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Improving the adoption of stress tolerant maize varieties using social ties, awareness or incentives: Insights from Northern Benin (West-Africa)

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ABSTRACT

Maize is the staple food of most households in sub-Saharan Africa. The adoption of stress-tolerant maize varieties (STMV) is being promoted due to climate change. There are various methods applied to disseminate these varieties. Unfortunately, the adoption at the household level is still unsatisfactory. This study evaluated the effectiveness of the dissemination methods used in Benin. We identified dissemination methods from key informants involved in STMV seed dissemination projects. The performance of the identified methods was assessed through the perceptions of 150 maize-farming households using the Likert scale. We assessed the extent to which each method leads to the knowledge, use, and continued use (appropriation) of STMV seeds. Friedman and Wilcoxon rank tests were used for data analysis. Nine dissemination methods were identified and categorized into four groups according to their theoretical driven: strengthening social ties, capacity building, incentive, and awareness raising. Our results revealed that dissemination methods that focus on strengthening social ties, raising awareness, and providing incentives are more effective in promoting STMV adoption. Depending on the intended adoption (awareness, use, and appropriation), extension services and STMV promotional projects could focus on strengthening social ties, raising awareness, and providing incentives. However, future research must identify which of the methods leads to a higher rate of adoption of STMV.

1. Introduction

The impacts of stress-tolerant maize varieties (STMV) are of increasing concern to scientists and are well documented in the literature [1,2]. The use of STMV improves household resilience to climate variability [1,3–6]. They improve food security for poor households [7–10] by increasing yield and farm income [11] and market participation [5]. They provide commercial opportunities for seed companies [1].

Despite the reported effects, the adoption of STMV by smallholder farmers remains low [6,12], and the drivers of adoption are not fully understood [13]. According to Walker and Alwang [14], the adoption rate of STMV is about 52%. This rate seems modest but needs to be nuanced according to the categories of farmers and the specificities of each sub-Saharan African country [13]. For instance, Adu et al. [3] in Ghana reported low adoption of STMV and low cultivar replacement rate. A similar observation was made in Uganda by Simtowe et al. [13]. According to Voss et al. [15], the slow growth adoption rate of STMV discourages promoters from not benefiting from their investment in breeding.

Several reasons for low adoption and slow growth in adoption rates are reported in the literature. A lack of information and awareness is revealed as one of the main barriers to STMV adoption [4,6]. Smallholder farmers in particular are still reluctant about the performance of STMV [16]. STMV dissemination methods are inefficient and do not allow smallholder farmers in sub-Saharan Africa to access information [10]. Access to STMV seed is also indicated as a constraint to the adoption. These barriers are reflected in high seed prices that make access to the technology particularly challenging for vulnerable groups [4,6,16], resulting in gender disparity in STMV adoption [15,17]. The lack of information on local sources of STMV seeds also makes access to the technology difficult. For instance, Simtowe et al. [13] showed that the adoption rate could increase to 30% and 47% if STMV seeds were availed to the farming population and sold at a more affordable price to farmers. Farmers are not willing to take the risk of adoption when access to the technology is not guaranteed for future uses [13].

Typically, technology adoption is explained by the attributes of the technology, the characteristics of the adopter and their farm, and

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environmental factors [18]. In the specific case of STMV, these factors are largely addressed [1,5,12]. Dissemination methods have received little attention, although their effectiveness determines the adoption of STMV.

Agricultural technologies diffusion is generally based on two approaches. The top-down approach –based on classical methods of capacity building, and the bottom-up approach –based on partnership and cooperation between actors [19,20]. The top-down approach focuses on the transfer of technologies developed by research. In this context, adoption requires the capacity building of farmers [21,22]. The partnership and cooperation approaches assume that innovations emerge spontaneously from social norms, trust, interactions, traditions, traditions, and beliefs between actors [23,24]. The two approaches affect adoption in different ways. Top-down dissemination methods seem to be more effective for technological innovations, However, bottom-up dissemination methods are effective for organizational and institutional innovations [25]. The issue of STMV seeds seems to be delicate. STMV seeds are perceived as technological innovation and their adoption depends on several factors, including the attributes of the technology and the adopter's propensity to innovate. However, the varieties released for inclusion in the variety's catalog, seed certification, etc. remain institutional issues in most sub-Saharan Africa countries. Thus, the issue of seed adoption in this region becomes challenging. Between capacity building and partnership approaches, which should be the ideal dissemination methods for the sustainable adoption of STMV seeds? This paper addresses this issue by analyzing the diffusion/promotion methods developed for scaling up STMV seeds in Sub-Saharan Africa. Data are from the activities of the Accelerating Genetic Gains in Maize and Wheat for Improved Livelihoods (AGG) project in Benin. Identifying the best STMV seed dissemination techniques will help extension services and STMV promotion projects to improve their interventions. It may impact STMV adoption due to improving the effectiveness of field interventions.

2. Progress in innovation diffusion approaches in sub-Saharan Africa

There is a wide range of theories on adoption processes in the literature [10,16,26–28]. Most researches on adoption are based on Rogers' theory of diffusion, which describes how innovations are adopted over time [22,29]. Diffusion refers to the process by which innovations spread among members of a social system over time. The decision to adopt is a mental process that is influenced by five attributes: relative advantage, compatibility, complexity, testability, and observability [22]. In addition, how the innovation is positioned or spread determines the level of adoption [30,31]. In this sense, several works have shown the contribution of dissemination approaches to innovations' adoption rate [3,25,32,33].

Partisans of top-down approaches believe that building stakeholders' capacity encourages adoption of agricultural technologies. This capacity-building is carried out through several methods and techniques such as demonstrations/on-farm trials, Farmer Field Schools (FFS), Training and Visit (T&V) [1,3,13,34] etc. In this category, new methods based on information and communication technologies usage are increasing. It is the case of capacity building of smallholder farmers through videos [35]. Some work has recognized that capacity building approaches are efficient in the diffusion of agricultural technologies [25,36,37]. However, the success of these approaches is mitigated and does not achieve the desired results [25]. Partnership approaches based on the concept of innovation systems (IS) have recently been introduced to address the limitations of traditional dissemination approaches mostly developed by National Agricultural Research Systems [23,38–40]. Innovation system approaches are based on the assumption that technology adoption is effective when stakeholders with different backgrounds and interests come together to diagnose problems, identify opportunities, and find ways to achieve their goals [24]. The most effective form of partnership and cooperation approaches is the innovation platform, which has been proven successful in scaling up agricultural technologies [23,30,38–40].

It is widely recognized that agricultural technology diffusion approaches lead to adoption outcomes, although performance remains questionable in some contexts. For most studies, the adoption decision is usually measured as a dichotomous variable, adopted or not adopted. Since adoption is a process that operates over time, it is important to serialize the levels of adoption. According to Rogers [22], adoption is a process of five steps: knowledge, persuasion, decision, implementation, and confirmation. In understanding the process of agricultural technology adoption, Lambrecht et al. [41] distinguished three adoption steps: awareness, tryout or use, and continued adoption. Srisopaporn et al. [42] measured the adoption of agronomic practices between never, only once, and continued adopters.

3. Methodological approach

The study is conducted in two main phases: the identification of STMV seeds dissemination methods and their evaluation.

3.1. Identification of stmv seed promotion methods

The first phase was to identify initiatives that promote STMV seed in Benin. Two sources were examined: the National Institute of Agricultural Research (Institut National des Recherches Agricoles du Bénin, INRAB), and the Territorial Agency of Agricultural Development (Agence Territoriale de Développement Agricole, ATDA). They constitute the operational services of the Ministry of Agriculture, Livestock and Fisheries (Ministère de l'Agriculture de l'Elevage et de la Pêche, MAEP) related of agricultural research and extension in Benin.

Interviews with key informants from these structures revealed that there had been only one initiative to promote STMV seeds in Benin. It was the "Drought Tolerant Maize for Africa (DTMA) project", which became "Accelerating Genetic Gains in Maize and Wheat for Improved Livelihoods (AGG) in 2020. The project is jointly implemented by International Maize and Wheat Improvement Center (CIMMYT), and the International Institute for Tropical Agriculture (IITA), in collaboration with Benin's agricultural research systems through in-country grants. The institutions involved in the implementation are INRAB through its research centers and the University of Parakou through the Laboratoire Société-Environnement (LaSEn).

We conducted unstructured in-depth interviews with 12 key informants involved in the implementation of this project in Benin, including two researchers and 10 field technicians. The interviews identified and described the methods used for the promotion and dissemination of STMV seeds in the intervention areas. These methods are summarized and described in this paper.

3.2. Evaluation of stmv promotion and dissemination methods

The second phase was to evaluate the dissemination methods used by the STMV seed promotion project based on farmers' perceptions.

3.2.1. Study area and sampling

The study was conducted in the district of Kandi in northern Benin. The average annual rainfall in this district is 904.9 mm. Despite the low rainfall, Kandi is the leading maize-producing district (MAEP, 2020). STMV projects have been implemented in this district since 2007. Therefore, maize farmers are familiar with the activities of STMV projects.

The evaluation is based on a total of 150 maize producers who were involved in STMV dissemination/promotion initiatives. They were randomly selected from maize farmers' cooperatives. The maize farmers involved in the study were 82% men and 18% women. Women's participation in rural projects was generally low in the sample population. They have small land areas. Most of their decisions are made by their husbands who are the head of household. In this research, the women involved are heads of their household, so they had more time to participate in the project activities.

3.2.2. Implementation of evaluation

In this research, we consider adoption as a three-step process: knowledge, use, and continued adoption of agricultural technologies. Indeed, this research assesses the extent to which the dissemination methods utilized contribute to the acquisition of knowledge, use, and continued adoption of agricultural technologies through the case of STMV seeds. Each farmer was asked whether a particular method is suitable for disseminating, using, or appropriating STMV seeds. Thus, the farmer gives his perceptions of three statements related to a particular dissemination method (DMi):

- DMi is the suitable method to make STMV seeds known by farmers;
- DMi is the suitable method to encourage the use of STMV seeds by farmers;
- DMi is the suitable method to induce the adoption of STMV seed by farmers.

DMi varies according to the dissemination methods identified in the first phase of the study. Farmers' perceptions were estimated on a five-point Likert scale (1 = strongly disagree to 5 = strongly agree).

In addition, socio-demographic characteristics of farmers were collected, including gender, age, level of formal education, maize cultivation experience and knowledge of STMV. The reliability of farmers' perceptions was tested using Cronbach's alpha (Table 1). Cronbach's alpha value assesses reliability by comparing the amount of variance shared, among the overall variance of the measured items. Cronbach's alpha is most robust when it is close to 1 [43]. A Cronbach's alpha value less than 0.6 is unacceptable [43].

After checking the reliability of the measurements, the items related to the "Village General Assembly (VGA)" method were removed from the analysis because Cronbach's alpha value is low (0.373) (Table 1). The Friedman test was applied to analyze the differences between the methods evaluated because the variables measured are ordinal (Likert scales) [44]. The Friedman test is the non-parametric alternative to the one-way ANOVA with repeated measures. It does not require a normal distribution of observations. To examine the differences, we applied the Wilcoxon rank test to the different combinations of related groups [45].

4. Results

4.1. Characteristics of maize farmers involved in the study

Descriptive statistics of respondents are presented in Table 2. It emerges that the average age of the maize farmers included in the sample is about 47 years. The average number of years recorded in maize production in the sample population was approximately 21 years (Table 2). Farmers have gained experience and been involved in several projects in the maize sector. They know project intervention methods and are able to give their perceptions on the effectiveness of these methods.

The number of years of formal education of farmers is about 9 years, which corresponds to secondary education (Table 2). However, the number of years of education for women is low at about 5 years, which corresponds to the primary level. With these levels of formal education in rural areas in the context of North Benin, farmers are open to innovation and to participate in extension activities in their field of activity.

4.1. Main techniques used in stmv seeds diffusion

A variety of methods were used in STMV seed dissemination. A total of 9 methods were identified and grouped into four categories according

Table 1
Reliability of items based on Cronbach's alpha.

Dissemination methods	Items	Cronbach's alpha value
Innovation platform	■ Innovation platform is the suitable method to make STMV seeds known by farmers; ■ Innovation platform is the suitable method to encourage the use of STMV seeds by farmers; ■ Innovation platform is a suitable method to induce the adoption of STMV seed by farmers.	0.740
Demonstration/ trial	■ Demonstration is the suitable method to make STMV seeds known by farmers; ■ Demonstration is the suitable method to encourage the use of STMV seeds by farmers; ■ Demonstration is the suitable method to induce the adoption of STMV seeds by farmers.	0.691
Competition	■ Competition is the suitable method to make STMV seeds known by farmers; ■ Competition is the suitable method to encourage the use of STMV seeds by farmers; ■ Competition is the suitable method to induce the adoption of STMV seed by farmers.	0.587
Prize/incentive of users	■ Incentive of users (throught award) is the suitable method to make STMV seeds known by farmers.	0.881
Donation/ subsidy	■ Donation is the suitable method to make STMV seeds known by farmers; ■ Donation is the suitable method to encourage the use of STMV seeds by farmers; ■ Donation is the suitable method to induce the adoption of STMV seed by farmers.	0.863
Exhibition at Fair	■ Exhibition at Fair is the suitable method to make STMV seeds known by farmers; ■ Exhibition at Fair is the suitable method to encourage the use of STMV seeds by farmers; ■ Exhibition at Fair is the suitable method to induce the adoption of STMV seed by farmers.	0.574
Radio broadcast	■ Radio broadcast is the suitable method to make STMV seeds known by farmers; ■ Radio broadcast is the suitable method to encourage the use of STMV seeds by farmers; ■ Radio broadcast is the suitable method to induce the adoption of STMV seed by farmers.	0.862
Video projection campaign	■ Video projection campaign is the suitable method to make STMV seeds known by farmers; ■ Video projection campaign is the suitable method to encourage the use of STMV seeds by farmers; ■ Video projection campaign is the suitable method to induce the adoption of STMV seed by farmers.	0.633
General Assembly organization	■ General Assembly organization is the suitable method to make STMV seeds known by farmers; ■ General Assembly organization is the suitable method to encourage the use of STMV seeds by farmers; ■ General Assembly organization is the suitable method to induce the adoption of STMV seed by farmers.	0.373

Table 2
Characteristics of maize farmers involved in the study.

Farmers' characteristics	Female (N = 27)		Male (N = 123)		All (N = 150)	
	Mean	SD	Mean	SD	Mean	SD
Age (year)	47.04	6.94	46.43	9.63	46.54	9.19
Experience in maize production (year)	19.56	7.55	21.83	16.49	21.42	15.28
Formal education (year)	4.59	4.02	9.50	4.19	8.61	4.56

to the principles that motivate their implementation: social ties strengthening, capacity building, incentive, and awareness-raising (Table 3).

The strengthening of links between actors was examined through the implementation of innovation platforms. Due to the difficult access to seeds of adapted varieties in the context of climate change, cooperatives of maize farmers are developing partnerships with certified seed companies. Farmers' cooperatives creation is mostly motivated by seed entrepreneurs (case of maize innovation platform in Couffo). In the functioning of innovation platforms, awareness raising activities, capacity building (specific training, exchange visits, etc.), and even subsidies for STMV seeds were noticed.

On-farm trials were conducted to demonstrate the performance of improved maize varieties compared to local varieties. These trials were conducted either by farmers with the support of technicians or directly by technicians. Exchange visits were organized at the demonstration sites. These locations were also set up as training fields for the farmers. These methods are based on technology transfer through capacity building of farmers.

Incentive-based promotion methods include organizing contests, rewarding the user, and donating or subsidizing STMV seeds. These methods were used when farmers have low income and not very receptive to innovation, either due to cultural limitations or adoption history. Radio broadcasts, video projection campaigns, exhibitions at fairs, and the organization of village assemblies are utilized to sensitize farmers to adopt STMV seeds.

4.2. Perceived performance of stmv promotion methods

Table 4 presents the median values and mean ranks of the dissemination modes analyzed. There are statistically significant differences in perceived performance of STMV seeds dissemination methods depending on which form of adoption ($\chi2 = 442.625$, $p = 0.000$ for technology known; $\chi2 = 515.923$, $p = 0.000$ for technology use; $\chi2 = 508.645$, $p = 0.000$ for technology appropriation).

4.2.1. Form of adoption by dissemination method

Analysis of the median values for each promotion method of STMV seeds shows that the establishment of innovation platforms promotes the knowledge, use, and appropriation (continued use) of agricultural technologies, including STMV seeds.

The median scores for the Innovation Platform and Price methods, are 5 and 4, respectively, regardless of the form of adoption. This indicates that both methods were highly appreciated by maize farmers. Thus, to induce knowledge, use, and appropriation of STMV seed, PI implementation is the indicated method, followed by user incentives through awards.

Demonstrations/trials and seed donations/subsidies are more appropriate to generate both knowledge and use of STMV seed (median values are 5 and 4 for demonstrations and donations, respectively). Fair exhibits and radio broadcasts are more effective according to farmers in promoting knowledge of agricultural technologies such as STMV seeds.

Video projection campaigns, on the other hand, are more suitable for inducing the use and appropriation of STMV seed. Regardless of the forms of adoption targeted, organizing competitions is not an ideal

Table 3
Key methods used in STMV seed dissemination.

Reported technique	Description	Theoretical driven
Creation of innovation platforms	Social links were reinforced between maize farmers' cooperatives and certified seed companies by zone. Depending on the difficulties faced by the farmers in the platform, seed companies identify, produce and provide them with adapted STMV. Awareness-raising, demonstration and motivating actions, donation of STMV seeds were also carried out in the platforms by the seed companies to persuade farmers to adopt the STMV.	Social link strengthening
Demonstrations / Trials	Two types of trials were conducted in Benin as part of the scaling up of maize varieties. The first type of trial was entirely under the management of farmers who grow STMV according to his usual cultivation practice compared to the local maize variety. The second type of trial was conducted by agricultural advisors. The objective is to show the performance of STMV compared to local maize varieties when appropriate technical itineraries are respected. The trials were carried out in maize-producing villages, usually in a plot facilitating visibility. Furthermore, experience-sharing visits were organized at the sites.	Capacity building
Organization of Competition	Competitions were organized between maize farmers in the villages. It aims to test their knowledge of STMV. The best farmer is awarded (Tshirt, cap, STMV seeds, etc. with STMV project logo, with an awareness raising message). Football competitions were also organized between colleges. The best team was also awarded. These festive occasions that mobilize large numbers of people in the villages, have allowed us to promote STMV.	Incentive
Prize for users	STMV areas per household were recorded. The best users of STMV were awarded based on cultivated areas. The surveys were carried out by the agricultural advisors in the villages.	Incentive
Donation of STMV seeds	5 kg packs of STMV seed were made with labels showing the characteristics of the variety. Seed donation sessions were organized in maize production areas. The beneficiaries are farmers belonging to maize farmers' cooperatives. They were invited to test the varieties and the results will be appreciated by other farmers in the area at the end of the season.	Incentive
Exhibition at Fair	STMV were exhibited at fairs. That is to inform and sensitize people about STMV seeds. Particular attention was paid to the performance of the varieties in terms of yield, resistance to different types of stress and diseases.	Information, awareness
Radio broadcast	Awareness programs were periodically organized on local radio stations. During these broadcasts, information is given on the performance of different varieties in response to the difficulties encountered by producers.	Information, awareness
Village General Assembly (VGA)	VGAs are organized periodically by agricultural advisors involved in	Information, awareness

(*continued on next page*)

Table 3 (*continued*)

Reported technique	Description	Theoretical driven
	STMV diffusion. These VGAs were the mean to inform and sensitize producers about the STMV. Good production practices for these varieties were also discussed on these occasions.	
Campaign of video projection	In each village, producers were mobilized to follow thematic videos. These videos focus on the impacts of climate change on maize production, the performance of STMV in the face of climatic risks, and good maize production practices in general.	Information, awareness

Table 4
Median and mean ranks of dissemination methods of STMV seeds.

Dissemination method of STMV seeds	Technology known		Technology use		Technology appropriation	
	Median	Mean rank	Median	Mean rank	Median	Mean rank
Innovation platform	5.00	6.82	5.00	7.30	5.00	7.12
Demonstration	5.00	5.01	4.00	4.16	2.00	3.71
Competition	2.00	1.93	1.00	1.94	1.00	2.21
Prize/ Award	4.00	3.41	4.00	4.49	4.00	5.14
Donation	4.00	5.17	4.00	5.54	3.00	5.25
Exhibtion at fair	4.00	4.98	2.00	2.97	1.00	2.51
Radio broadcast	4.00	5.16	3.00	4.30	3.00	4.58
Video projection	2.00	3.53	4.00	5.30	4.00	5.49
N	150		150		150	
Khi-deux	442.625		515.923		508.645	
ddl	7		7		7	
P	0.000		0.000		0.000	

method according to maize farmers.

4.2.2. Perceived performance among dissemination methods

4.2.2.1. Technology knowledge. Innovation platform implementation has a significantly higher mean rank than the other dissemination methods at the 1% level of significance (Table 5). Therefore, maize farmers consider innovation platforms to be the more suitable method for technology awareness.

The difference between the ranks of the methods "radio broadcast, seed donation/subsidy, and trade show exposure" is not significant at the 5% level (Table 5). But the ranks of these three methods are significantly higher than the ranks of the other methods. It turns out that these methods are the second most effective way for farmers to promote STMV seeds. Organizing competitions is not an ideal method to promote knowledge about STMV seeds.

4.2.2.2. Technology use. The average rank of innovation platforms is significantly higher than the average rank of other dissemination methods (Table 5). The implementation of an innovation platform emerges as the more suitable method for inducing the use of STMV seed. Innovation platform, video projection campaigns and seed donations/ subsidies have similar average ranks ($z = -0.122$ and $p = 0.903$ for VIDEO- DON; see Table 5) but are statistically higher than the ranks of the other methods. Awarding users and radio broadcasts came third. The average rank obtained by organizing competitions is still statistically the lowest, indicating that this method is not ideal for inducing the use of STMV seeds.

4.2.2.3. Technology appropriation. The results in Table 3 show that the Innovation Platform is the best method for technology appropriation

Table 5
Results of Wilcoxon signed-rank tests.

Test pairs	Technology known	Technology use	Technology appropriation
DEMO - PI	−7.217*	−10.595*	−10.320*
COMP - PI	−10.587*	−10.717*	−10.761*
PRIZ - PI	−10.750*	−10.384*	−7.618*
DON - PI	−7.765*	−8.199*	−8.226*
FAIR - PI	−8.376*	−10.544*	−10.691*
RADIO - PI	−8.150*	−10.081*	−9.986*
VIDEO - PI	−9.308*	−6.764*	−7.712*
COMP - DEMO	−8.700*	−8.887*	−7.382*
PRIZ - DEMO	−6.465*	−2.989*	−5.399*
DON - DEMO	−1.732***	−6.515*	−6.618*
FAIR - DEMO	−1.522	−5.914*	−5.429*
RADIO - DEMO	−2.960*	−0.955	−4.728*
VIDEO - DEMO	−3.714*	−3.340*	−6.507*
PRIZ- COMP	−7.340*	−9.218*	−8.972*
DON - COMP	−9.802*	−9.845*	−9.667*
FAIR - COMP	−9.871*	−6.125*	−2.266**
RADIO - COMP	−9.907*	−9.396*	−9.575*
VIDEO - COMP	−6.124*	−9.006*	−9.627*
DON - PRIZ	−6.955*	−4.009*	−0.348
FAIR - PRIZ	−6.606*	−6.725*	−8.063*
RADIO - PRIZ	−7.076*	−0.763	−1.842***
VIDEO - PRIZ	−1.569	−2.276**	−1.639
FAIR - DON	−0.184	−8.943*	−9.024*
RADIO - DON	−1.646	−4.203*	−2.436**
VIDEO- DON	−5.457*	−0.122	−1.569
RADIO - FAIR	−1.689***	−6.455*	−8.362*
VIDE- FAIR	−6.000*	−7.734*	−9.164*
VIDEO- RADIO	−7.368*	−3.314*£	−3.771*

* significant at 1%.
** significant at 5%.
*** significant at 10%.

according to farmers. This method had a statistically significantly higher mean rank than the other methods. Video projection campaigns, donations/grants and, user prizes follow. The least ideal dissemination method for technology appropriation remains the organization of competitions.

In summary, innovation platforms, based on strengthening links between actors are seen by farmers as a suitable method to promote STMV seeds and induce their use and appropriation. Capacity building methods such as demonstrations seem to be more interesting to promote knowledge and use of STMV seeds. However, they do not lead to the appropriation or sustainable use of agricultural technology. Incentive-based methods such as donations/subsidies, user prizes/awards seem to have the same perceived effect on adoption as innovation platforms. However, their performance in agricultural technology appropriation remains less appreciated than social methods based on strengthening links. Awareness-based methods, particularly radio broadcasts, are also valued by maize farmers for the adoption (knowledge, use, and appropriation) of a technology.

5. Discussion

This research aims at assessing STMV farmers' perceptions of the effectiveness of STMV dissemination techniques. Our results revealed that dissemination methods that focus on strengthening social ties, raising awareness, and providing incentives are perceived by farmers to be more effective in promoting STMV adoption.

The implementation of innovation platforms, a method based on strengthening social links between stakeholders, is more suitable to raise awareness, inducing use, and continued adoption of STMV. In the same perspective as our results, most research on innovation dissemination has confirmed the performance of innovation platforms [39,46,47]. Stronger market connections, value chains, improved productivity, technical knowledge, and stronger social ties are reported as some advantages of innovation platforms [46]. This method combines several other techniques depending on the dynamics of the network and the difficulties faced by stakeholders: capacity building, incentives, awareness-raising, etc. [25]. In particular, this is the success factor of the Innovation Platform for the sustainable adoption of agricultural technologies such as STMV seeds. That is what Ouidoh et al. [25] called co-capacitation in scaling up innovations on the traditional leafy vegetable. For Ouidoh et al. [25], the best dissemination approach in their context should combine building connections and capacity for stakeholders to accelerate the adoption. As reported by Sinyolo [10], partnerships and cooperation between stakeholders increase the likelihood of STMV seed adoption as they facilitate access to and exchange of important information about modern technologies. To increase adoption of STMV seeds, interventions need to focus on building social links between stakeholders to facilitate farmers' access to improved seeds [11]. Strengthening social links between stakeholders substantially increase awareness, knowledge, and technology adoption [28].

Awareness-based dissemination methods have also proven effective for the dissemination of agricultural technologies. These techniques use theories of persuasion to explain the change in attitude and belief that occurs when people are exposed to the technologies advocated by a communicator [48,49]. In the specific case of STMV dissemination, some authors, including Simtowe et al. [13], Fisher et al. [4] and Kassie et al. [8] argued that the lack of awareness is one reason for the low rate and rapid adoption of STMV in sub-Saharan Africa. In this sense, STMV adoption could be significantly improved if dissemination policies emphasized persuasion-based techniques, such as raising awareness.

Our findings support that incentive-based dissemination methods, including STMV seed donation, appear to be effective in raising awareness of the technologies and inducing their use. Fisher and Kandiwa [50] found similar results, showing that subsidies significantly narrowed the gender adoption gap when targeted at female-headed households. Nevertheless, its effectiveness remains mitigated with regard to the continued adoption of agricultural technologies, including STMV seeds. Previous work by Mason and Ricker-Gilbert [51] revealed that subsidies for STMV seeds induce adoption but crowd out commercial purchases of STMV seeds by smallholder farmer, negatively impact continued adoption of the technology.

This research has made a substantial contribution to by clarifying the forms of adoption induced by the different methods of STMV dissemination. Depending on the intended adoption form (awareness, use, and continued adoption), extension services and STMV promotional projects could focus on strengthening social ties, raising awareness, and providing incentives. This can be considered a significant advance in the field of dissemination of agricultural innovations for sustainable adoption. Regardless of the effectiveness of the methods, the question remains which of the three methods leads to faster adoption of agricultural technologies. Future studies may address this question.

6. Conclusion

The study evaluated the effectiveness of methods for promoting STMV seeds using the case of the Republic of Benin. We based our analysis on the perceptions of STMV farmer households using the Likert scale to assess each method's contribution to knowledge, use, and continued adoption of STMV seeds.

The methods that promote STMV seed are categorized into four groups based on their principle. The first group, based on strengthening links between stakeholders, is represented by innovation platforms. Capacity building methods were implemented through on-farm trials associated with exchange visits. Awareness raising methods include radio broadcasts, Village General Assemblies (VGAs), video projection campaigns and exhibitions at fairs. Stakeholders' incentive techniques include the donation of STMV seeds, the organization of competitions between farmers and the awarding of prizes to STMV seed users.

The evaluation of these methods indicate that innovation platforms, a method based on strengthening links, are the most effective to simultaneously promote knowledge, use, and continued adoption of STMV seeds. User awards –a motivational/incentive method, are also valued for their effectiveness, but not as innovation platforms. The effectiveness of other dissemination methods in inducing continued adoption of technologies remains limited. However, among the awareness-based methods, video projection campaigns are valued by STMV farmers for generating continued adoption. These results help to clarify the performance of agricultural technology dissemination methods by highlighting the forms of adoption they generate. Future research may focus on assessing the level of adoption induced by each method of dissemination.

Declaration of Competing Interest

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