Analyzing the Efficacy of Communication Channels in Promoting the Adoption of Intercropping Technology Among Western Kenyan Smallholder Farmers

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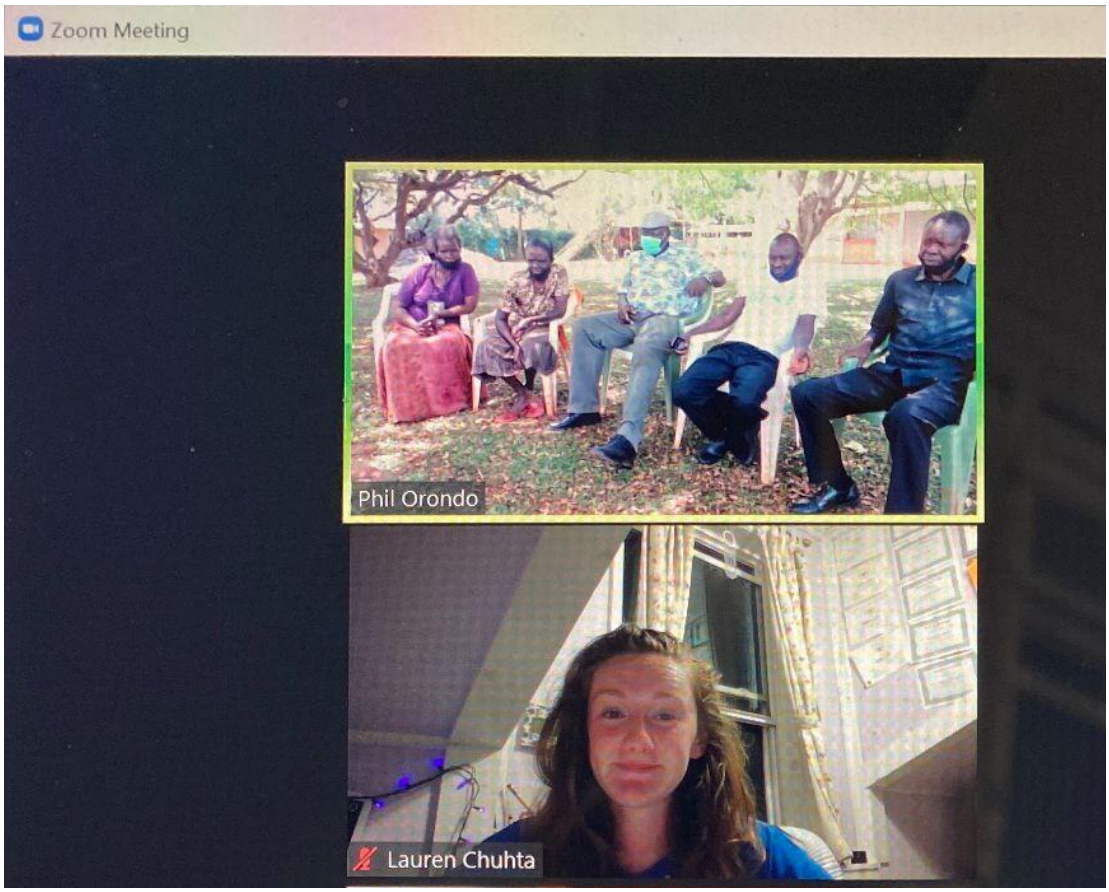
Increasing the Accessibility of Push-Pull Technology Benefits



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THE WORLD FOOD PRIZE

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Personal Reflection

This is my first bout of writer's block, trying to organize an infinity of self-expansion into 1-2 pages. In a mere three months, I developed exponentially the skills that mean the most to me: my ability to communicate, to act with professionalism, to connect with others, and to discover through science. I gained astronomical cultural insight, connecting with farmers and scientists across the barriers of differing lifestyles, geography, and computer screens. I caught a glimpse at the expanse of agriculture. There is a purpose for me there, and I aim to become an asset to the field, combining my love of people and science to work in the communication of research, or perhaps some area of diplomacy.

These realizations and self-advancements came through a variety of experiences within this internship. The barriers posed by the pandemic and virtual working conditions provided unimaginable opportunities for growth. The eight-hour time difference between Kenya and New York meant I had to plan out my communications with my mentors in advance, pushing me to act with a higher level of professionalism than I previously considered myself to be capable of. Any self-doubt I held was given no room to continue. Crackling Zoom audio on top of local dialect prompted me to find the confidence to speak up and ask for clarification, background information, and help. And there is no such thing as saying the right thing in two different ways, I discovered. Across a language barrier, words are not simply words. I was propelled to speak with clarity and conciseness not previously required of me.

Working with the farmers and researchers I had the blessing to meet was hugely influential. Education is a privilege and not to be taken for granted, truly. Dairy cows, the kind I drive by on my way to school, are gold. Agriculture is not just sweetcorn and beef, it is bananas and goats and groundnuts and cassava. Cultural differences taught me all these things and more. But it was cultural similarities that introduced me to my biggest discoveries. To interact with people with whom I am culturally, generationally, professionally, and geographically different, and on top of that be separated by language barriers and computer screens, and *still* be able to connect with them, feel their pains and triumphs as if they are my own- how inherently bonded we are as humans. How connected. And I realized that this is what I want to do. I want to use the innate strength of humanity's given connection to aid our advancement as a society. I want to serve as a connector (whether that be a diplomat or a scientific communicator, I am still discovering) in the field that has fed me. There is a role in agricultural, scientific communication, and it is this purpose that I enter the next phase of my education pursuing.

Taking what I had learned of the scientific method outside of the classroom was a phenomenal experience. Designing and performing research to which there was no answer key was an astounding realization of the nature of discovery. I realized the infinity of knowledge, all there is to understand and develop and utilize, and it has granted me a greater love of learning and a stronger passion for my education. To design and perform original research that may contribute to a far broader effort of agricultural advancement- to play, perhaps, a small, indirect role in helping feed the world- has allowed me a glimpse at my purpose and potential. The motivation this realization has provided me with is beyond words.

I am continuing to recognize the benefits and personal growth promoted by this incredible experience. It would not have been unreasonable for the staff at *icipe* and the World

Food Prize Foundation to have taken this year off from the Borlaug-Ruan Internship Program, waiting for the pandemic to calm down and times to be easier. But the scientific and agricultural communities cannot pause for ease when there are advancements to be made- simply another lesson provided by those who made this opportunity possible for me. I am thankful beyond words for Dr. Matilda Ouma, Mr. Phil Orondo, Prof. Zeyaur R. Khan, Mr. Jimmy Pittchar, and Dr. Frank Chidawanyika for taking me in, opening my eyes, and introducing me to the real world of agricultural advancement. Ms. Barbara Stinson and Mr. Keegan Kautzky, you have provided me with the greatest gift of self-expansion by connecting me with *icipe* and working with me to be sure I realized the opportunity for all it could be. Without the work of Mrs. Betsy Foote, Mr. John Nevins, and Mr. Tom Manera in fostering my love of agriculture, communication, and science, I would not have been able to take these skills outside of the classroom for all the wonderful purpose and opportunity that awaited. This experience is more to me than words can embody. Thank you to all who made it possible.

Abstract

Push-pull, a system of intercropping, is a knowledge-based technology. Because of that, the key to making Push-pull and its associated benefits more accessible lies in increasing the efficiency with which this information is provided to smallholder farmers. This study explores the shortcomings and strengths of existing outreach methods and analyzes farmers' understanding of Push-pull and their desire to expand their understanding of the technology. It was found that 59% of farmers did not acquire all information necessary to implement Push-pull at their first education of the technology. Additionally, 66.7% of farmers suggested improving dissemination by adjusting methodology and content, with the most frequent proposals calling for an emphasis on group learning, hands-on training, and the increased use of

COVID-compliant media such as the internet and radios. The majority of farmers expressed a desire to learn more about Push-pull regardless of current sufficient understanding, and an analysis of farmers' understanding of Push-pull impacts reveals that environmental benefits are lesser known and therefore can be emphasized in Push-pull promotion to supplement word of mouth and draw in more farmers to dissemination programs. By adjusting Push-pull dissemination through these means to achieve higher quality and efficiency, knowledge about Push-pull can reach more farmers at a faster pace while maintaining the quality of education, helping increase the number of farmers who utilize Push-pull and realize the benefits.

Introduction

The International Centre for Insect Physiology and Ecology

In the year 1970, within the context of African postcolonialism, the International Centre for Insect Physiology and Ecology (*icipe*) was founded to address the continent's need for sustainable agriculture and an expanded community of indigenous scientists (Our History, n.d.). Today, *icipe* is an intergovernmental organization that staffs more than 400 and works with over 200 national institutes around the world (Our History, n.d.). The Centre performs interdisciplinary research on environmental systems and agriculture while simultaneously promoting social development, including female empowerment and involvement of the country's youth.

By focusing on insects, *icipe* works with one of the world's most diverse lifeforms. The environmental impacts of these animals are multifarious. While some arthropods like bees and silkworms provide smallholder farmers business opportunities, others impede agricultural productivity and promote poverty by destroying crops and degrading land. *icipe* works to manage these effects in the favor of farmers and the natural environment.

Push-pull Technology (PPT)

The financial foundation for millions of sub-Saharan farmers is the cultivation of cereals, with staple crops including maize and sorghum. However, crop yields are minimized by stemborers (a type of insect pest), poor soil fertility, and striga weed. Stemborers alone account for yield losses ranging from 30-70% in maize crops, and recent studies point to the pest's expansion into new areas (Mawuku et al., 2021). Striga weed is considered one of the greatest biological constraints to food production in sub-Saharan Africa. The specialized root-parasitic plant causes losses in cereal crop yields ranging from 15-100% (Atera et al., 2013). The severity and prevalence of soil degradation in Kenya is a fundamental agricultural barrier and is acknowledged by studies like the Kenya Soil Suitability Evaluation for Maize Production (Kamau, 2015). Working with Rothamsted Research, United Kingdom, *icipe* has developed an intercropping technology to address all three of these problems in maize and cereal fields (Push-pull Technology, 2019).

Push-pull involves the use of attractant and repellent plants to deter insects from the crop. An attractive trap plant, such as Napier grass (*Pennisetum purpureum*), is planted around the border of a repellant plant, such as various species of desmodium. These complexes are planted at specific intervals throughout the field, serving to pull stemborers away from the target crop and maximize yields. Additionally, desmodium inhibits the growth of striga, addressing the issue of weeds, and as both desmodium and Napier grass are perennial, soil moisture is conserved and soil fertility enhanced (Push-pull Technology, 2019). Current development of Push-pull focuses on the technology's application to other crops, including cereals and vegetables, as well as adapting the technology to hotter and drier climates through the use of different companion crop varieties.

The benefits provided by this technology are multidimensional. In 2009, an independent evaluation of Push-pull discovered that 75% of assessed farmers realized a three- or four-fold increase in crop yields by utilizing Push-pull in maize fields (Push-pull Technology, 2019). The resulting increase in income improves livelihood by making food security and education more accessible. Additionally, Push-pull promotes the diversification of farms by promoting livestock cultivation. The companion crops of Push-pull, including Napier grass and desmodium, are high in protein, and therefore make high-quality fodder crops (Push-pull Technology, 2019). As such, they can be sold to other farmers or used to feed one's cows for increased milk production. Whichever way harvested companion crops are used, they provide an additional source of income for smallholder farmers.

Push-pull is an efficient, low-cost innovative technology, specific inputs including the seeds of companion crops but no special tools. Push-pull is, however, knowledge-intensive, as the understanding of how to plant and arrange the companion crops is what makes the technology work. As such, it is a lack of information that prevents most non-Push-pull farmers from utilizing it and realizing the benefits of the technology.

Disseminating Push-pull Information

icipe uses a variety of approaches in making information on Push-pull available to smallholder farmers. The institute works with government institutions, non-governmental organizations (NGOs), community groups, and private sector stakeholders. Examples include *icipe*'s work with agricultural extension officers, organizations such as Heifer International, and local churches in expanding the outreach of Push-pull dissemination programs. Such programs include a variety of methods including information bulletins, farmer teachers (local farmers trained by outreach staff in teaching other farmers how to implement Push-pull), mass media,

field days, mobile phone technology, participatory video (in which farmers record their experiences with Push-pull on projectors to be shared with other communities), and farmer field schools (Push-pull Technology, 2019).

With the technology's emphasis on farmer understanding, these publication and training programs are continually assessed. Not only must more farmers be informed, but current farmers need to be kept updated on developments of the technology. What is the most efficient, quality manner to educate farmers about Push-pull? The solution to this query evolves with the field of agriculture, and thus consistent research is required to maintain ideal dissemination. If the feedback of Push-pull farmers regarding dissemination is collected and analyzed, then it may be used to revise current outreach efforts so that more farmers can be provided with the information they need to implement the technology and derive the benefits.

This study held the following specific objectives:

I. Learn about the effectiveness of existing communication channels for accessing and sharing information about Push-pull technology
II. Determine the extent of farmers' understanding of Push-pull mechanism and impacts
III. Identify the most influential factors outside of communication channels that contribute to Push-pull technology adoption

To address these objectives, the study was developed with the following overarching questions in mind:

I. How were farmers who practice Push-pull exposed to the technology, and how influential do these farmers believe these outreach methods were in leading them to practice Push-pull?
II. To what extent do farmers understand the Push-pull mechanism and what further information do they seek?

III. What are the most influential factors outside of communication that contribute to Push-pull technology adoption?

These objectives and supporting questions were designed to analyze the effectiveness of current dissemination and the need for continued training/education of current Push-pull farmers, as well as to confirm the importance of information and awareness in Push-pull adoption amid other factors.

Methodology

Interviews and Demographics

Apparatus

To address these objectives, a series of survey questions were composed to address each overarching question. Questions were reworded and some were eliminated based on feedback from Dr. Ouma and preliminary interviews, in which draft surveys were given to sample farmers to test for flow and ease of comprehension. After the eighth survey of data collection, two questions were eliminated due to time constraints. Analysis of the data focuses on the questions consistent through the surveys, and the answers collected in previous interviews to eliminated questions served as additional observations.

Procedure

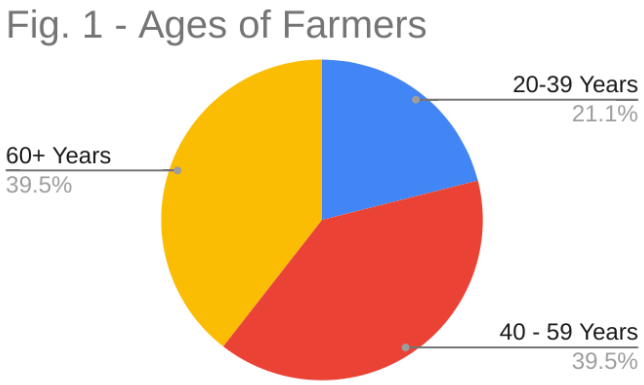
Dr. Ouma and Mr. Orondo visited Kenyan farms in person and set up computer audio and visual so that the survey could be conducted over Zoom. Dr. Ouma translated questions and responses for the farmers who could not speak English, and also explained general conditions and background information relevant to the data. For the first five surveys, farmers were interviewed one at a time. After that, for greater efficiency, multiple farmers were interviewed at once; one question was asked at a time (in the chronology of Appendix 1), and the responses from each farmer were given and recorded consecutively. Not all farmers answered every survey

question; time constraints cut some interviews short. However, interviews were conducted until at least thirty responses were recorded for each survey question.

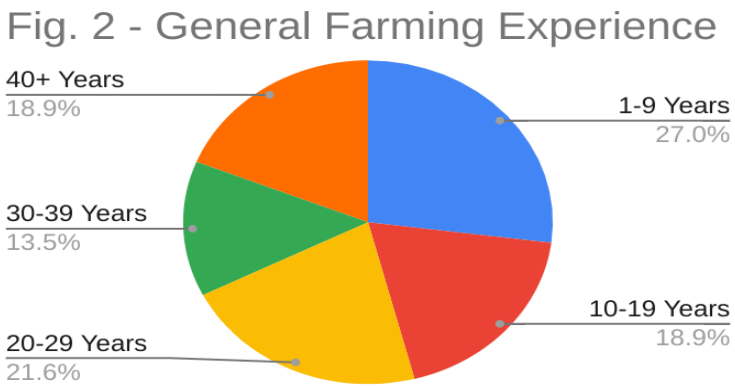
Participants

Before analytical questions were asked, basic demographic information was collected. 38 farmers were interviewed in total. 58% were women and 42% were male. The average household size of interviewed farmers was 7 people, and the average farm acreage was 2.5 acres.

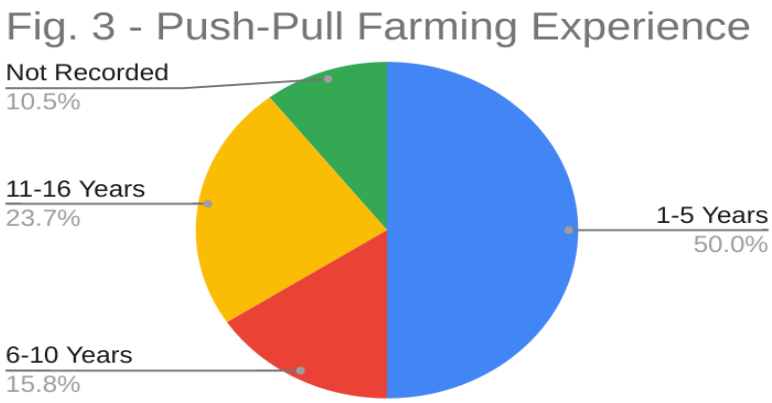
About 20% of interviewed farmers were Kenyan youth. The majority of farmers were over 40 years old. Farmers within the range of 40-59 years and 60+ years were equally represented (Fig. 1).



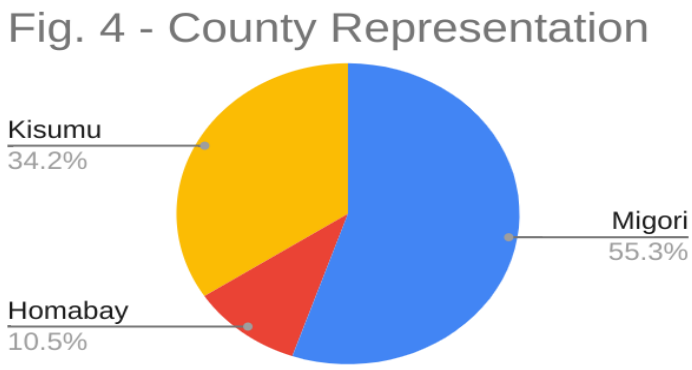
Farmers with differing lengths of general farming experience achieved approximately equal representation in this survey. General farming experience is defined as the years a person has spent farming professionally (Fig. 2).



50% of farmers had been using Push-pull technology for 1-5 years. For four farmers, their years of experience in Push-pull practice was not recorded (Fig. 3).



Interviews were conducted in three counties in the Lake Victoria region of western Kenya. The majority (55.3%) of interviewed farmers were sampled from Migori County of three different sub-counties including Uriri, Suna East, and Awendo (Fig. 4).



Focus Group Discussions and Demographics

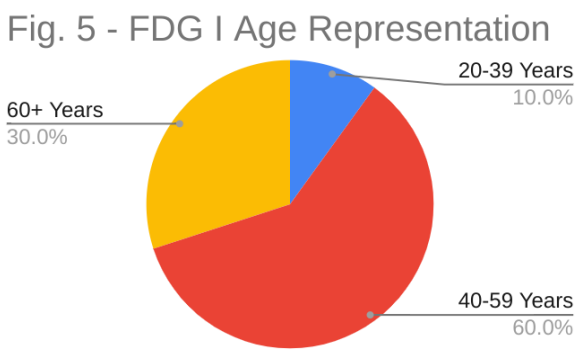
Apparatus and Procedure

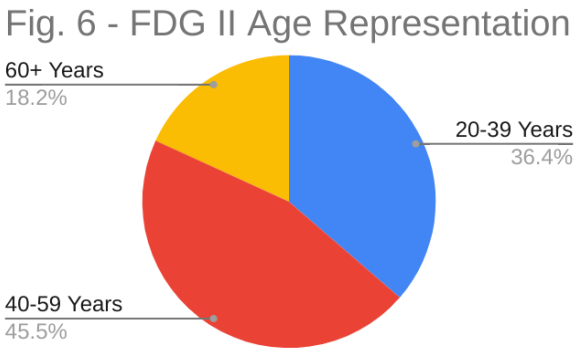
After the majority of individual interviews had been conducted, focus group discussion questions were designed (found in Appendix 2). Focus group discussions were executed to present an opportunity for the themes apparent in individual interviews to be corroborated by an additional means of analysis. Focus group questions were designed based on the data collected in individual interviews. The questions were then posed to a group rather than individuals, allowing participants to discuss with each other.

Five discussion questions were designed to address the major objectives of the survey. Two focus group discussions were held consisting of 11 farmers each, with the first administration serving partially as preliminary. In the first draft of discussion questions, the first two questions were structured with unnecessary complexity and as a result did not collect relevant responses. These questions were altered for the second administration when they successfully prompted applicable responses. The last three questions were satisfactory and remained constant for both administrations.

Participants

11 farmers participated in each discussion resulting in a sample size of 11 for the first two prompts (responses for the first two questions of the first administration were discarded) and a sample size of 22 for each of the last three questions. Both focus discussion groups (FDGs) were composed of 6 women and 5 men. The average age of the first Focus Discussion Group (Fig. 5) was 49, and the average age of the second group was 39. The second discussion group (Fig. 6) was held in Migori, Suna East, where the average Push-pull experience was 4 years.





Time Constraints

Time constraints played a major role in the interview process. The Kenyan COVID curfew limited the hours during which Dr. Ouma and Mr. Orondo could travel to reach farmers for interviews, and the farmers' schedules had to be worked around as well. What time was available was split between multiple studies; this survey was one of three to be conducted at a time. Additionally, factors such as weather and internet stability at times cut interviews short or expedited survey conduction. In one particular interview group, heavy rain cut the survey short, leaving only half the questions answered. This was addressed by conducting more interviews with the questions missed to achieve equal and adequate sample sizes for various analyses.

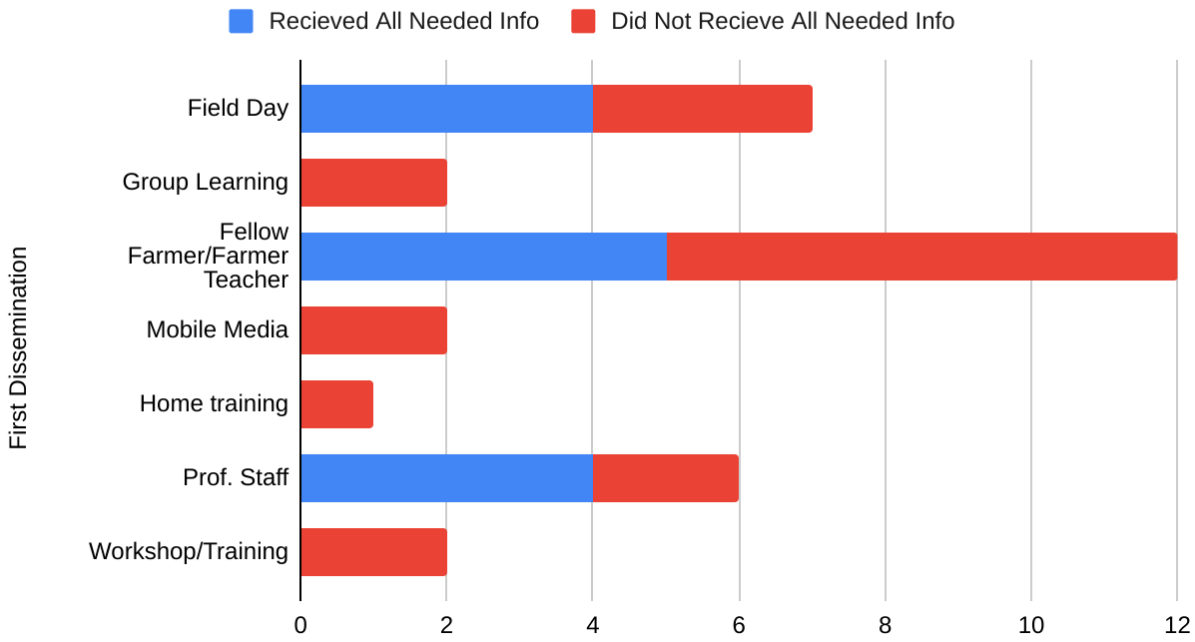
Results

Objective I - Learn about the effectiveness of existing communication channels for accessing and sharing information about Push-pull technology

Farmers were asked how they first heard about Push-pull technology, and if they received all needed information at this point. Needed information refers to the minimum level of understanding required to begin Push-pull farming. 59% reported that they did not receive all necessary information at their first contact, that they required further information in order to establish their Push-pull plot. Becoming aware of Push-pull from a fellow farmer, whether it be a farmer-teacher (a local farmer trained by ICIPE staff in training others in Push-pull), a spouse, or

a neighbor, was the most common primary access point. Field days and outreach by professional staff were the only reported means in which the majority of farmers received all necessary information. In every other dissemination approach, the number of dissatisfied farmers outnumbers those who acquired all needed information (Fig. 7).

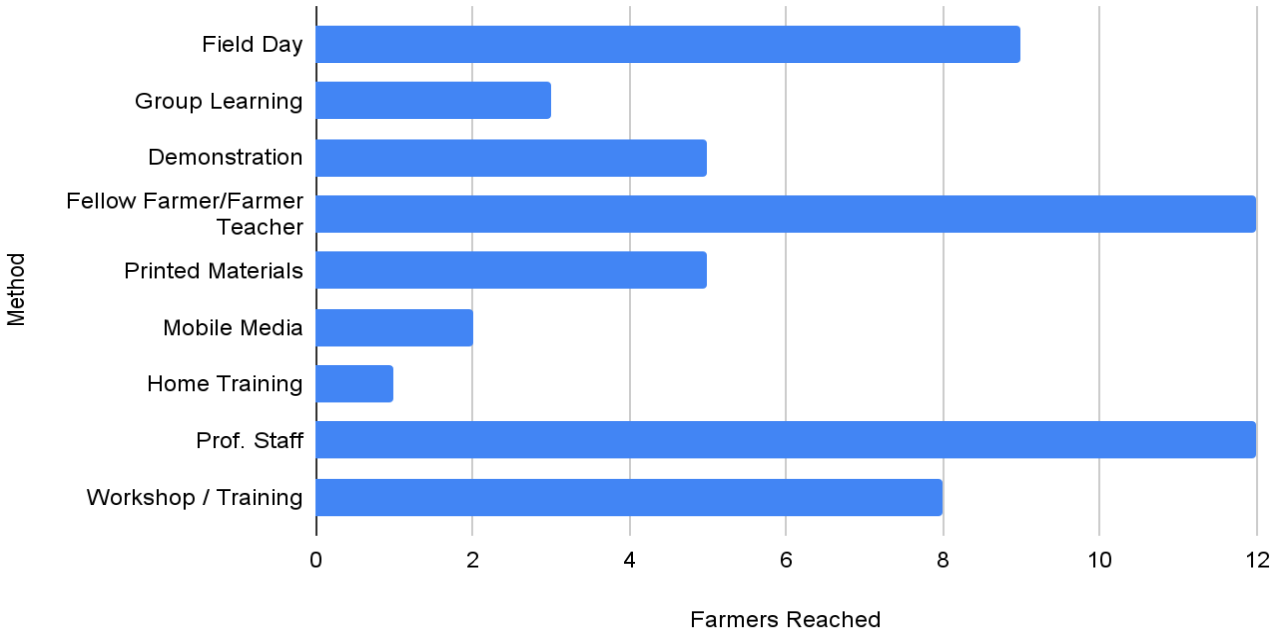
Fig. 7: Primary Dissemination and Farmer Satisfaction



Horizontal axis indicates the number of farmers who reported each primary dissemination.

Some farmers followed up their response on primary dissemination with additional outreach methods they had been exposed to. Field demonstrations, training by ICIPE field staff, field days, and trainings by fellow farmers were brought up as supplemental disseminations by four farmers each. Three farmers brought up workshops or hands-on trainings, and one farmer added group learning. These unprompted responses provided greater insight into the availability frequency of outreach methods. Fig. 8 shows the frequency of access for various dissemination methods, the data made up of both primary access points and supplemental disseminations.

Fig. 8 - Dissemination Methods Accessed



Farmers were then asked for suggestions on how to improve Push-pull dissemination. Most significantly, farmers suggested alterations of outreach methodology and content (Fig. 9). 16.7% wanted an emphasis on COVID-safe media, such as the radio or the internet. 11.9% suggested an increase in provided or subsidized Push-pull inputs, or monetary motivations to draw farmers into disseminations. Other farmers suggested an increase in the frequency of outreach methods, the intensity of trainings, and emphasis on publicity. Specific suggestions of methodology moderations included increased hands-on learning, group learning, and diversified sources (Fig. 10).

Fig. 9 - Farmer Suggestions to Improve PPT Outreach

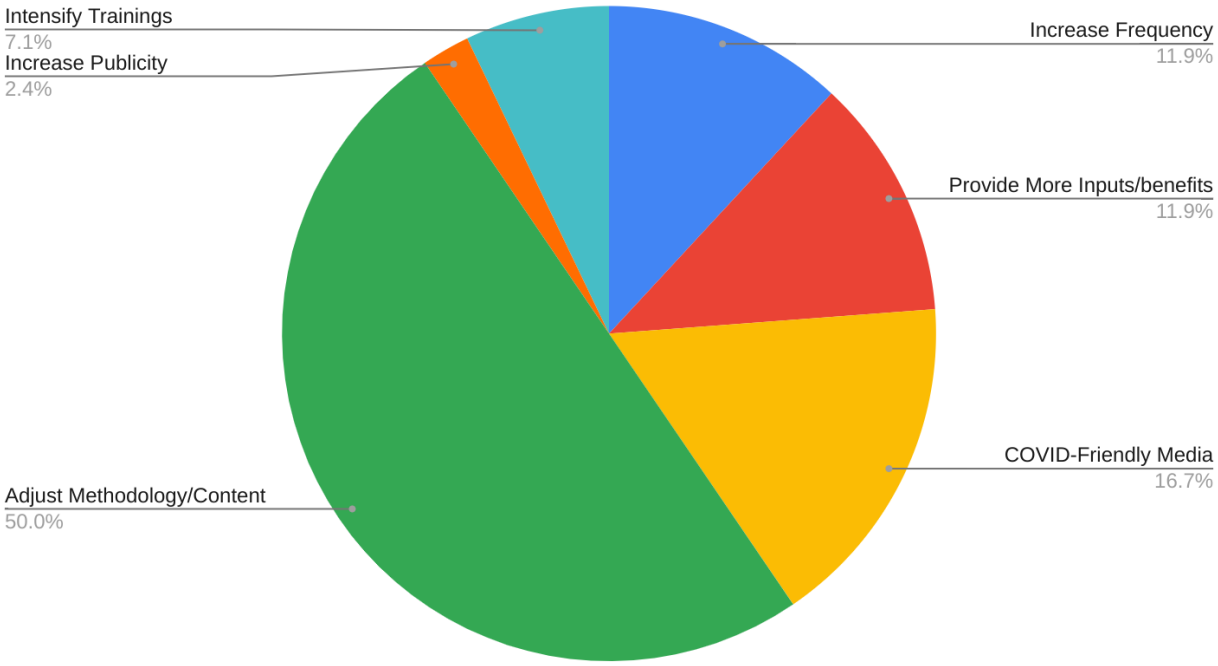
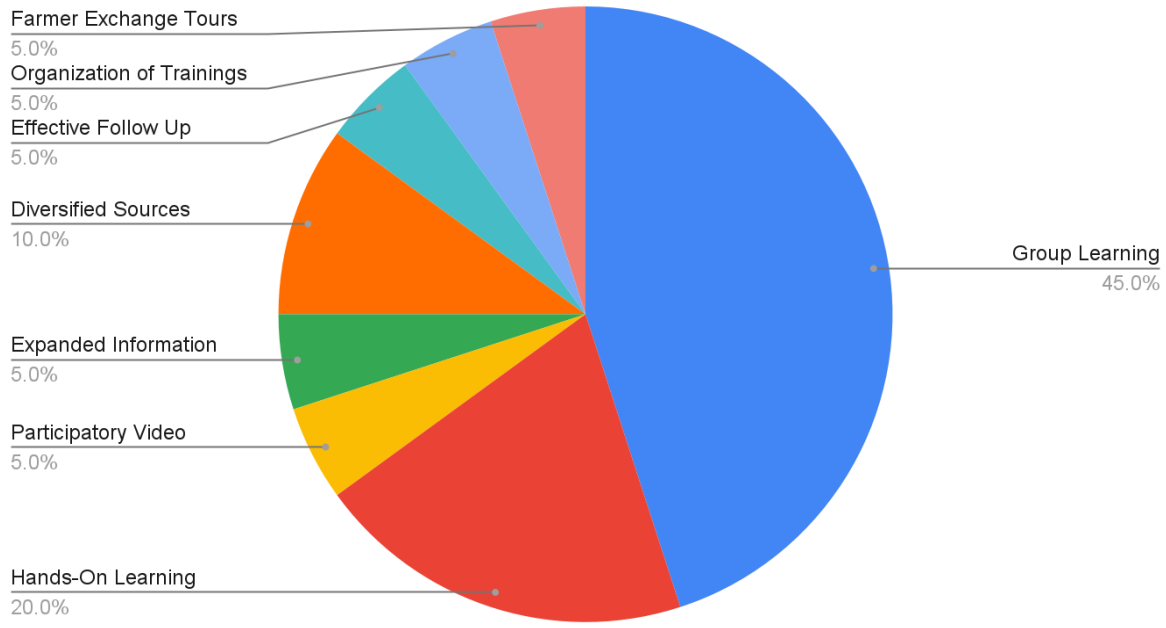
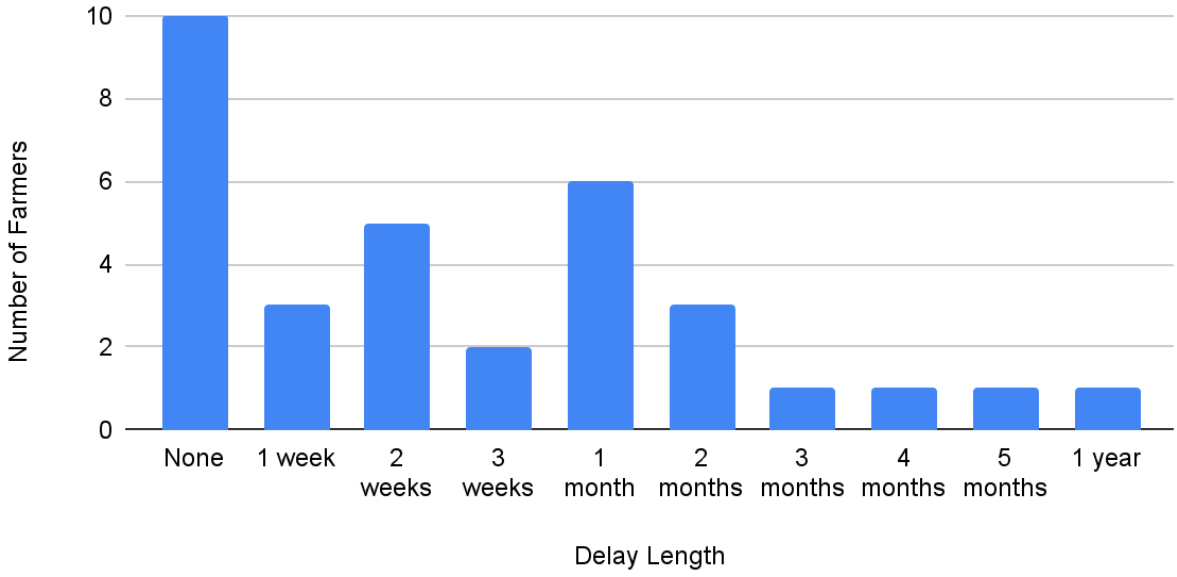


Fig. 10 - Suggested Emphasis Regarding Outreach Methodology / Content



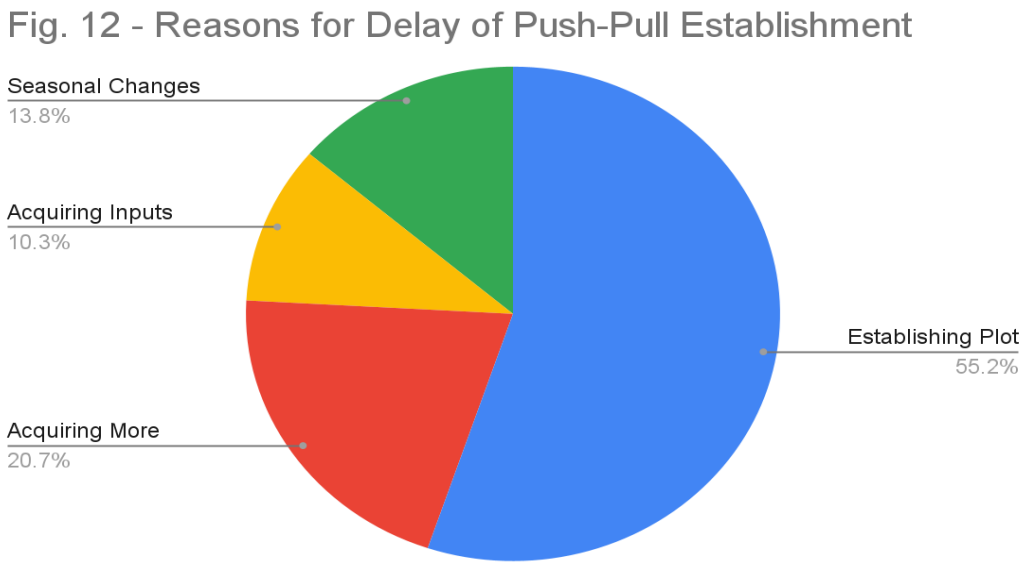
This study investigated causes of delay in Push-pull implementation. These factors were analyzed with the intent to determine the most significant causes of delay, and the role of inadequate dissemination among them. If many farmers reported delays caused by the time needed to acquire more information, then dissemination reform should focus on increasing the quality of outreaches. If another factor stood out as a significant barrier, then the Push-pull Program should direct attention towards addressing this cause of delay. However, significant periods of delay (over a month) were less frequent than periods of delay shorter than a month (Fig. 11).

Fig. 11 - Length of Delay Between Learning and Implementing PPT



Some delays are explained by inherent or unavoidable factors, such as seasonal changes and labor (Push-pull requires a very fine till of the soil, meaning that preparing the land is labor-intensive and takes time). However, a collective 30% of participants who reported delay attributed it to fixable problems, including low accessibility of inputs and, most significantly,

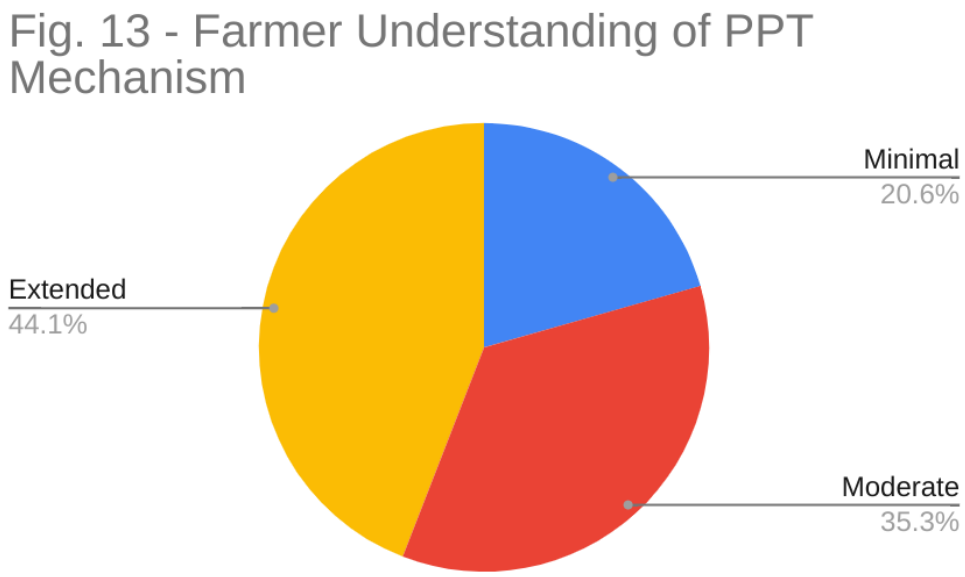
time needed to acquire more information on the technology (Fig. 12). This illustrates the need for enhanced dissemination and the aided availability of resources in order to bridge the time gap between introduction to and adoption of Push-pull.



Objective II - Determine the extent of farmers' understanding of Push-pull mechanism and impacts

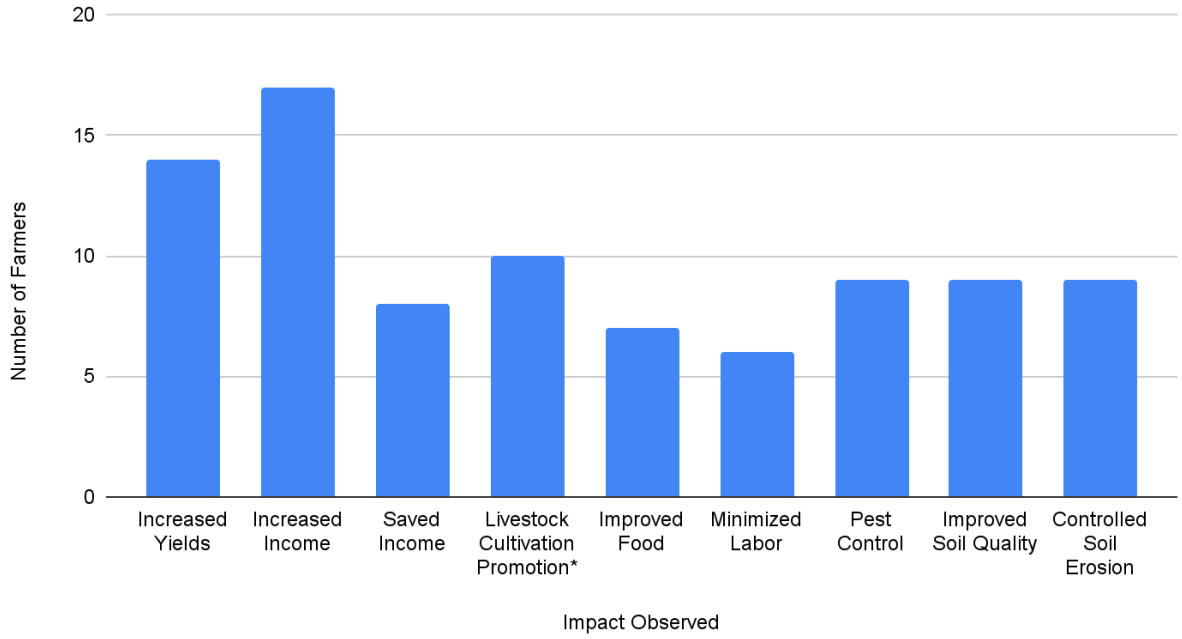
Farmers were interviewed on their existing understanding of Push-pull as well as their desire for further information. Firstly, farmers were asked to rate their understanding of Push-pull mechanism. Farmers rated themselves on a percentile scale. Respondents reporting 0-39% understanding were categorized as a minimal understanding; 40-60% were deemed to hold a moderate understanding; 61-100% an extended understanding. Farmers who were not sure what to rate themselves relayed what they knew about Push-pull mechanism and then were rated on the same percentile scale. The majority of farmers exhibited either extended or moderate understanding (Fig. 13). However, it is to be acknowledged that a third of the farmers who reported an extended understanding are farmer-teachers, meaning they are individuals

specifically trained by ICIPE in teaching other farmers about Push-pull. Additionally, two-thirds of farmers reporting extended understanding were over the age of sixty. This correlation with age suggests a connection between Push-pull understanding and hands-on experience in general farming. 62% of respondents with extended understanding were male; the other two classifications showed equal gender representation.



Participants were then asked to list the economic and environmental impacts of Push-pull observed on their farm. Fig. 14 depicts the number of times each impact was reported by a participant; participants were encouraged to list multiple impacts. Participants were more likely to list economic impacts as opposed to environmental ones. In addition to the impacts listed in the chart, one farmer each reported ecosystem conservation, a decrease in maize spoilage, a decrease in weeds, and a decrease in personal stress levels. The observation of stress reduction ties into the provided increase of food (in regards to both quantity and quality) and acknowledges the psychological aspects of farming.

Fig. 14 - Push-Pull Impacts Observed By Farmers



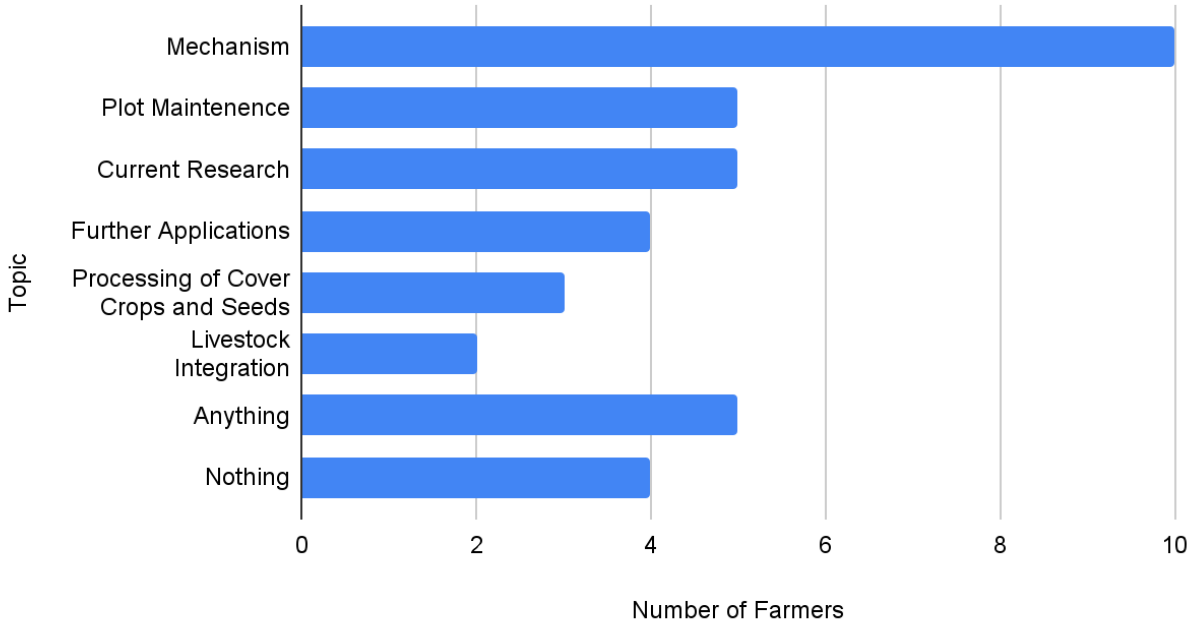
**The promotion of livestock cultivation stems from the high-protein quality of companion crops, which can be used as fodder and subsequently increase animal product production and quality*

Participants were then prodded for their desires for further information on Push-pull. All but one participant responded that they believe learning more about Push-pull would be beneficial to their farms and crop yields. This one participant stated that he was content with his current understanding of the technology.

All other participants were then asked what they would like to learn more about regarding Push-pull. The most significant number of participants answered that they would like to learn more about Push-pull mechanism, how the technology works (Fig. 15). In addition to the categories listed, some participants requested more specific information. One participant expressed his desire to learn more about mulato bruxaria, and another participant wants to learn how to expand her Push-pull plot while maintaining profitability at a larger scale. Of the five participants requesting information on crop maintenance, three expressed specifically that they

would like to learn more about drooping mulato leaves and the significance of this behavior. Fields of current research specifically mentioned include drought management, advanced maize varieties, and the fit of specific crop varieties for specific seasons. Four participants expressed that although they believed learning more about Push-pull would be beneficial for other farms, they were personally content in their knowledge and had nothing else they would like to learn.

Fig. 15 - Further Information on PPT Requested By Farmers

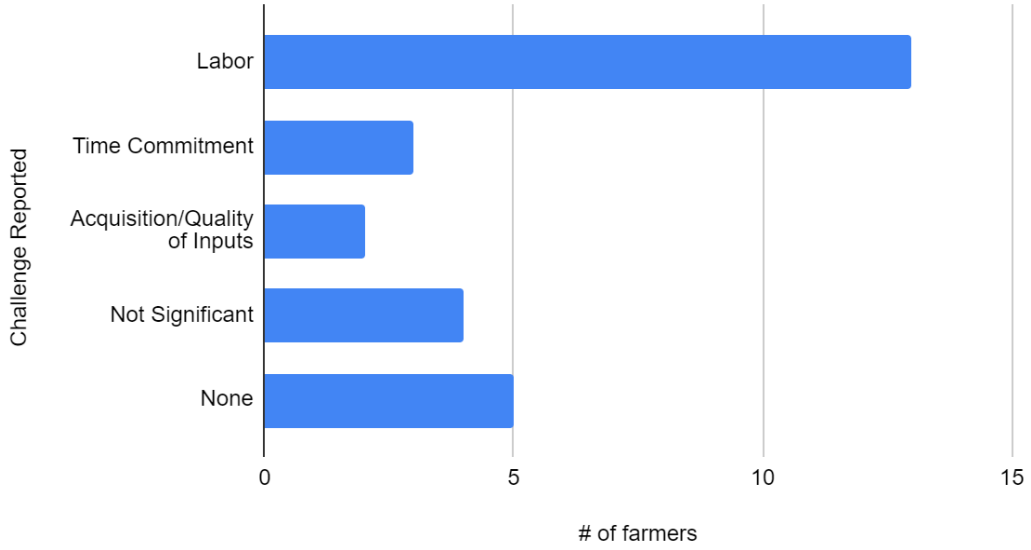


Objective III - Identify the most influential factors outside of communication channels that contribute to Push-pull technology adoption

Lastly, participants were interviewed on the biggest challenges and preventions of Push-pull adoption. When asked for their biggest challenges in Push-pull farming, the most frequent response was labor, particularly the trimming of companion crops which is tedious labor required to maintain the plot and use it for ongoing seasons (Fig. 16). Five participants reported that there were no challenges. Four participants admitted that there were challenges, but did not

give specifics, regarding these obstacles as insignificant. “Challenges have been turned into opportunities because of Push-pull,” one farmer reported. “The benefits outweigh the challenges,” another stated.

Fig. 16 - Challenges Experienced In Push-Pull Farming

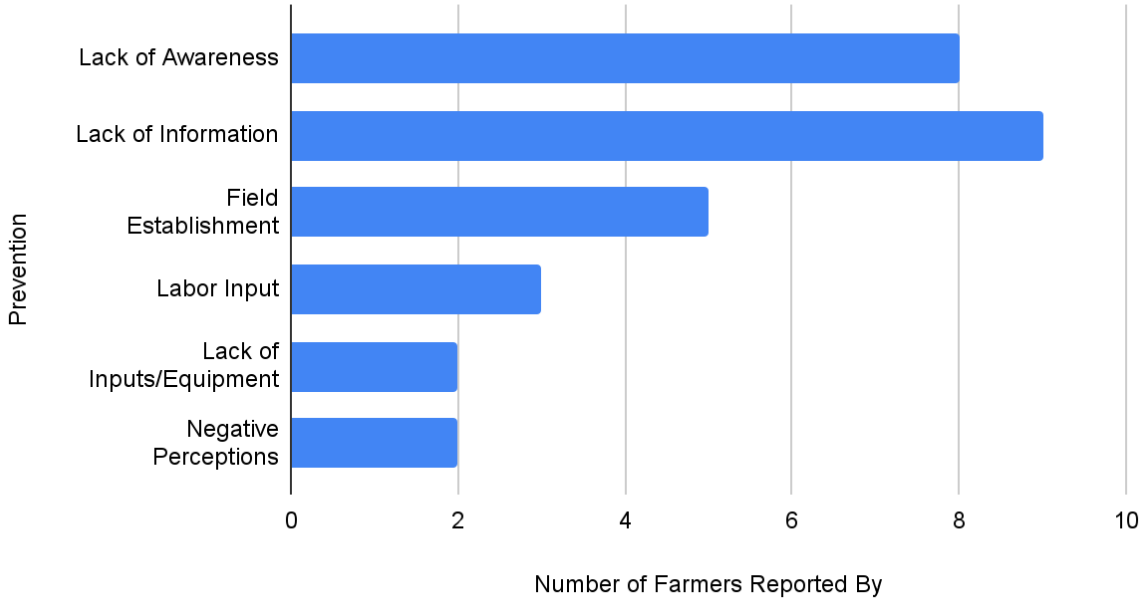


Specific challenges, listed by one participant each, include environmental conditions, plot establishment, and current insufficient knowledge. One farmer reported that his biggest challenge was a waste of fodder, that with no animals or market to feed his companion crops to, his biggest obstacle was the wasted opportunity. Another participant mentioned the challenge non-Push-pull farmers pose for Push-pull farmers. Because of his location at a lower elevation below non-Push-pull farmers, striga weed seeds flow with runoff from the mountains into his low-lying fields. If neighboring farmers implemented Push-pull, then this would not be a problem.

Participants were then asked what the biggest factor was that prevented them from earlier adoption of Push-pull. Some farmers responded with their personal preventions, others interpreted the question differently and listed the factors they had seen dissuade others. The most common prevention was lack of information (regarding both how and why to begin), closely

followed by lack of awareness (Fig. 17). This fits with Push-pull's identity as a knowledge-intensive technology.

Fig. 17 - Preventions of Push-Pull Practice



Farmer Discussion Groups

The revised introductory question (asked to 11 farmers, Group Two only) investigated the means through which farmers learned about and became aware of Push-pull. This question looked at overall outreach access as opposed to focusing on preliminary dissemination. 10 farmers responded to this discussion prompt, 50% of whom reported participation in field days and the other 50% of whom responded with trainings by ICIPE staff. It should be noted that all members of the focus discussion group were members of the same community, meaning many were likely to have attended the same disseminations based on locality. However, the methodologies noted (field days and ICIPE staff) corroborate the outreach type frequency indicated by the interviews.

Participants of the second group were also asked if they received sufficient information at their first Push-pull contact, or if they had needed to build their understanding through further means before they could begin their plot. The participants came to a majority consensus that their understanding after their first outreach was inadequate and that they had needed more information, highlighting farmer-teacher and professional staff demonstrations as the most efficient way to supplement and complete their fundamental understanding of the technology.

Participants of both groups were asked for their suggestions on improving Push-pull outreach. The most frequently brought up suggestion between both groups was introducing further trainings and improving follow up; in other words, extending dissemination efforts. Similar to the interviews, an emphasis on field days and mobile media was also requested. Farmers expressed their satisfaction with these methods for their accessibility, with regards to lack of literacy requirements and COVID compliance. Motivating farmers to implement Push-pull, organizing farmer field tours (in which farmers of one community are brought to tour farms of another community so that they may learn the different methodologies), using participatory video (in which farmers record their experiences with Push-pull on projectors to be shared with other communities), emphasizing farmer-teacher outreach, and increasing the presence of Push-pull dissemination materials at agricultural shows were also suggested.

Each focus group responded with two to three ideas when asked about their desire for further information on Push-pull. Group One mentioned the desire to learn about processing desmodium seed. The first Push-pull farmers used seed shipped from Australia, which was expensive due to shipping costs. Desmodium seed prices have decreased as the project expanded, but self-sufficient seed production would help farmers increase profitability. This group also expressed that they would like to know the downsides of Push-pull. “Whatever has positives has

negatives," one participant said. Group One also discussed their interest in further application of Push-pull technology, such as in vegetable and cereal crops. The second discussion group brought up farmer exchange tours. One farmer added that although he was content with his understanding, he would like to see how other farmers utilize the technology to see if he is missing anything. The group also discussed the implications of climate change and their desire to know more about the advancements of Push-pull in addressing its effects, specifically what varieties of companion crops are better for use in changing climatic conditions.

Lastly, each group was asked what major factors had impacted their practice of Push-pull. Labor was a commonly discussed issue. Group One discussed the intensity of labor, which is promoted, one farmer added, by the inability of casual workers to assist. This farmer argued that because Push-pull is knowledge intensive, casual labor is not a resource. Additionally, farmers expressed interest in the mechanization of Push-pull labor, particularly harvest. The second group also called for the mechanization of labor. Additionally, the second group agreed that the most significant challenges of Push-pull farming are as follows: Napier stunt disease (which affects a key companion crop); marketing Push-pull products (many farmers have their own fodder, so it is hard to sell companion crops as such); increasing seed production (plot maintenance requires trimming companion crops, but to get seed the crops must be let to grow); preparing and processing fodder. These challenges echo those brought up in interviews.

Limitations

The language barrier present in the conduction of this research should be acknowledged. It is possible that certain phrases may have been misinterpreted or the original meaning and wording of responses adjusted as responses passed through both a translator and a researcher's interpretation before being recorded as data. However, the expertise of the translator and

clarification asked for and received by the researcher provided a safeguard against this. Also, because surveys were conducted over Zoom, responses may have been attributed to the incorrect respondent as computer audio and visual makes it more difficult to tell who is speaking at a given time. However, as multiple questions were asked, this is unlikely as over time a voice was able to be assigned to a face and any (infrequent) mistakes in the earlier questions were adjusted.

Discussion

The driving objectives were as follows:

I. Learn about the effectiveness of existing communication channels for accessing and sharing information about Push-pull technology
II. Determine the extent of farmers' understanding of Push-pull mechanism and impacts
III. Identify the most influential factors outside of communication channels that contribute to Push-pull technology adoption

The data collected supports the conclusion that primary disseminations are in significant need of adjustments. With over half the participants reporting inadequate education provided by primary outreach, there is significant room for the improvement of this front of Push-pull education. The data suggest two different categories of adjustments.

Firstly, the data suggests improvement by change in methodology. By focusing on specific types of dissemination, outreach efficiency may be improved. 50% of participants requested some kind of methodology alteration when asked to suggest dissemination improvement. Group learning, hands-on learning, and COVID-friendly media were commonly requested because these are the methodologies participants already find most beneficial for farmers and the promotion of Push-pull adoption. This feedback suggests that not only should

these methods be emphasized and used in higher frequency, but that further research should be done into these types of outreach: what aspects make these methods the most preferred by farmers? How can these factors be incorporated or emphasized in other outreach methods to expand the number of viable dissemination means? Being able to identify the factors that grant preferred outreach methods success means that these aspects can then be applied to other methods, increasing the number of efficient dissemination strategies that can be used by the Push-pull Program.

Secondly, the data suggests altering dissemination content. Farmers were surveyed on what they do not know, what they wish to know, and the misconceptions of Push-pull they see in their communities. The data collected reveals what factors should be emphasized in disseminations to address current insufficiencies, misconceptions, and knowledge gaps. For example, participants were more likely to report economic factors when asked to list the benefits of Push-pull. Because farmers are more conscientious of economic factors, these are the aspects they are more likely to tell other farmers about. Therefore, awareness campaigns and Push-pull promotional material should emphasize the environmental and sustainability factors of Push-pull to supplement word of mouth. This can lead to a non-redundant, well-rounded promotion of Push-pull more effective at attracting farmers to disseminations. Additionally, preconceptions of Push-pull can repel farmers from the technology and so they must be addressed. These uneducated fears, like the dangerous snakes harbored by Push-pull plots (but only when untrimmed), must be addressed in promotional materials and by other means to eliminate harmful rumors and further promote interest in the technology. Further research should be conducted at *icipe* either by Push-pull developers or future *icipe* interns into what other negative conceptions farmers hold of Push-pull, and how they can be addressed. Additional insights into

farmer perspectives and reception of the technology will provide critical direction in improving the promotion and adoption of Push-pull.

Push-pull is a unique technology in that the most specialized resource needed to practice it is knowledge. Knowledge is an infinite resource, but its distribution depends on increasing the efficiency and quality with which it is provided. Adjusting dissemination methodology and content can serve to not only provide farmers with the needed Push-pull understanding quicker but also attract more farmers to disseminations. By increasing the rate at which farmers are provided the necessary information and increasing the number of people who desire such knowledge, farmers can flow through the education process at a quicker rate and therefore in greater quantities. Education is by no means a done-and-over experience; there is still current research on the technology and farmers plenty hungry for the technology's next advancement or newly discovered nuance. But increasing the availability of foundational understanding is the key to putting the benefits of Push-pull in the hands of more farmers: providing more families with reliable, healthy food; sending more kids to school; creating more opportunities for income and business expansion. It is the key to enabling the technology to live up to its full potential.

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Appendix

Appendix 1 - Individual Interview Survey

An Analysis of the Efficacy of Communication Channels in Promoting the Adoption of Push-pull Technology Among Smallholder Kenyan Farmers

Specific Objectives

I. Learn about the effectiveness of existing communication channels for accessing and sharing information about Push-pull technology (PPT)
II. Determine the extent of farmers' understanding of Push-pull mechanism (PPT) and impacts
III. Identify the most influential factors outside of communication channels that contribute to Push-pull technology adoption

General questions/ Background information

1. What is your name? Gender? Age? Household size? Farm size? Region?
2. How many years have you been farming?
3. What is your education level?
4. How many years have you been a PPT farmer?
5. What crops/animals do you grow/raise on your farm?
6. Who works on your farm with you?
7. *(If under the age of 30)* Do you intend to remain a farmer?

How were farmers who practice Push-pull exposed to the technology, and how effective do these farmers believe these outreach methods were in providing the information necessary to practice Push-pull?

8. How did you first hear about Push-pull technology?
   (*Probe*: Other farmer, field days, farmer field schools, mass media, information bulletins, mobile phone technology -----)
9. Did you find this communication channel helpful/informative? Yes/No
10. What suggestions do you have to improve the communication channel?
11. How soon after learning about Push-pull did you begin to practice it?
    a. *(If after more than a week)* What was the reason for this delay? (*Probe*: land preparation, acquisition of inputs, needed more information ----)

To what extent do farmers understand the Push-pull mechanism and what further information do they seek?

12. How well do you understand PPT mechanism? Exhibits (Minimal/Moderate/Extended) understanding
    (Minimal - 0-39 % understanding; Moderate- 40-60 % understanding; Extended- 61-100 % understanding)
13. Describe the environmental and economic impacts PPT has had on your farm.
14. Do you believe learning more about Push-pull would be helpful in increasing your crop yields? Yes/No
15. If yes, what further information do you seek?

What are the most influential factors outside of communication that contribute to Push-pull technology adoption?

16. What challenges have you experienced in your practice of Push-pull?
17. What was the biggest factor keeping you from practicing Push-pull? (*Probe*: lack of information, lack of resources, etc)

Appendix 2 - Focus Group Questions

An Analysis of the Efficacy of Communication Channels in Promoting the Adoption of Push-pull Technology Among Smallholder Kenyan Farmers

1. Through what means did you learn about Push-pull, and did it teach you everything you needed to know?

2. How long did it take you to acquire all the information about Push-pull you needed to implement the technology?

3. What suggestions do you have for making learning about Push-pull more efficient? (What changes would you like to see in Push-pull outreach?)

4. Are you satisfied with your current understanding of Push-pull, and if not, what would you like to learn more about?