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Effect of the Push-Pull Cropping System on Maize Yield, Stem Borer Infestation and Farmers' Perception

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Abstract: The productivity of maize in Ethiopia has remained lower than the world average because of several biotic and abiotic factors. Stemborers and poor soil fertility are among the main factors that contribute to this poor maize productivity. A novel cropping strategy, such as the use of push-pull technology, is one of the methods known to solve both challenges at once. A push-pull technology targeting the management of maize stemborers was implemented in the Hawassa district of Ethiopia with the ultimate goal of increased food security among smallholder farmers. This study evaluated farmers' perception of push-pull technology based on their experiences and observations of the demonstration plots that were established on-farm in Dore Bafano, Jara Gelelcha and Lebu Koremo village of the Hawasa district in 2016 and 2017. This study examined farmers' perception of the importance of push-pull technology in controlling stemborers and improving soil fertility and access to livestock feed. In both cropping seasons, except for Jara Gelelcha, the maize grain yields were significantly higher in the climate-adapted push-pull plots compared to the maize monocrop plots. The majority (89%) of push-pull technology-practising farmers rated the technology better than their maize production methods on attributes such as access to new livestock feed and the control of stemborer damage. As a result, approximately 96% of the interviewed farmers were interested in adopting the technology starting in the upcoming crop season. Awareness through training and effective dissemination strategies should be strengthened among stakeholders and policymakers for the sustainable use and scaling-up of push-pull technology.

Keywords: farmer's perception; maize; push-pull technology; stemborer

1. Introduction

In Ethiopia, agriculture is the dominant economic sector that contributes 42% of the total gross domestic product (GDP), employs approximately 83% of the population, is a source for more than 90% of export revenues, and provides raw materials for more than 70% of the country's industries [1]. According to the World Bank [2] report, within the Ethiopian agricultural sector, 60% of income comes from crop production, while 30% comes from livestock, and the rest (10%) comes from forestry products. Smallholder farmers account for the largest share of agricultural production. The country produces more maize than all other crops, accounting for more than 27% of production. Maize is widely produced in almost all agro-ecologies with both rain-based and artificial irrigation systems. Although the crop plays a leading role in maintaining food security with a high population growth, productivity remains low with an average yield of 3.24 ton/ha compared to the world average of

4.5 ton/ha [3]. Maize productivity is limited by biotic and abiotic factors. Abiotic factors include inefficient production methods, low soil fertility, drought, and small landholdings, while biotic factors include diseases, weeds and insect pests [4]. The stemborer insect pest can cause an average yield loss of 20–50% and, in some cases, a complete loss of maize and sorghum crops in Ethiopia [5].

Stemborer moths lay eggs on maize that hatch into larvae that eat the maize leaves and burrow into the stems as they grow. Hence, the stem borer eats the food that the maize plants would use to produce grains. The economically important species of stem borers in Ethiopia include *Busseola fusca* Fuller (Lepidoptera: Noctuidae), *Chilo partellus* (Swinhoe) (Lepidoptera: Crambidae) and *Sesamia calamistis* Hampson (Lepidoptera: Noctuidae) [6]. A study that was conducted on the ecology of the African maize stemborers also indicated that *B. fusca* occurs in all agro-ecological zones from the lowland semi-arid and arid savannahs to the highland wet mountain forests in Africa and is one of the most economically important species of the stemborers [7]. Cultural methods, such as intercropping maize with beans and crop residue disposal, biological control methods, and host plant resistance and insecticidal methods, have been recommended for the control of stem borers. These control methods are either not effective or not affordable by farmers, hence, alternative stem borer control strategies are necessary. As a response to this, the International Centre of Insect Physiology and Ecology (ICIPE) and its partners have developed a novel cropping strategy, the push-pull technology, which can address such efficacy and affordability constraints at once [8]. Push-pull technology is a system of biological intensification that involves attracting gravid female stem borer moths with a trap plant, either Napier grass or Brachiaria, along the border (pull) while driving them away (push) from the main crop, either maize or sorghum, using a repellent intercrop of Desmodium [9].

Previous studies have shown that companion grasses (Brachiaria and Desmodium) can also provide high-value animal fodder, thereby improving milk and meat production and diversifying farmers' income sources [10]. Moreover, Desmodium is an efficient nitrogen-fixing legume that enhances soil fertility, conserves soil moisture, and prevents soil degradation. Push-pull technology is appropriate, environmentally friendly and fits well with resource-poor smallholder farmers of traditional crop-livestock mixed farming systems as it uses locally available and adapted bio-resources [8]. Furthermore, recent studies in East Africa have demonstrated the effectiveness of push-pull technology in controlling the invasive fall armyworm, *Spodoptera frugiperda* (J E Smith), in maize [11]. Push-pull technology was introduced in early 2016 on 32 smallholder farmers' fields in the area of the Hawassa district as demonstration plots targeting the control of stem borers. All other practicing neighborhood farmers in the villages have exercised and shared the knowledge on the implementation and importance of the technology. Since the technology is new to the farmers in the district, they could have different insights into its practical implementations and attributes. In this study, therefore, farmers' perception of push-pull technology was assessed and analyzed to evaluate the level of understanding of practicing (demonstrating) and non-practicing (visiting) farmers based on observations and day-to-day follow-up of the demonstration plots against their local farming practices. Therefore, this paper reports on the assessments of farmers' perception of push-pull technology, their awareness of the levels of yield reduction caused by stem borers, and the control methods that the farmers were exercising.

2. Materials and Methods

2.1. Study Area

The experiment was conducted during the 2016 and 2017 cropping seasons. In the 2016 cropping season, the study was conducted at two kebeles (kebele is the lowest administrative unit in Ethiopia), Dore Bafano and Jara Gelelcha, in the Hawassa district of the Sidama zone in the South Nation, Nationality and People Regional (SNNPR) State of Ethiopia. In 2017, the study was conducted in four kebeles: Dore Bafano, Jara Gelelcha, Wudo Wotatie, and Lebu Koremo. The Hawassa district is located 250 km from the capital, Addis Ababa, to the south following the main road to Kenya (Figure 1). The soil type of the study areas is clay-loam with an average pH of 5.67; the elevation is 1709 masl with a longitude of 38°21.535′ E and latitude of 07°01.921′ N. The annual total rainfall was 654 mm, while the average annual temperature was 11.6 °C, calculated as averages from the data from 2000–2012.

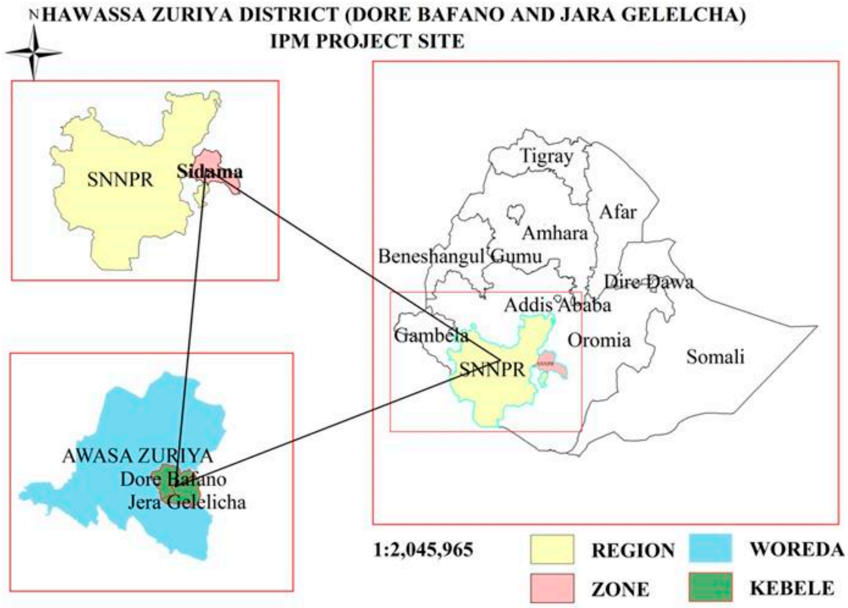

Figure 1. A map showing the Hawassa district and the study sites in Ethiopia.

2.2. Push-Pull Technology Demonstration Plots

As per the information from the agricultural office of the district, the Hawasa district ranks first in the zone for its maize production area of approximately 11,000 hectares. Unfortunately, maize is susceptible to production constraints such as insect pests, particularly stemborers, and loss of soil fertility. This calls for easily accessible and appropriate integrated pest management (IPM) technologies such as push-pull technology. Accordingly, through the IPM project in partnership with the Ministry of Agriculture and Natural Resource (MoANR), the ICIPE established push-pull technology demonstration plots in the two selected kebeles of the district beginning in May 2016. The sites were selected in consultation with the zone and district agricultural experts and the development agents of the two kebeles based on the potential productivity of maize and the presence of major constraints, such as maize stem borers and low soil fertility. From all 23 kebeles of the district, Dore Bafeno and Jara Gelelcha were selected as the implementation sites for the demonstration plots. A total of 32 model farmers, 16 from each kebele, were selected for the establishment of the demonstration and control plots. The farmers were selected based on their willingness and readiness to adopt the new technologies on their lands by setting selection criteria of having their land, experience in maize cultivation and livestock ownership. All the selected farmers with their spouses (husband or wife), the development agents and the agricultural experts were trained on the strategy and implementation methods of push-pull technology.

After acquiring enough levels of awareness regarding the push-pull technology, the farmers planted the demonstration and control plots with an average area of 900 square meters on their lands. In the demonstration plots, maize was planted on average areas of 30 m by 30 m with 28 total rows, 40 cm spacing between maize plants and 80 cm spacing between the rows. The companion plants used for the control of maize stem borers were the grass Brachiaria (Mulato-II) and the legume Greenleaf Desmodium, *Desmodium intortum* (Mill.) Urb. Desmodium seeds were planted by broadcasting between the maize rows. Desmodium produces a smell (semio-chemical) that stem borer moths do not like, hence, it pushes the stem borers away from the maize and enhances soil fertility. Brachiaria was planted in 3 rows surrounding the maize plots (40 cm between plants and by 40 cm between rows) as a trap plant to attract stem borer moths, hence, the term pull [12,13]. Due to the incorporation of drought-tolerant companion plants (Brachiaria cv mulato II and *D. intortum*), the push-pull system is termed the climate–adapted push-pull system [13]. All the maize, Desmodium and Brachiaria seeds were planted from 5–10 June 2016 on the same date at each plot with the support and close supervision of the development agents and ICIPE field technicians. Similarly, the control plots were also planted on the same land area as the push-pull plots following the farmers' conventional practices (without using the companion plants). The control plots were used for checking and comparing the effectiveness and importance of the technology to the farms' conventional practices. In both the demonstration and the control plots, the maize seed hybrid, fertilizer rate, and type and additional agronomic practices were each applied as per the research recommendations for the area.

2.3. Data Collection

2.3.1. Maize Grain Yields

At physiological maturity, all the maize plants in each plot were harvested and the cobs sun-dried separately for each plot (see Section 2.2 for description). Then, the cobs were shelled manually and the maize grain sun-dried to 12% moisture content, and the grain weights were individually taken for each plot and farmer. The grain weights were calculated per plot area harvested, and the yield data converted to kg/hectare.

2.3.2. Survey Data Collection

The household survey data were conducted in the project kebeles from September to October 2016. The data were collected from 71 (29 push-pull practising and 42 randomly selected non-practising) farmers. The structured questionnaires were used to obtain information from the sampled farmers. The questionnaires comprised questions including demographic details such as gender, age, education level, and household size, the owner's land size and the proportion of its area used for maize production. The farmers' awareness and perception of stem borer damage, cultural control methods and push-pull technology were also included in the questionnaires. To promote their understanding of the levels of stem borer damage, the farmers were asked to estimate the potential yield of their maize crops (if no stem borer damage) compared with their actual harvested yield in the 2015–2016 crop season. The questionnaires were pre-tested before starting the survey to check the consistency of the questions. The data collection was conducted by trained enumerators using local languages under the close supervision of researchers and supervisors.

2.4. Statistical Analysis

The data on the maize grain yields were averaged for each plot and farmer (each farmer being a replicate), and comparisons between the climate-adapted push-pull technology and the farmers' practice plots were analysed using t-tests. All statistical analyses were performed using MINITAB 16 statistical software.

The survey data were summarized, and descriptive statistics (means and percentages) were calculated using the Statistical Package for Social Sciences (SPSS). The percentage of farmers who gave similar responses to each question was calculated for each site. The surveys that did not contain responses to certain questions were excluded from the calculations. In instances where a farmer indicated more than one answer to a given question, the percentages were calculated for each group of similar responses. The comparative statistical tools, such as chi-square and t-tests, were conducted to assess the differences regarding the socio-demographics and farm characteristics and the knowledge and perceptions of stemborers and their management practices. The level of significance was set at 0.05, and the means were separated by Tukey's honestly significant difference (HSD) test.

3. Results

3.1. Maize Grain Yields

In all kebeles except for Jara Gelelcha in the 2017 cropping season, the maize grain yields were significantly higher in the climate-adapted push-pull plots than in the maize monocrop plots ($p < 0.05$). In the 2016 cropping season, the maize yields ranged from 3359 to 3983 kg/ha in the climate-adapted push-pull plots and from 2641 to 2960 kg/ha in the maize monocrop plots. In 2017, the season yields ranged from 4761 kg/ha in Jara Gelecha to 6451 kg/ha in Dore Bafano in the climate-adapted push-pull plots and from 4360 kg/ha in Lebu Koromo to 4721 kg/ha in Wudo Wotatie in the maize monocrop plots (Figure 2).

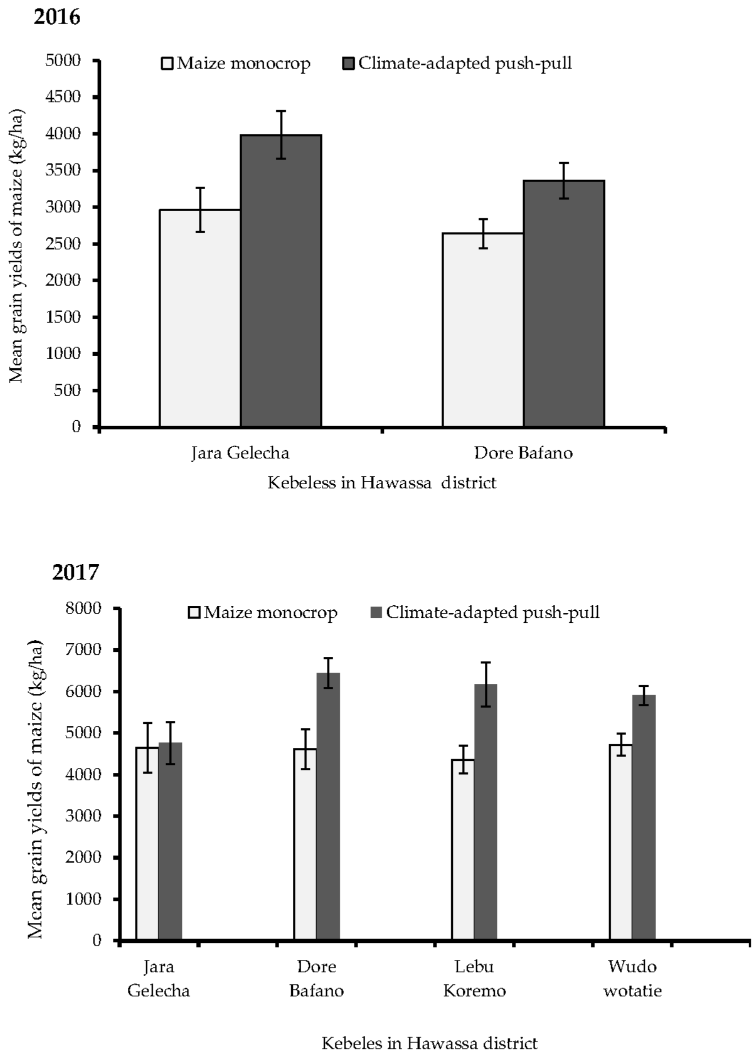

Figure 2. The mean (±S.E.) grain yields of maize (kg/ha) planted in the maize monocrop or climate-adapted push-pull stands in the Hawassa district in the 2016 and 2017 cropping season.

3.2. Socio-Economic and Farm Characteristics

The majority (80%) of both the push-pull technology (PPT)-practising and the non-practising farmers were male. The age of the household head ranged from 24 to 73 years with an average of 42.5. The family size of the households differed significantly between PPT-practising and non-practising farmers with an average of 6.6 persons. Most farmers (94%) had some formal education with an average of 5.15 years of education. The average farm size of the households was 1.15 hectares, while the area used for maize production was 0.71 hectares (63.5%) (Table 1). The survey results indicated that approximately 15% of the interviewed farmers grew fodder crops, such as Napier grass and Rhodes, on their small plots, while the remaining majority (85%) of them collected feed from other sources, such as crop residues from their farms (64%) or natural pastures (24%), or they purchased from other farmers in the village (12%) (Table 1).

The survey results indicated that the majority (approximately 97%) of PPT-practising and non-practising farmers practised mixed, maize-based, crop-livestock farming systems, while 3.4% of the farmers cultivated only crops, whereas the remaining households practised crop-livestock production (Figure 3A). Maize ranked first both in its use as food (94.4%) and as a cash resource (80.3%) (Figure 3B,C), whereas enset (*Ensete ventricosum*) was the second most important food crop in supporting household food security (Figure 3B). Most PPT-practising and non-practising farmers gave high ratings for farming constraints, such as maize stemborer damage (62.5%), the loss of soil fertility (42.75%) and the lack of quality livestock fodder (34.85%), in the study areas (Table 2).

Table 1. Socio-economic characteristics of the respondents in the Hawassa district, Ethiopia.

Variable	PPT-Practicing	Non-Practicing	Mean	χ^2	*t*-Test
	***N* = 29**	***N* = 42**	***N* = 71**		
Gender					
Male	86.2	73.8	80	1.582 ^{ns}	
Female	13.8	26.2	20		
Age	43.2	41.8	42.5		0.649 ^{ns}
Level of education (years)	4.6	5.7	5.15		−1.441 ^{ns}
Family size	7.2	6	6.6		2.841 **
Total land size	1.1	1.2	1.15		−1.030 ^{ns}
Total area of maize	0.62	0.80	0.71		−1.369 ^{ns}
Source of livestock feed (%)					
Own fodder	62.1	66.7	64.4	2.6919 ^{ns}	
Buy fodder	6.9	16.7	11.8		
Free grazing fields	31.0	16.7	23.85		

Statistically significant at * $p < 0.05$, ** $p < 0.01$; ns = not significant.

Table 2. Farmers' perception of farming constraints in the Hawassa district, Ethiopia.

Farming Constraints Response	PPT-Practicing	Non-Practicing	Mean	χ^2
	***N* = 29**	***N* = 42**	***N* = 71**	
Stemborer damage				
Very high	31.0	38.1	34.55	0.412 ^{ns}
High	65.5	59.5	62.5	
Low	3.4	2.4	2.9	
Soil fertility problem				
Very high	20.7	21.4	21.05	1.606 ^{ns}
High	37.9	47.6	42.75	
Low	34.5	21.4	27.95	
Not a problem	6.9	9.5	8.2	
Shortage of livestock feed				
Very high	34.5	54.8	44.65	5.950 ^{ns}
High	48.3	21.4	34.85	
Low	13.8	21.4	17.6	
Not a problem	3.4	2.4	2.9	

ns = not significant.

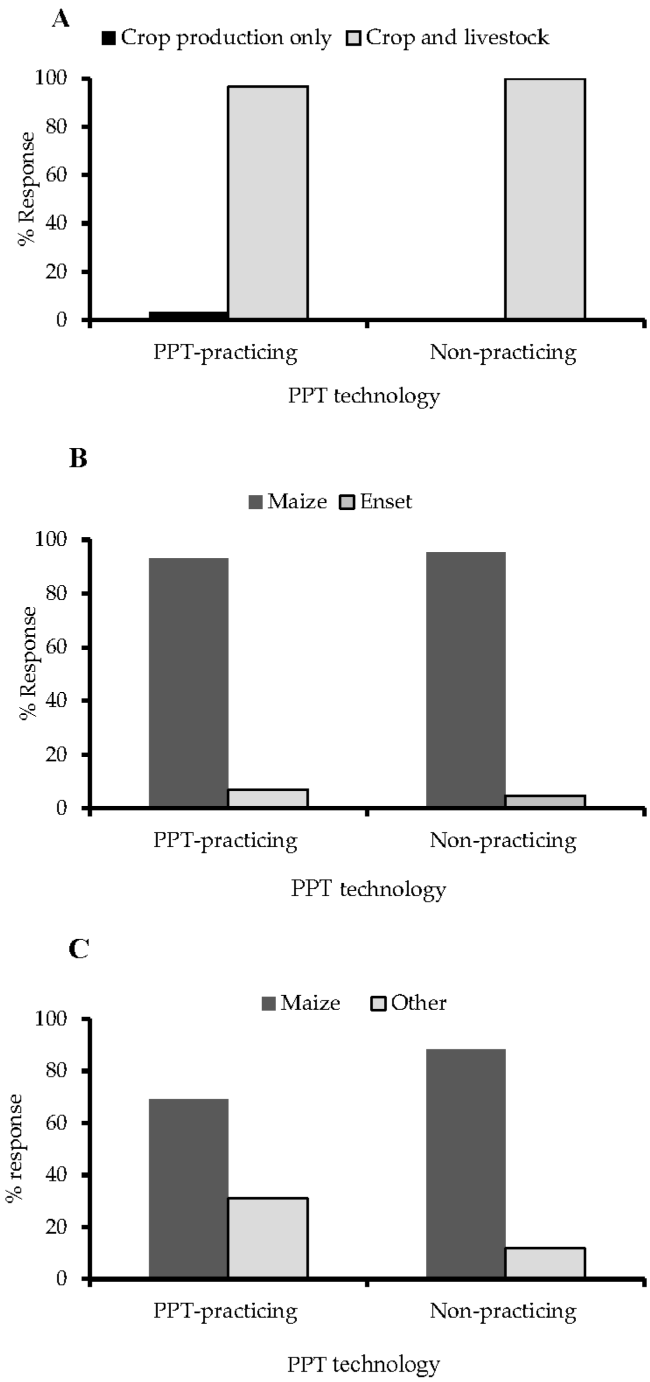

Figure 3. (**A**) Farming systems, (**B**) major food crops grown and (**C**) major cash crops grown in push-pull technology (PPT)-practicing and non-practicing plots in the Hawassa district, Ethiopia.

3.3. Maize Stemborer Knowledge, Damage and Control Methods

All of the interviewed farmers knew stemborers by their local name, Santoo, and approximately 98.1% of them cited maize damage caused by stemborers in the last cropping season. All of the farmers produced maize during the main/rainy season from June to September. The majority (80.8%) of PPT-practising and non-practising farmers perceived that stemborer damage to their crops was serious during the rain shortage. However, 17.5% of the interviewed farmers revealed that neither rain shortages nor long-term rain had any effect on the occurrence of stem borer damage (Table 3). The survey results indicated that stemborers reduced the average maize yield by approximately 29.3%, comparing the estimated yield with the actual harvested maize yield in the 2015 cropping season. This was computed from 2.15 ton/hectare of actual harvested maize with 3.0 ton/hectare of potential maize yield estimated by farmers if there were no stemborer damage. Approximately 86% of PPT-practising and non-practising farmers practised different stemborer control methods. The methods used by the farmers included timely planting (34.05%), insecticide applications (20.4%), the application of wood ash (16.8%), up-rooting damaged stems (14.55%) and intercropping with other legume crops (1.7%) (Table 3). Farmers mentioned that of all the methods used were neither affordable nor consistent in controlling stemborer damage.

Table 3. Farmers' knowledge and perceptions of stemborer in the Hawassa district, Ethiopia.

Variables	PPT-Practicing	Non-Practicing	Mean	χ^2	*t*-Test
	N = 29	*N* = 42	*N* = 71		
Know stemborer (Yes)	100	98.0	99.3	2.013 ns	
Encountered stemborer damage (Yes %)	98.2	98.0	98.1	6.003 *	
A season where stemborer is serious					
Long rain	3.4	0.0	1.7	2.068 ns	
Short rain	75.9	85.7	80.8		
All-season	20.7	14.3	17.5		
Expected maize yield (kg/ha)					
If no damage by stemborer	2670	3230	2950		4.969 ns
Infested by stemborer	1910	930	1420		4.462 ns
The severity of stemborer damage					
Very high	31	38.1	34.55	0.412 ns	
High	65.5	59.5	62.5		
Low	3.4	2.4	2.9		
Pest control method					
Insecticide spray	24.1	16.7	20.4	9.393 ns	
Timely planting	27.6	40.5	34.05		
Intercropping	3.4	0.0	1.7		
Wood ash	24.1	9.5	16.8		
Uprooting damaged stem	17.2	11.9	14.55		
No control	3.4	21.4	12.4		
Have you heard/know as PPT control stemborer damage? (Yes %)	100	100	100		
Interested to adopt PPT (Yes %)	79.3	95.2	87.3	4.253 *	

Statistically significant at * $p < 0.05$; ns = not significant.

3.4. *Farmers'Perceptionof Push-Pull Technology*

The majority of the PPT-practising farmers gave high ratings to the PPT technology compared to their maize production practices (Table 4). These perceptions were based on the major attributes of the technology, such as access to new livestock feed (Desmodium and Brachiaria) (51%), the control of stemborer damage (by observing holes on the maize stems and or leaves) (41%), the improved soil fertility (by observing changes in soil colour and moisture) (6%) and erosion control (through observations of reduced run-off) (3%) (Figure 4A). Although the push-pull technology is new in the district, an average of 87% of the interviewed farmers were interested and ready to practice the push-pull technology on their land starting in the upcoming crop season based on their perception of the multiple benefits of the push-pull technology. On the other hand, a few (13%) farmers were still hesitating to adopt push-pull technology mainly because of the shortage of cultivable land (7%) and fear of taking risks of using an unknown technology (4%) (Table 3). Most (45%) interviewed farmers mentioned that the implementation of the push-pull technology decreased workload, while other farmers reported no change (28.2%) or an increased (26.8%) workload during field management, including land preparation and weeding, compared to their maize cultivation methods (Figure 4B). Some farmers also suggested that the technology demanded more labour for the construction of fences to protect the perennial companion grasses from damage caused by free-grazing livestock after the crops were harvested.

Table 4. Push-pull technology practicing farmer's perceptions on PPT in the Hawassa district, Ethiopia.

Technology Attributes Observed	Frequency	Percent
Controls stemborer		
Very high	32	45.1
High	32	45.1
Lower	6	8.5
No	1	1.4
Increased maize grain yield		
Very high	20	28.2
High	45	63.4
Lower	4	5.6
No	2	2.8
Increases fertility		
Very high	21	29.6
High	38	53.5
No change	9	12.7
Reduced fertility	3	4.2
Provides fodder		
Very high	44	62
High	23	32.4
Lower	4	5.6
Increased milk production		
Very high	25	35.2
High	9	12.7
Lower	2	2.8
No change	2	2.8

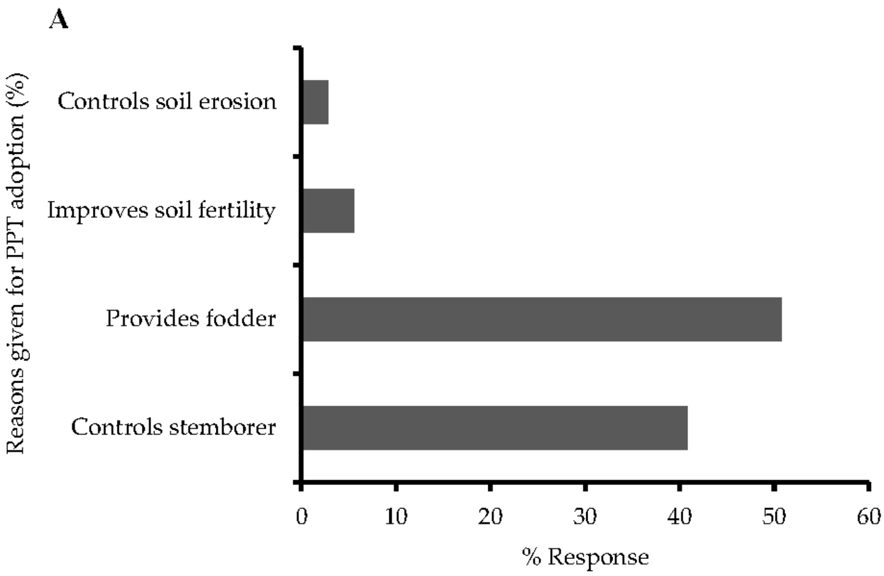

Figure 4. *Cont.*

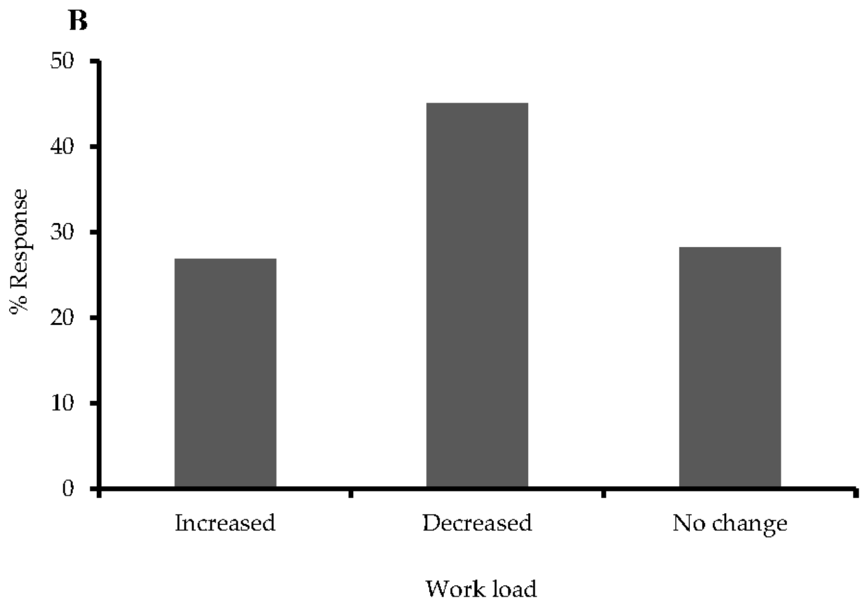

Figure 4. Farmers' perception of (**A**) motivating factors for adoption of the push-pull technology and (**B**) workload in implementing push-pull technology in the Hawassa district, Ethiopia.

4. Discussion

The average family size of the households in the study area was 6.6, which is greater than the national average of 5 persons [1]. Previous research findings indicate that family and landholding size have a significant and positive influence on a households' decisions to employ new agricultural technologies that are particularly targeted towards smallholder farmers because of the requirement for more family labour. In this study, a larger family size, therefore, indicates a potential for the sustainability of the push-pull technology because of access to more family labour. The average landholding size of the households was 1.15 hectares per household, where the majority (63.5%) of farmers allocated a larger portion of the average area, 0.71 hectares, to maize production. Maize has vital importance as both a food (94%) and cash (80%) crop sold either as green cobs or grains for household use. This is consistent with the study by Below et al. [14], which stated that maize producers in Ethiopia are mostly smallholder subsistence farmers in both land size and production volume. The reasons for the maize dependency of the households was not only from their farming preferences but also from their limited land size to cultivate other crops. Usually, households with a larger area of maize are relatively more food secure and are more concerned with adopting and using proper technologies.

The study area was characterized by rain-fed (bimodal, with short rain from February to April and long rain from June to September), crop-livestock, mixed farming systems that were mainly recognized by mono-cropping patterns with dominant maize cultivation. Crop production is the main source of food and income for households. The farmers cited that livestock provided not only milk, meat and draft power for the household, but also sources for manure that can improve soil fertility. This can be considered a better option for strategies that enhance maize productivity, as push-pull companion plants (Desmodium and Brachiaria) could be an important source of animal feed [15].

Farmers rated stemborers as their most important constraint limiting maize production. However, other challenges, such as the lack of quality livestock feed, the loss of soil fertility and run-off, were also reported by farmers. All these constraints can be solved by the novel, push-pull technology at once [9]. These attributes of the technology-initiated farmers to adopt the technology on their farms starting with the next cropping season. The farmers estimated that stemborers can reduce the estimated maize yield by approximately 29.3% compared with actual harvested yields in the 2015–2016 cropping season. This result is consistent with Getu et al. [5] study on the level of damage caused by stemborers, which was an average of 20–50% maize yield loss in Ethiopia. Similarly, a study by Groote et al. [16] also showed that the average maize yield loss caused by stemborer damage was estimated to be 20–40% in Africa.

In the study area, only approximately 20% of farmers applied chemicals for stemborer control, whereas 80% used chemical-free cultural methods, including timely planting, the application of wood ash, the up-rooting of damaged maize stems and intercropping with other legume crops. Similarly, a study conducted by Oben et al. [17] reported the use of different cultural methods, such as wood ash and botanicals, for the control of maize stem borers in Cameroon. In addition, Tefera [18] also indicated that intercropping and crop rotation of cereals with legumes decreased the incidence of pests, which resulted in increased yields. As a result, farmers held a positive attitude that the push-pull technology was the best fit for their maize cultivation and livestock management practices through their observations of the demonstration plots on field days and their frequent visits. A study conducted by Khan et al. [8] also showed that such attitudes were found to positively and significantly influence the likelihood of farmers adopting the technology.

Labour is an important factor of production in crop cultivation and is one of the main constraints in the adaptation of new technologies [19]. In this study, about 27% of farmers reported that the technology required more labour during land preparation, plantation and weeding activities compared to their conventional practices. Women and children were often subjected to weeding the companion grasses. In this regard, a study by Khan et al. [20] revealed that push-pull technology increased the cost of labour during the initial cropping season due to the extra labour required for the planting and hand weeding of Desmodium and Brachiaria compared to the farmers' conventional practices. However, 45% of farmers appreciated that the technology decreased the farm labour required, particularly after the first weeding of the maize field since Desmodium covers the soil and reduces/suppresses the presence of weeds. This result corroborates earlier findings that push-pull technology begins to yield benefits in terms of increased production and decreased labour demand in the second and third years after its establishment [12,21].

5. Conclusions

The findings of the present study demonstrate that stemborers and poor soil fertility are among the main factors that contribute to poor maize productivity in the study areas. In both cropping seasons, except for Jara Gelelcha, better maize grain yield was obtained from the climate-adapted push-pull plots than in the maize monocrop plots. Furthermore, most push-pull technology-practicing farmers perceived that push-pull technology is better than their practices due to the different attributes of climate-adapted push–pull technology. Given its multiple benefits, the climate adapted push-pull technology has great potential to positively impact the livelihoods of smallholder farmers in the region [12,21]. However, the dissemination of the climate adapted push-pull technology to reach more and more farmers requires strong partnerships among different practitioners/actors such as farmers, researchers, non-government organizations (NGOs), the Ministry of Agriculture, agricultural universities and seed companies.

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Conflicts of Interest: The authors declare no conflict of interest.

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