participating in PVS from both groups.

For preference differences, if any, discussions were re-opened to reach a consensus. Since development agents were also independently undertaking variety selection, their results were used for triangulation for the preference difference between male and female farmers' groups. However, reaching a consensus does not mean underestimating individuals' (either female or male) selection criteria or the weight of the criteria given for each selection criteria.

Secondary data on rice variety development approaches and breeding activities undertaken by the national rice breeding program were collected from the internet and FNRRTC's annual research reports and research directories, respectively. Research activities being carried out by the national rice breeding program have been critically evaluated, and key informant interviews with rice breeders have been undertaken to understand farmers' level of participation in rice variety development research activities and their role in wider technology adoption. The main reason for reviewing different countries' experiences with PTD is to magnify the role of farmers' participation in technology development that simplifies its adoption. The key informant interview was undertaken to understand the stage at which farmers are involved in the technology development process. The data collected from PVS were analyzed using direct matrix ranking, while secondary data were analyzed using the critical review method.

3. Results and Discussion

This section has three sub sections. The first one focuses on the review of literature on CTD and PTD process and level of farmers' participation while the second one deals with technology development procedure of the national rice program and its research outputs. The third one discusses about rice PVS results and its contribution for better adoption.

3.1 Review of literature on conventional and participatory technology development

3.1.1 Theoretical Consideration of participation

The Chinese Philosopher Lau Tse (1963) explained the essence of the participatory approach to community development as follows:

> "*Go and meet your people, live and stay with them, love them, work with them. Begin with what they have, plan and develop from what they know, and in the end, when the work is over, they will say: "We did it ourselves".*

The quote clarified how participation in the community is put into practice. Again, a crucial message of the quotation is that working hand in hand with end-users begins with scanning the environment and leads to an expected success. Moreover, the explanation of "We did it ourselves" clarifies how to obtain a higher degree of end-users' engagement in community development. Similarly, this section try to view Lau Tse believes from agricultural development points of view via briefly describing the levels of farmers' participation, the difference between CTD and PTD, and procedures of technology development.

Levels of farmers' participation

According to Pretty and Cornwall (1994) [20], the level of farmers' participation is explained as the intensity of farmers' involvement in the agricultural technology development process. It is broadly categorized into 6 differentiated groups. Each category is briefly described below.

Passive participation (Compliance): farmers participate by being told what has been decided or already happened. It involves unilateral announcements by an administration or project management without listening to their response. The information belongs only to external professionals. Outsiders control the implementation and evaluation process of activities with no input from the farmer's side.

Participation by consultation: farmers participate by being consulted or by answering questions. External agents define problems and information-gathering processes, and so control analysis. Such a consultative process does not concede any share in decision-making, and professionals are under no obligation to take on board people's views. Farmers participate in activities decided by outsiders who define the evaluation process. And farmers provide information and might make suggestions for improvement.

Participation for material incentives: farmers participate by contributing resources such as labor, in return for material incentives (e.g., food, cash). It is very common to see this called participation, yet people have no stake in prolonging practices when the incentives end.

Functional participation (Cooperation): Farmers' participation is seen by external agencies as a means to achieve project goals, farmers participate by forming groups to meet predetermined project objectives; they may be involved in decision-making, but only after major decisions have already been made by external agents.

Interactive participation (Co-learning): farmers participate in joint analysis, development of action plans, and formation or strengthening of local institutions. Participation is seen as a right, not just the means to achieve project goals. The process involves interdisciplinary methodologies that seek multiple perspectives and make use of systemic and structured learning processes. As groups take control over local decisions and determine how available resources are used, so they have a stake in maintaining structures or practices.

Self-mobilization (collective action): farmers participate by taking initiatives independently of external institutions to change systems. They develop contacts with external institutions for resources and technical advice they need but retain control over how resources are used. Self-mobilization can spread if governments and NGOs provide an enabling framework of support. Such self-initiated mobilization may or may not challenge existing distributions of wealth and power.

3.1.2 History of Participatory Plant Breeding

Practicing the PTD approach has an age of only 65 years (Ceccarelli, 2012) [6]. It emerges to fill gaps in the CTD approach to succeed in a marginal environment and for poor farmers. It grew from the 1950s' critiques on the ineffectiveness of development projects to bring useful new technologies to new areas. The criticisms focus on the absence of joint work between expertise and farmers, and farmers being passive recipients of the technology, which leads to lost farmers' preference and their farming conditions. As a counter-movement of CPB, farming systems research emerged in the 1970s, due to gaps in CPB to bring farmers back into agricultural development activities and experimentation. In farming system research, it is assumed that farmers are more likely to adopt technology as they are actively involved in the development process (Shelton & Tracy, 2016) [21]. PPB in practice was also part of the counter-movement of CPB which promotes the concept of participatory research, in response to criticisms of the failure of post-green-revolution in addressing the needs of poor farmers in developing countries (Ceccarelli & Grando, 2009) [5].

Research centers under CGIAR have experienced breeding experiments using a participatory approach. The International Potato Centre (CIP), International Center for Tropical Agriculture (CIAT), and International Rice Research Institute (IRRI) were among the members of the CGIAR applying the PPB approach in the 1970s (Shelton & Tracy, 2016) [21]. These efforts stood in contrast to the dominant model in CGIAR, which was a top-down transfer of technology model used in the national research system and extension workers to farmers in a one-way process (Biggs, 1990) [4]. By the late 1990s, success has been achieved by the research centers in CGIAR, national research institutes, and NGOs using participatory research including PVS in plant breeding. It is found to be superior to the conventional breeding implemented on-station for the selection of varieties for formal certification. The PPB and PVS terms were first used at a workshop in 1995, sponsored by Canada's International Development Research Centre (IDRC) (Shelton & Tracy, 2016) [21].

Refereeing to successes achieved in participatory projects, CGIAR (in 1996) launched a system-wide initiative called Program on Participatory Research and Gender Analysis for Technology Development and Institutional Innovation (PRGA), co-sponsored by CIAT, CIMMYT, International Center for Agricultural Research in the Dry Areas (ICARDA) and IRRI. In 2000, a recommendation was made to the CGIAR Technical Advisory Committee that PPB become an integral part of each CGIAR center's plant breeding program (Vernooy, 2003) [24]. Since 2000, a wide range of PPB projects has been recorded globally. Accordingly, in 2009, there were about 80 PPB programs worldwide (Ceccarelli & Grando, 2009) [5].

3.1.3 Comparative Analysis of CPB and PPB

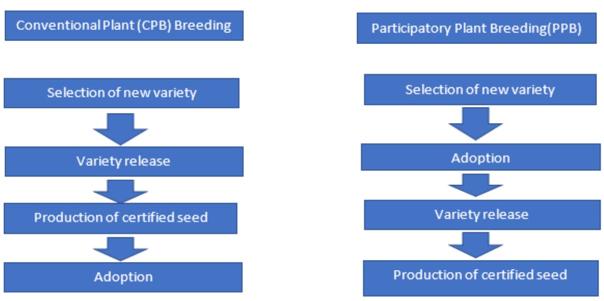
Conventional Plant Breeding (CPB) has been going on for hundreds of years and is still commonly used today. It has been more beneficial to farmers in high-potential environments or those who could profitably modify their environment to suit new cultivars than to the poorest farmers who could not afford to modify their environment through the application of additional inputs and could not risk the replacement of their traditional, well-known, and reliable varieties. In CPB farmers' participation in the breeding and variety selection process is very limited. Farmers may participate in the variety selection at around the last stage of technology release. CPB is similar to PPB with three major differences, namely testing and selection take place on the station rather than on farms, key decisions are made by the breeders and the process is not implemented in a large number of locations (Ceccarelli & Grando, 2009) [5].

Participatory Plant Breeding (PPB) is the active participation of farmers in some or all of the set of sequenced breeding activities; namely, priority setting, genetic materials acquisition and selection, crossing (not always), the selection at early stages (many segregating lines) and late stages (a small number of nearly finished lines), in situ experimentation/testing, and production and sharing of genetic materials and knowledge. The general intention amongst practitioners is not for PPB to be a substitute for station-based research or scientist-managed on-farm trials; rather it is considered a complementary breeding process (Hardon *et al.*, 2005; Ceccarelli & Grando, 2009) [13, 5]. For many formal sector breeders, the objective of PPB is to facilitate quicker and more extensive uptake of new cropping technologies (Morris & Bellon, 2004) [18]. Although farmer participation is often advocated for reasons of equity, there are sounds scientific and practical reasons for farmer involvement, too, as it can increase the efficiency and effectiveness of the breeding program (Wakjira *et al.*, 2008) [25]. Therefore, from a scientific viewpoint, the process is similar to a CPB with three major differences, namely (1) testing and selection take place on-farm rather than on-station; (2) key decisions are made jointly by farmers and breeders, and (3) the process can be independently implemented in a large number of locations. Differences between the two plant breeding approaches are briefly summarized in Table 1 below.

Table 1: Conventional versus Participatory plant breeding

Parameters	Conventional	Participatory
Crop improvement	Linear with a distinct finished product as the output, disposal of unwanted germplasm	Cyclical with materials continuously feeding into living adaptive processes in the field, germplasm enters into the production system throughout the process
Development orientation	Supply driven	Demand driven
Priority setting	Private sector, breeders, industrial users	Farmers and breeders, at times other users
Sources of germplasm	Farmers via national gene banks, CGIAR institutions, private collections	Farmers directly, national gene banks, CGIAR institutions
Institutional locus	Private companies, Agricultural Research Institutions /universities	Farmer organizations, Agricultural Research Institutions/ universities, NGOs
Operational structure	Centralized	Decentralized
Selection and testing	Breeders, at times including farmers in PVS towards the end of the process	Farmers and breeders
Location of field trials	On station	Farmers field and on station
Product	Officially released varieties	Improved materials for own use, sometimes officially released varieties
Characteristics	Few traits, yield maximization, genetically homogenous, broad adaptability	Bundle of traits, diverse characteristics, genetically heterogeneous, local adaptation
Extension	Private, public	Public, farmer-to-farmer

Source: Modified from Greenberg (2018) [11]



Modified from Wakuma (2017) [26]

Fig 1: The similarity and difference between CPB and PPB

Above all, as shown in Fig 1, despite many parallels between the two approaches, there is also one significant difference in the procedure they followed. The issue of variety adoption by farmers in CPB is coming after the completion of technology development (variety release), while in PPB, variety acceptance verification by farmers is confirmed in advance of the germplasm officially released as an improved variety. In the procedure difference between the two breeding approaches, the stage where genotypes are exposed to the farmers gives the key to unlocking the question of why the adoption rate of improved varieties is enhanced in the implementation of PPB.

3.1.4 Experience of Africa on Participatory Plant Breeding

Plant breeding was a cornerstone to the successes registered in the implementation era of the green revolution. The criticism of the sole focus on increasing the yield of cereals in the era of the green revolution leads to the establishment of the International Maize and Wheat Improvement Center (CIMMYT) and the International Rice Research Institute (IRRI) (Kaur, 2010) [15]. These centers have been using the PPB approach to consider farmers' opinions for better adoption. In 1971, the Consultative Group on International Agricultural Research (CGIAR) was established to expand the success story of the green revolution to many developing countries by incorporating new crops in addition to crops used in the green revolution. (Kaur, 2010) [15]. The CGIAR which coordinates agricultural research in developing countries worldwide has taken the initiative to use PPB since CPB has threatened farmers' seed systems and affected farmers' role in agricultural biodiversity conservation and use. Conversely, the PPB approach, which is initiated by CGIAR, bring farmers back into the breeding process as active participants (Witcombe *et al*., 1996; Sperling & Ashby, 1999) [27, 22].

Africa Rice experiences in Burkina Faso indicated that mother and baby trials for iron toxicity tolerance rice varieties were carried out in three locations in 2009 and 2010. The trials have been containing eight new varieties and checks. These had been tested in multi-location (mother and baby trials). At the maturity stage of the rice crop, at each site, farmers (from 43 to 66) were invited to evaluate trials. Besides, criteria identified by farmers include grain quality, tillering capacity, yield, panicle weight, tolerance to iron toxicity, disease resistance, grain appearance, panicle size, and plant vigor. They selected three best and three worst varieties. Farmers were asked to list the reasons for their choices and rank them in terms of priority from high to low. Besides, small-pack seeds of these three varieties were given to farmers for testing. Finally, farmers had selected one popular variety over checks by the end of 2010.

Between 1997 and 2003, the PBB approach was used for rain-fed upland rice in Ghana. Over 100 rice varieties were introduced and tested with farmers in two major agro-ecological zones and in a variety of farming systems. As part of this work, the PVS approaches were implemented, and issues raised by them were considered. An important part of PVS, and one that has implications for PVS processes, is that farmers have been accessed to varieties they like, and farmers are given seeds of the demanded varieties (Dogbe *et al*., 2002) [9]. Then approximately 30 male and 30 female farmers evaluated plots several times in the growing season and at maturity. Then, 60 varieties had been selected for the next step. The experiment was repeated for two more years and the seed of the nine most frequently selected varieties was distributed to farmers for on-farm comparisons. A total of 94 farmers (47 males and 47 females) in the communities received seeds of up to two varieties (1 kg per variety). Following this, all had visited and evaluated the mother trials in 1997 and 1998 and three varieties (IDSA 85, WAB 126-15-HB, and WAB 209-5-HB) had become popular in two communities. Then, a small pack of seed (2 kg per farmer) of these varieties was given to farmers in five new communities in 2000 and to a further ten new communities in 2001. Finally, after five years of the experiment, an adoption study has been conducted in the areas where different rice varieties were demonstrated. It has been found, 37% of farmers grew one or more PVS varieties in 2002. Overall, across the communities, there was no marked difference in percentage uptake between male and female farmers which was 35 percent and 38 percent, respectively (Dorward *et al*., 2007) [10]. This result is an indicator that female farmers have highly participated in the PVS process.

3.2 Varity Development Procedure and Research Outputs of the National Program

3.2.1 Rice Varity Development Procedure and Farmers' Levels of Participation

More than ten research centers in different regions of Ethiopia are coordinated to conduct research under the national rice breeding program. The program is currently being coordinated by the Fogera National Rice Research and Training Center (FNRRTC). It administers rice variety improvement activities in all of three rice ecosystems, known as irrigated, rain-fed lowland, and rain-fed upland, aiming to respond to biotic and abiotic stresses. Biotic stresses include diseases (rice blast, rice sheath rot, brown spot, and rice yellow mottle virus) and insects (rice stalked eyed fly, stem borer, and weevils) and abiotic stresses include cold, terminal moisture, and low soil fertility. The program is responsible for variety improvement through either the introduction of germplasms from collaborative international organizations like IRRI, Africa Rice, and Korea-Africa Food and Agriculture Cooperative Initiative (KAFACI) or the hybridization of parental lines for targeted traits using released rice varieties. After germplasm introduction (acquisition), the genotypes will be quarantined in the laboratory at Holeta Agricultural Research Center and then, if the germplasms (genotypes) pass the laboratory-based quarantine process, they will be again checked in the field at the FNRRTC quarantine site. The quarantined genotypes will then be evaluated in field conditions, and a seed increase of the genotypes will follow. After observation nursery evaluation, promising and adopted genotypes will be advanced to a Preliminary Variety Trial (PVT) in FNRRTC, and sometimes the location will be increased to two locations based on the availability of the seed to increase the chance of evaluation. According to the standard procedure, after one year of PVT, promising genotypes will be advanced for multi-location trials as National Variety Trials (NVT). Finally, after NVT evaluation, the best and most stable genotypes will be proposed for a Variety Verification Trial (VVT). At the VVT, a variety releasing committee will be invited to decide the fate of the genotypes, either to be released or not to be released. In all of this variety development procedure, farmers are only getting a chance to see the genotypes after they reach the VVT stage. The performance evaluation of rice genotypes at VVT is tested under farmer's conditions, yet it is still managed by researchers. In the variety development procedure that allows the participation of farmers, its level was very minimal and not at the expected level. Furthermore, concerning the location of the trials, almost all research activities have been established on the station and are fully administered by researchers, with the exception of VVT and validation and evaluation trials. In VVT, small numbers of farmers are invited to provide their opinions about the candidate varieties. In the CTD approach farming system studies and stakeholder platforms were used as sources of information to keep the demand of farmers.

As shown in Table 2, the level of farmers' participation in most rice research activities was passive participation, where breeders controlled the implementation and evaluation processes of activities with almost no input from the farmer's side. Conversely, participation through consultation and functional participation was also exercised in research activities like variety verification trials and adaptation and validation trials. To make technology supply more demand-driven and thereby enhance the adoption rate of improved rice varieties, the program recently recognized the importance of endorsing the "product profile" concept, which works as a contract between all stakeholders in a network to design and deliver market-oriented products. Using a "product profile" as a source of information for technology development could be one of the possible ways to incorporate farmers' or other relevant stakeholders' inputs indirectly. However, the indirect information source may not always be satisfactory; farmers have to directly participate in a variety development processes.

Table 2: Summary of rice breeding program research activities by farmers' level of participation

Activities	Objectives	Locations	Year	Level of participation
Cold tolerant upland rice preliminary variety trial	To identify cold tolerant and high yielding upland rice genotypes	Fogera and Jima	2020	Passive participation
Upland rice observation nursery	To evaluate different rice genotypes for their reaction to disease pests and agronomic performance for further breeding	Pawe	2020	Passive participation
Participatory variety evaluation of released rice varieties in new rice areas	To select and recommend varieties that meet farmers' demand	Tis Abay, North Achefer, Takusa, Dembia and Tepy	2020	Functional participation
Participatory variety evaluation of released rice varieties in upland and irrigated environment	To select and recommend varieties that meet farmers' demand and better adapted to the new rice growing areas	Pawe, Jinka and Bonga	2020-2021	Functional participation
Evaluation of performance and yield stability of introduced upland rice genotypes tested across Northwest Ethiopia	To develop high yielding, early maturing and disease resistant rice varieties	Fogera, Pawe, Metema and Maitsebri	2018-2020	Passive participation
Performance evaluation of early and medium maturing lowland rice genotypes in major lowland rice growing areas of Ethiopia	To evaluate and identify genotypes of high agronomic performance, disease resistant and early to medium maturing lowland rice types	Woreta, Pawe, Assosa, Mai-Tsebri, and Jimma	2020-2021	Passive participation
Variety verification for cold tolerance under upland condition	To develop high yielding, disease resistant, early maturing and cold tolerant upland rice varieties	Fogera, Jima, Dembia and Shire	2020	Participation by consultation
Validation of potential technologies to emerging opportunities	To validate and identify promising varieties in the new rice growing areas	Dangla, Dejen Aneded, Ayuhu Guagusa	2020-2022	Functional participation

3.2.2 The National Rice Program Research Outputs (2016-2020)

Since its inception, a total of thirty-nine, and in the past five years only, ten improved rice varieties, of which four of them were suitable for upland ecosystems while six were for lowland ecosystems, have been released by the national rice breeding program of Ethiopia. As shown in table 3, out of all, Shaga (4.9-ton ha-1), Wanzaye (4.5-ton ha-1), and very recently, Selam (5.2-ton ha-1) are becoming prominent improved rice varieties in the leading rice-producing hubs of Ethiopia, the Fogera plain, which significantly contribute in improving the national average yield, which is 3.1 ton ha-1 (CSA, 2021) [7]. Different biotic and abiotic factors have been considered in breeding activities to succeed the program objectives. It prominently considered traits attribute to high grain yield, caryopsis color, shattering and logging resistance, and thresh ability, etc. However, evidence also showed that in view of rice-growing farmers during the PVS process, variety selection traits (parameters) were going beyond the above-mentioned traits. In the PVS process, farmers used existing rice variety selection traits given by researchers, however, they additionally incorporated selection criteria including biomass yield, early maturity, flour density and softness stay of *Injera*, etc.

Table 3: Recently released improved rice varieties

Variety name	Year of Release	Ecosystem	Yield (ton ha-1)		Caryopsis color
			On-farm	On-station	
Pawe-2	2020	Upland	4.8	5	White
Selam	2020	Lowland	4.8	5.2	White
Azmera	2019	Upland	4.6	4.8	White
Maitebri-3	2018	Upland	3.5-4.0	4.8-6.0	White
Shaga	2017	Lowland	3.9-5.0	4.9-6.8	Brown/White
Wanzaye	2017	Lowland	3.5-3.9	4.5-6.5	Brown/White
Erib	2017	Lowland	3.0-4.1	4.7-5.3	White
Abaye	2017	Lowland	3.5-4.0	4.4-5.3	White
Fogera 1	2016	Upland	3.2-3.9	4.2-5.0	White
Fogera 2	2016	Lowland	3.7-4.9	4.2-6.1	White

Source: MoA (2020) [17]

3.3 Rice PVS and its Contribution for Wider Adoption

3.3.1 PVS on Improved Rice Varieties in Fogera plain Ethiopia

The variety development approach followed by the national rice breeding program of Ethiopia has its own strengths and weaknesses. To mention some of its strong points, within its short period of research endeavors, it has developed many alternatives and a total of thirty-nine improved rice varieties. The program significantly contributes to improving rice productivity from 2.1-ton ha-1 to 3.1 ton ha-1 within a decade through the development and utilization of improved rice varieties suitable for the three rice ecosystems. It is also proactive in addressing some of the gaps in rice development. For instance, despite the fact that the Shaga variety has been widely adapted and highly adopted by numerous farmers, it has also received complaint from the producers' side related to its brown caryopsis color, which is assumed to lower the market price. In response to this complaint, the program exerted its efforts and developed improved rice variety named "Selam", which addresses complaint about the brown caryopsis color of Shaga by fulfilling the demand for white caryopsis color in addition to fulfilling most (but not all) of the qualities of Shaga.

Besides its strengths, partners have also questioned the contribution of technology development procedures in supplying rice varieties that are highly preferred and demanded by the farmers. Farmers' participation in rice research and development efforts has increased in recent years, particularly in adaptation and validation trials, which are primarily conducted in emerging rice-growing areas. However, the adoption status of improved rice varieties was found to be too low, at 15 percent (Abebaw *et al.*, 2018 as cited by Atnaf *et al.*, 2021) [2], mainly due to the technological development followed by the program, which allows a lower level of farmer participation. Accordingly, practicing PVS using released varieties is assumed to be one of the possible options for bridging the gaps. Accordingly, this sub-section addresses the PVS of improved rice varieties undertaken in the three major rice-growing districts of the Fogera plain.

Table 4: Fogera district, Quhar Abo kebele: Male Farmers group

Criteria \ Varieties	Wanzaye (a)	Erib (b)	Abay ©	Shaga (d)	X-Jigna (e)	Relative Weight (f)	a*f	b*f	c*f	d*f	e*f
Tillering capacity	1	3	5	2	4	2	2	6	10	4	8
Spike[1]	5	2	1	4	3	1	5	2	1	4	3
Grain size	5	4	1	3	2	3	15	12	3	9	6
Biomass	1	2	3	5	4	1	1	2	3	5	4
Disease	4	4	4	4	4	3	12	12	12	12	12
Total Score[2]							35	34	29	34	33
Overall performance							1st	3rd	5th	2nd	4th

Source: Own data (2017)

[1] Spike is length of rice carriage in which rice seed lined. As farmers' view, having long and bending down spike means having high grain yield.

[2] Total score means farmers' preference score calculated as multiplication of variety selection criterion and relative weight of the criterion.

As shown in Table 4, in the Fogera district male farmers gave high relative weight for grain size and disease while they gave lower relative weight to biomass yield. The grain size was linked with high grain yield. It has been also confirmed that the disease concern of rice-growing farmers by the study of Zeleke *et al.* (2019) [30] was sheath rot and sheath brown rot were important diseases in the lowland rice production system under Fogera plain. According to PVS results, based on the overall performance score, farmers primarily preferred Wanzaye, followed by Shaga, despite Shaga being preferred as a prior variety referring to the total score. Due to farmers' preference result difference using the overall performance and total score, discussions have been held on the spot of the farmers' field, and they have reached a consensus that Shaga is preferred over Wanzaye.

Female farmers in the Fogera district gave high weight to tillering capacity, followed by biomass yield. Tillering capacity was related to both grain yield and biomass yield. Since the study area has a crop-livestock mixed farming system, biomass was considered a major criterion for farmers. As shown in Table 5, in the female group, the overall performance and total score of the PVS showed consistent results. Accordingly, female farmers in the Fogera district primarily preferred Wanzaye, followed by Shaga.

Table 5: Fogera district, Quhar Abo kebele: Female Farmers group

Criteria \ Varieties	Wanzaye (a)	Erib (b)	Abay ©	Shaga (d)	X-Jigna (e)	Relative Weight (f)	a*f	b*f	c*f	d*f	e*f
Tillering capacity	5	2	1	4	3	3	15	15	3	12	9
White Caryopsis color	5	3	1	4	2	2	10	6	2	8	4
Biomass	4	3	1	5	2	3	12	9	3	15	6
Spike	5	3	1	4	2	1	5	3	1	4	2
Total Score							42	33	9	39	21
Overall performance							1st	3rd	5th	2nd	4th

Source: Own data (2017)

In the Dera district, the male farmers' group gave high weight for stalk strength, followed by tillering capacity and white caryopsis color. Farmers relate stalk strength as a proxy indicator of high resistance to lodging. Tillering capacity is related to both grain and biomass yields, as rice bi-product is considered the primary source of animal feed in the study area. White caryopsis color was linked to market in which rice varieties with white caryopsis color has receiving high market value than brown rice. Shaga and Wanzaye were preferred first and second in both rice PVS measurement scores.

Table 6: Dera district, Zara kebele: Male Farmers group

Criteria \ Varieties	Wanzaye (a)	Erib (b)	Abay ©	Shaga (d)	X-Jigna (e)	Relative Weight (f)	a*f	b*f	c*f	d*f	e*f
Stalk Strength	4	2	1	5	3	3	12	6	3	15	9
White caryopsis color	4	2	1	5	3	2	8	4	2	10	6
Biomass	4	2	1	5	3	1	4	2	1	5	3
Spike	4	2	1	5	3	1	4	2	1	5	3
Disease	2	3	4	5	2	1	2	3	4	5	2
Tillering capacity	4	2	1	5	3	2	8	4	2	10	6
Total score							38	21	13	50	29
Overall performance							2nd	4th	5th	1st	3rd

Source: Own data (2017)

The female farmers' group in the Dera district gave high weight to spike length and biomass yield. According to female farmers' view, having too long and the bend-down spike is a proxy indicator for high grain yield. Similarly, as the bi-product of rice is the main source of livestock feed, biomass yield was also considered as a primary criterion for the group. They articulately explained the equivalent importance of biomass as "it is worthless having *Injera*[3] without *wott*[4] "Therefore, based on the overall performance and total score results, Shaga was preferred, followed by X-Jigna.

Table 7: Dera district, Zara kebele: Female farmers group

Criteria \ Varieties	Wanzaye (a)	Erib (b)	Abay ©	Shaga (d)	X-Jigna (e)	Relative Weight (f)	a*f	b*f	c*f	d*f	e*f
White Caryopsis color	4	5	5	4	5	1	4	5	5	4	5
Biomass	2	1	3	4	5	3	6	3	9	12	15
Spike	3	4	1	5	2	3	9	12	3	15	6
Total score							19	20	17	31	26
Overall performance							4th	2nd	5th	1st	3rd

Source: Own data (2017)

Male farmers in Libo-kemkeme gave high relative weight for shattering and early maturity. In areas where there is high rainfall and wind, the issue of yield loss due to shattering is a great deal. Early matured and relatively high-yielding rice varieties were chosen as hunger-relieving varieties because of their propensity to mature ahead of most other crops and long-matured rice varieties during a critical income shortage, specifically for the farmers who do not yet have multiple farm business enterprises. Accordingly, referring to the overall performance and total score results, male farmers preferred Shaga, followed by Wanzaye.

Table 8: Libo-kemkeme district, Agid kirigna kebele: Male farmers group

Criteria \ Varieties	Wanzaye (a)	Erib (b)	Abay ©	Shaga (d)	X-Jigna (e)	Relative Weight (f)	a*f	b*f	c*f	d*f	e*f
Spike	4	1	2	4	5	1	4	1	2	4	5
Biomass	3	1	2	5	4	2	6	2	4	10	8
Early maturity	5	4	1	3	2	3	15	12	3	9	6
Shattering	4	3	3	5	3	3	12	9	9	15	9
Total score							37	24	18	38	28
Overall performance							2nd	5th	4th	1st	3rd

Source: Own data (2017)

In contrast, female farmers in the Libo-kemkeme district gave high weight to caryopsis color and biomass yield. Caryopsis color was associated with crop market value. The rice variety having white caryopsis color is preferred over brown or red rice and has higher value in the market. Based on overall performance and total score results, female farmers groups primarily selected Wanzaye and followed by Shaga. Tables 8 and 9 showed that there was a preference difference between male and female farmer groups in the Libo-Kemkeme district. Following the preference mismatch between male and female groups, the discussion has been re-opened to reconcile their preference mismatch. After the critical discussion, the two groups reached a consensus, whereby Shaga was preferred over Wanzaye.

Table 9: Libo-kemkeme district, Agid kirigna kebele: Female farmers group

Criteria \ Varieties	Wanzaye (a)	Erib (b)	Abay ©	Shaga (d)	X-Jigna (e)	Relative Weight (f)	a*f	b*f	c*f	d*f	e*f
Grain yield	5	1	2	4	3	1	5	1	2	4	3
Early maturity	4	5	3	2	1	1	4	5	3	2	1
Tillering Capacity	5	1	2	4	3	2	10	2	4	8	6
Biomass	4	1	2	5	3	3	12	3	8	15	9
White caryopsis color	5	1	4	3	2	3	15	3	12	9	6
Total score							46	14	29	38	25
Overall performance							1st	4th	5th	2nd	3rd

Source: Own data (2017)

3.3.2 What has been done so far following up of rice PVS?

As it accesses the demands of end-users from farming system studies and feedbacks from stakeholders' platforms, the selected rice varieties via PVS, Shaga, and Wanzaye, with other improved varieties are the results of the CTD

[3] Injera is an Amharic word referring a type of local bread made of floor of tef and rice

[4] Wott is an Amharic word synonymous with English word "Stew"

approach. In addition, the PVS approach supports the planning decisions of seed multiplying institutions that have limited financial and physical resources, as it helps to identify highly demanded rice varieties to that of less preferred varieties developed by the CTD. Accordingly, Shaga has been multiplied using seed-producing cooperatives, community-based seed multiplication schemes, and individual-based seed multiplication schemes in addition to seed multipliers in the formal seed system, like Amhara Seed Enterprise, Ethiopian Seed Enterprise (ESE) and FNRRTC. In the key informant interview, researchers witnessed that accessing the PVS results significantly contributed to having demand-driven seed multiplication and wise utilization of FNRRTC's limited land resources in the multiplication of Early Generation Seed (EGS), allowing certified seed multiplying agents such as government seed enterprises (Amhara and Ethiopia Seed Enterprise) and Seed Producing Cooperatives (SPCs) to supply required seed amounts. Using seeds from multiple sources, Shaga has been promoted and scaled up by partnerships of actors from different Governmental Organizations (GOs) and Non-Governmental Organizations (NGOs) like MEDA and World vision) using an approach known as Large Scale Demonstration (LSD). Accordingly, within the past 3 years, Shaga's percentage share of the area covered from improved rice varieties and total rice cultivation reached 73 and 12 respectively. In contrast, the local rice cultivar, X-jigna, percentage share of the total rice cultivation within the same years has decreased from 95 to 84.

Table 10: Fogera district percentage share of rice cultivated area by variety

Year	Total Rice Cultivation Area (in ha)	Local (X-Jigna)	Improved	Shaga	Shaga % share from improved	Shaga % share from total	X-Jigna % share from total
2019	22295	21118	1177	112	10	1	95
2020	22323	20337	1986	756	38	3	91
2021	22363	18753	3610	2634	73	12	84

Source: Authors' analysis from district level agricultural office data (2022)

3.3.3 Is the Wider Adoption of Shaga Driven by PVS approach?

In this study, we saw two facts that have been validated empirically. The first one is Shaga and Wanzaye have been selected by farmers involved in the PVS. The second one is Shaga, which is recognized as widely adaptable and Wanzaye, which is identified as a high-yielding improved rice variety in its niche area were found to be highly adopted by numerous farmers. Despite the enactment of the PPB approach and the direct involvement of farmers in a variety development procedure executed by the national program at the infant stage, PVS backed up the gap generated by the lower participation of farmers in the variety development procedure and put a substantial contribution to enhance the adoption rate of improved rice varieties, mainly Shaga. In spite of Shaga also being a result of CTD, as PVS is both a research and extension approach, it supports the rice seed system to have better focus in selecting highly demanded varieties and thereby invest its limited resources (mainly farmland and financial resources) for multiplication of different seed classes to have better investment returns. The contribution of PVS in the wider adoption of improved rice varieties that were preferred by the farmers like Shaga could be justified theoretically. The study pinpointed the Technology Acceptance Model (TAM) out of the four major theories and models of technology adoption to justify the contribution of PVS to the better adoption of rice variety. The model defines perceived usefulness and perceived ease of use as major influencing factors of technology adoption. In this model, perceived ease of use is defined as the degree to which an innovation is perceived not to be difficult to understand, learn, or operate. In this model, the two factors (i.e., perceived usefulness and perceived ease of use) influence technology adoption by altering an individual's attitude toward using the technology (Davis & Davis, 1989) [8]. As we have seen in section 3.3, perceived usefulness is assumed to be developed by farmers' engagement in PVS, as it gives farmers a chance to select the varieties by themselves and results in wider adoption of Shaga.

4. Conclusion

Results of this study showed that despite some efforts, like developing and using product profiles as a source of information that taking into consideration of end-users demand in the technology development procedure, and also allowing direct engagement of farmers mainly in variety verification trials and variety validation trials, the level of farmers' participation in rice breeding activities is not at the expected level to incorporate their inputs in technology development procedure for better adoption success. Results of this study also confirmed that PVS research activities have been complemented and backed up the limitations of the CTD approach implemented by the national program to have highly demand-driven EGS multiplication by the FNRRTC and certified seed multiplication by SPCs for wider utilization of improved rice varieties, more specifically Shaga. In general, the study concludes that developing rice varieties mainly through the eyes of breeders is not satisfactory to address the lower adoption rate of rice varieties. Hence, there should be a combination of breeders' and farmers' views in the development and selection of highly acceptable improved rice varieties for enhanced adoption. Therefore, it is suggested that setting alternative modalities for farmers to be involved and represent both groups of farmers' views in breeding activities at the expected level is prominently vital to accelerate the adoption of improved rice varieties.

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