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Perception of Farmers on Push-Pull Technology: Using Farmers Research Network Approach in Eastern Amhara, Ethiopia

Seid Hassen[a]*, Tewodros Alemu[a], Asmare Dejen[a], Tizazu Mulugeta[b], Endeshaw Ashine[b] and Muluken Girma[a]

[a] College of Agriculture, Wollo University, Dessie, Ethiopia
[b] College of Agriculture, Woldia University, Woldia, Ethiopia

ABSTRACT

Striga and stem borer are the major challenges to sorghum production and causing serious food security problems in Ethiopia. Therefore, the study was aimed to assess the perceptions of farmers on stem borer and Striga management, other multifunction of the push-pull forage plants, and social value of the farmers research network (FRN) on push pull technology (PPT). Data were collected using household-based semi-structured questionnaires on Likert scale using Open Data Kit. In all study areas, the major challenges of sorghum production were pests (99%) followed by moisture stress (91%). Low soil fertility (86%) and input unavailability (79%) were the other sorghum production challenges. Stem borer was the major insect (99%) of sorghum and followed by fall army worm (92%). Striga weed was the major sorghum challenge (97%) and followed by Parthenium (21%). Majority of the farmers (98%) preferred to use PPT as a remedy to control pests. Most of the respondents (89%) perceived PPT was safer for human health, environmentally friendly and affordable compared to pesticides. PPT has contributed to increase grain yield (99%). All the respondents reported that PPT was used as a feed source for livestock, resulting in increased milk yield and weight gain. Most farmers (97%) responded that FRN enhanced knowledge transfer resulting in adoption of PPT and improved social interaction (96%). Most farmers who participated in the FRN have adopted the technology; hence, dissemination of the system to other farmers who are involved in sorghum production is recommended.

Keywords: Brachiaria, Desmodium, Farmer Research Network, perception of technology.

INTRODUCTION

Sorghum and maize are among the major staple crops playing an important role in the food security of the poorest and most food insecure people of the world. Stem borer (*Busseola fusca* and *Chilo partellus*) and striga (*Striga hermonthica*) are among the biotic constraints on maize and sorghum production, causing grain yield losses up to 100% (Kfir et al., 2002; Oswald, 2005; Asmare et al. 2011). Although many alternative measures are developed, farmers tend to use synthetic pesticides because quickly knock out stem borer and other insect pests. Using synthetic pesticides is expensive to buy and has negative impacts on human health and the environment (Asmare, 2014). Spraying synthetic pesticides for stem borers control is not only expensive and harmful to environment but, is also ineffective. Hand weeding for striga is time consuming and labor intensive (Khan et al., 2005).

*Corresponding author: seidhassen19@yahoo.com

The term push pull was first conceived as strategy for insect pest management by Pyke et al. (1987) in Australia. Push pull is a platform technology around which other agricultural innovation can develop to bring an overall improvement in the farming system and livelihoods. It simultaneously reduces crop losses, improve productivity, household nutrition, incomes, it enables increased production of livestock fodder; address soil fertility constraints and enables a minimum tillage system (Khan et al., 2005).

To minimize the destructive effects of striga and stem borer on sorghum, push-pull technology (PPT) has been promoted as an integrated ecological management system. PPT uses a repellent intercrop (*Desmodium* spp.) and an attractive trap plant (either Brachiaria or Napier grass) (Khan et al., 2005). Insect pests are repelled from the food crop and are simultaneously attracted to a trap crop. PPT was developed by the International Centre of Insect Physiology and Ecology (ICIPE) and its collaborators for the

control of stemborers and striga weed in resource-poor farming systems in Kenya (Khan et al., 2005). This technology controls both stemborers and striga and improves soil fertility. PPT was introduced to Ethiopia by Amhara Agricultural Research Institute in 2009 (Asmare, 2014). Asmare (2014) reported that sorghum grain yield advantage of 47-69% over mono sorghum was recorded in push pull system.

Farmers research network (FRN) is one way of farmers learning platform which is newly emerged approach under development to build the evidence base for agroecological intensification of smallholder farming systems. FRNs are an approach under development within the McKnight Foundation Collaborative Crop Research Program. It aims at linking problem-solving research with action that can provide a context-specific evidence base for Agro-ecological intensification, facilitate positive changes for farmers at scale and meet requirements of mutuality, reciprocity, beneficiary ownership and local agency. Agro-ecological intensification in turn means improving the performance of agricultural systems through integration of ecological principles into farm management (Khan et al., 2005).

Farmers' perceptions of agricultural technologies influence their decisions to adopt them (Rogers, 1995). Other scholars emphasize that age, gender, education, farmer group, access to extension advice, distance to nearest administration center, farmers' perception on severity of stem borer and striga weed constraints, awareness of technology, access to input markets, and other factors play significant role in influencing PPT adoption (Khan et al., 2008). The objective of this research was to assess farmers' perceptions of PPT on stem borer and striga management, as well as the fodder production. In addition, we assessed the social value of the FRN approach.

MATERIALS AND METHODS

Description of the study area:

The project was implemented in three zones: South Wollo, North Wollo and Oromiya in Amhara Region of Ethiopia. Within these three zones, the project includes seven districts: two in South Wollo (Ambassel & Kallu), two in Oromiya (Artumafursi & Dawachefa) and three in North Wollo (Raya-kobo, Habru & Gubalafto). The districts are located in the North Eastern Lowlands of Amhara Region at latitude and longitude of 110 56'- 12018' N and 390 23' – 390 47' E, respectively (Fig. 1). The project sites are located between 1500 and 1850 meter above sea level with average annual rainfall between 674 and 880 mm per year (EMA, 2016). The sites were selected because they are located within the 'sorghum belt' and are known to face stem borer and Striga as production constraints. Sorghum farmers from the seven districts participated in FRNs focused on implementing PPT) to prevent stem borer and Striga infestation. The specific participant Kebeles (the smallest administrative unit in Ethiopia) in the survey are indicated in Table 1.

Table 1: FRN-Push pull technology participant farmers in the project (N=166)

District	Kebele	Frequency	Response (%)
Raya kobo	Aradom	80	48
Habru	Ergibo	35	21
Gubalafto	Gedober	19	11
Kalu	Chorisa	14	8
Dawachefa	Bedeno	9	5
Artumafursi	Chefadire	4	2
Ambasle	Tisabalima	5	3

Kebele = the smallest administrative unit in Ethiopia

Data collection:

Data on the perception of farmers were collected using household-based semi-structured questionnaires using Open Data Kit. The data were collected from the sampled PPT implementer' on: characteristics of the respondents, effeteness of PPT to control stemborer and striga, value of PPT plants to livestock feed and other values of Brachiaria and Desmodium, advantage and disadvantages of FRN. We have used the Likert scale to take the perception of farmers on the push-pull technology.

Sample size and sampling technique:

Purposive and random sampling techniques were employed to collect the perception data. The study districts and the participant farmers were selected purposely since the districts and the participant farmers should be PPT implementers. But, from the PPT participant farmers, some farmers were selected randomly for the interview. During data collection households were stratified into male and female headed to see heterogeneity.

From the total number of 273 FRN-PPT participant farmers, 166 farmers (59%) were taken to collect the perception data. The sample size of respondents taken from districts of the project area for the perception data are indicated in (Table 1).

Data Analysis:

Interview data were collected using Open Data Kit and the results were analyzed using SPSS version 16 and using functions for descriptive statistics in KoboToolbox

RESULTS

Education level and sex of the respondents:

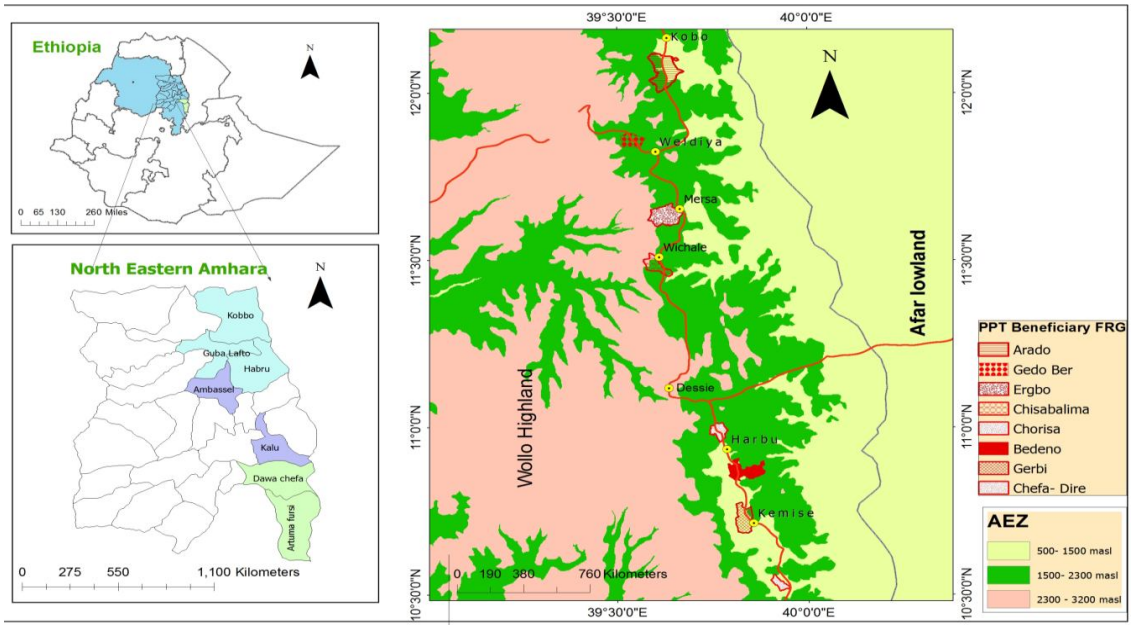

Fig. 1: Map of the study area

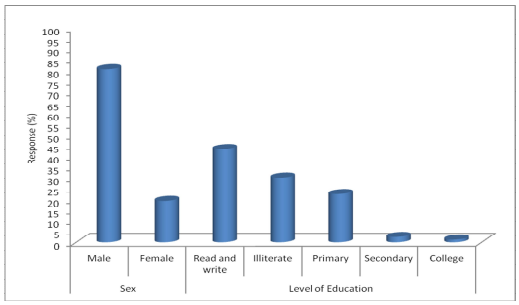

Fig. 2: Education level and sex of respondents involved in the push pull technology (N=165)

The sex of respondents was 81% males and 19% females. Most of the respondents educational level was read and write (44%) but about 30% respondents were an illiterate (Fig. 2).

Major sorghum production constraints:

Most respondents (99%) answered that the major challenges of sorghum production were insects and weed and moisture stress (91%) (Fig 3). During the assessment, the respondents reported that the major sorghum productions challenges were insects (99%), weed (99%) and moisture stress (91%). Farmers responded that the major sorghum insect causing high grain yield losses were stemborers (99%) and fall army worm (96%). Most farmers (100%) answered that PPT was the most stem borer management methods (Fig. 4). Similarly, Striga was the major weed species causing huge sorghum grain yield losses (Fig.5).

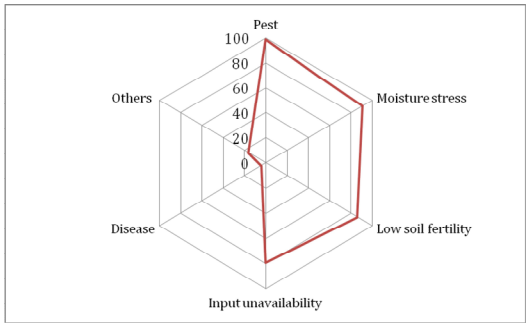

Fig. 3: Major challenges of sorghum production reported by farmers in the study area (N=166)

Growth stage of push pull plants for effective control of the pests:

Farmers Responded that the best grow stage to transplant PPT plants (*Desmodium* and *Brachiaria*) was at mid stage or growth (81%) and followed by at late growth stages (61%). They explained that transplanting PPT plants at early growth had low survival (Table 2).

Contribution of PPT to sorghum grain yield:

From all respondents about 77% farmers noted that PPT increased sorghum grain yield of 5-10% and 13% of the respondents replied that 50-60% of sorghum yield increased (Fig. 6).

Table 2: Growth stage of push pull plants for effective control of the pests (N=166)

Stage of Push pull plants	Response (%)±SD	χ^2
Late stage	61±24.75	
Mid stage	81±44.75	57.11**
Early stage	1±35.25	
All stages	2±34.25	

SD=standard deviation; χ^2 =chi square; ** 0.01 significance level

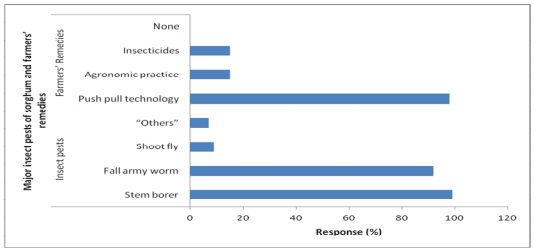

Fig. 4: Major insect pests of sorghum reported by farmers and their remedies for control (N=166)

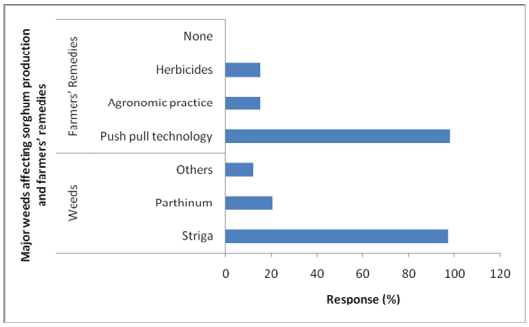

Fig. 5: Major weeds affecting sorghum production reported by farmers and their remedies (N=166)

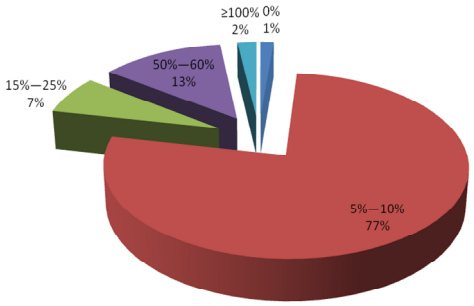

Fig. 6: Effect of push pull technology on sorghum grain yield (N= 144)

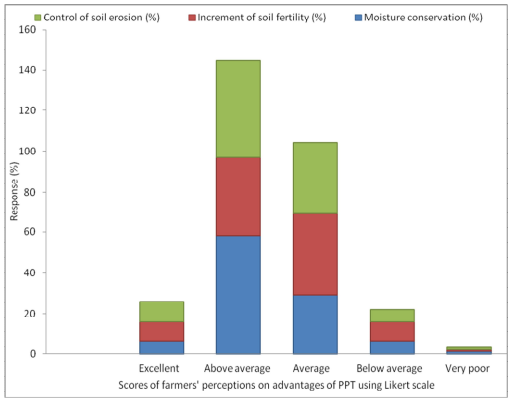

Fig. 7: Effect of push pull technology on other agronomic parameters (N=145)

Extra benefits of push pull technology:

Most respondents (60%) revealed that PPT had advantages in minimizing soil erosion and about 40% of the respondents showed PPT increased soil fertility (Fig. 7).

Contribution of PPT for livestock feed:

The perception of participant farmers on the advantage of the push pull plants for livestock feeds is reported in Fig. 8. They were used to enhance milk yield and weight gain.

Contribution of farmers research network on other technology adoption:

The response of farmers to the advantages and disadvantages participating in the farmer's research network to adopt technologies is shown in Fig. 9. The advantages and disadvantages of FRN were on technologies other

DISCUSSION

Education level and sex of the respondents:

About 19% of the PPT than the PPT.

Advantage of PPT over pesticides application:

The comparison of farmers' perception on PPT and pesticides application in controlling stem borers and striga is reported in Fig.10.

participant farmers were found female in sex and the rest 81% were males. The result is similar to the report of Murage et al. (2015) who mentioned the highest percentage of female-headed households of PPT users in western Kenya was 32.6%. Regardless of the respondents' sex, most farmers had some level of education. Majority of the respondents (43.6%) was read and write, and 22.5% of respondents had gone to primary school. The second largest group of respondents (30.3%) indicated that they had not any level of education or illiterates. In contrast to this finding, Amudavi et al. (2009) indicated 56.7 % of the household heads had no formal education in Ethiopia. Only four farmers (2.4%) indicated that they received secondary school education.

Major challenges of sorghum production in the study area:

About 99% of the respondents reported that the major challenge of sorghum production were pests (insects and weeds) followed by moisture stress (91%). This result is similar with Wanyama et al. (2015) who reported 70% of the both Striga and stem borer were the major problems for sorghum production. Similarly, About 80% of the farmers in Trans-Nzoia, Homa Bay, Kisii and Suba districts, and more than 50% of those in Bungoma, Butere-Mumias, Migori and Teso districts reported reduced stem borer infestation after adopting PPT

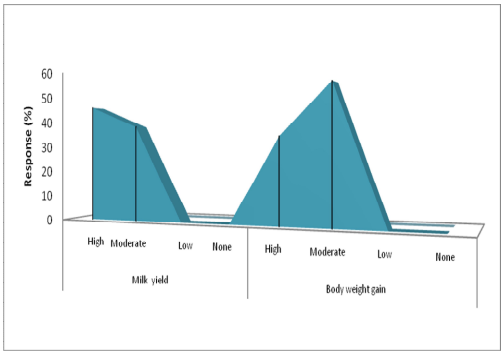

Fig. 8: The importance of PP plants for livestock feeds to enhance milk yield and weight gain (N=145)

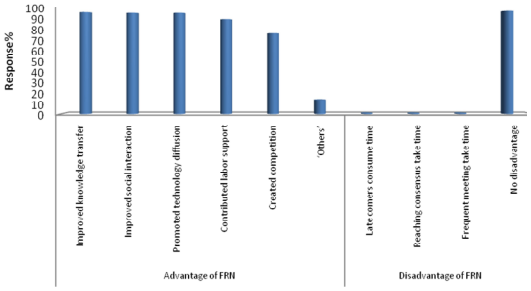

Fig. 9: Advantages and disadvantages of participating in FRN reported by farmers (n=166).

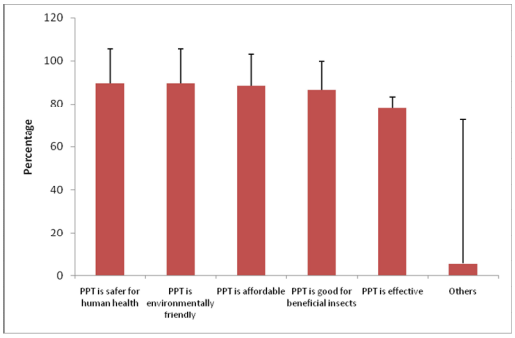

Fig. 10: Advantages of push pull technology over pesticide application (N=166)

(Wanyama et al., 2015). Low soil fertility (about 86%) and input unavailability (79%) like improved seeds, fertilizers, etc were the other main challenges of sorghum production in the area reported by the respondents.

According to the respondents, the major insect affecting sorghum production in the study area were stem borer (*Chilo partiles*), fall armyworm (*Spodoptera frugiperda*), sorghum shoot fly, sorghum aphid, and sorghum chafer (*Pachnoda interrupta*).

Majority of the respondents (99%) indicated stem borer as the major insect of sorghum followed by fall army worm (92%). Farmers used different techniques to control the insect pests. Majority of the interviewed farmers (98%) preferred to use PPT (*Desmodium* and *Brachiaria*) as a remedy for the control of the infestation of insect pests compared to the use of agro-chemicals and agronomic practices. The other farmers used agronomic practices such as hand weeding (15%) and application of agro-chemicals (15%) to control the insect pests.

The major weeds affecting sorghum production in the study area were Striga, Parthenium and others like *Amaranthus* spp., *Commelina* spp. and Cypress spp.

A majority of the respondents (97%) mentioned striga to be the major weed of sorghum followed by Parthenium (21%). Farmers used different techniques to control the weeds. Majority of the interviewed farmers (98%) preferred to use PPT as a remedy for the weed infestation as a control mechanism compared to the use of agro-chemicals and agronomic practices. This result is in line with Wanyama et al. (2015) who reported majority of farmers reduced striga infestation after using PPT. Other farmers used agronomic practices such as hand weeding (15%) and application of agro-chemicals (15%) to control the weeds. The result is in line with this result of Wanyama et al. (2015) who reported that 86% use conventional hand hoeing coupled with up-rooting and leaving the weeds or/and throwing outside the plot as a field sanitation practice to control of striga.

Majority of the respondents (98%) indicated PPT as the main preference of farmers to control the major pests of sorghum. This result is in line with Wanyama et al. (2015) who reported majority of farmers reduced striga infestation after using PPT. For effective control of these pests it is better to know which growth stage (early, middle, late or all stages) of the push pull plants is more effective. Accordingly, the perception of the respondents was taken which growth stage of the push pull plants do they think is more effective for the control of the pests. Majority of the respondents (71%) observed that middle growth stage of the push pull plants was the most effective stage in controlling stem borer and striga. Late stage was reported by the respondents (53%) as the second stage of push pull plants to control stem borer and striga effectively.

Majority of the respondents (98%) indicated PPT as the main preference of farmers to control the major pests of sorghum. This result is in line with Wanyama et al. (2015) who mentioned majority of farmers reduced striga infestation on their farms after adopting the technology.

Growth stage of push pull plants for effective control of the pests:

For effective control of these pests it is better to know which growth stage (early, middle, late or all stages) of the push pull plants (*Desmodium* and *Brachiaria*) is more effective. Accordingly, the perception of the respondents was taken which growth stage of the push pull plants do they think is more effective for the control of the pests.

There was a significance difference ($p < 0.01$) among the stage of the push pull plants ($p < 0.01$). Majority of the respondents (81±44.75) observed that middle growth stage of the push pull plants was the most effective stage ($p < 0.01$) in controlling stem borer and striga. Early stage (1±35.25) was found significantly lower ($p > 0.01$) in controlling stem borer and striga in the sorghum field.

Contribution of PPT to sorghum grain yield:

About 98.6% of the respondents perceived that the use of push pull plants has contributed for the increase in the grain yield of sorghum as compared to the grain yield obtained from the conventional (control) plots. This result is similar with ISD (2013) of field reports which estimates that an effective PPT field can raise the yield of maize and sorghum by 50 to 90%. However, about 1.4% (2) of the respondents did not believe that the use of push pull plants contributed grain yield variations. In contrary, about 78 % of the respondents believed that there was a 5-10% yield increment due to the use of the PPT as compared to the conventional (control) practice. On the other hand, about 13% of the respondents revealed that there was about 50%-60% sorghum yield increment due to the use of PPT. This result is similar with the study of Hailu et al. (2015) who mentioned sorghum grain yields of PPT plots in South Wollo showed yields were 50% of more than the national average (1.7-2.1 t/ha). Only a small proportion of respondents (2%) believed that there was sorghum yield increment that ranges from 100% to 200% as compared to the grain yield obtained from the conventional plots. The main reasons mentioned by farmers for the higher grain yield of sorghum from the PPT were reduction of stem borer, reduction of striga infestation, suppression of other weed species, improvement in soil fertility, and the conservation of moisture and reduction of soil erosion. This result in line with the finding of Fischler (2010) in which farmers practicing PPT observed significant reduction in incidence of Striga, stem borer and soil erosion, and increased soil fertility and soil moisture. Moreover, it is similar with other study of Wanyama et al. (2015) who stated 97% increased productivity due to increased maize yields for food and cash, 86% reduced Striga infestation, and 43% mentioned improved soil fertility and moisture holding capacity.

Some of the soil-related roles of grasses and legumes are soil aggregation, erosion reduction, and water infiltration mainly by their root networks (Horrocks & Vallentine, 1999). Additionally, legumes are desirable components in areas where nitrogen is a limiting factor for optimal growth of plants since they fix atmospheric nitrogen into a form utilized directly by the legumes themselves and made available to associated plants. Legumes fix N through a symbiotic relationship with bacteria that infect their roots and form root nodules (Crowder & Chheda, 1982). Transfer or movement of legume N to the associated plant primarily occurs by decaying of nodules where N is released into the soil solution (Butler & Bathurst, 1956) and can be readily available to roots of the associated species. Besides, decomposition of legume components such as leaf and petiole fall adds considerable organic matter to the soil surface and releases N into the soil as decomposition occurs (Crowder & Chheda, 1982). This implies that the sorghum planted in association with the forage plants benefitted from the fertile soil with high infiltration and reduced erosion with a consequent increase in crop yield.

Extra benefits of push pull technology:

According to the respondents, farming with the use of PPT enhances the grain yield of sorghum by reducing the infestation level of stem borer and striga. Moreover, the respondents mentioned other additional advantages of PPT like: improving soil fertility, conservation of moisture and control of soil erosion to enhance the productivity of sorghum. This study results agreed with ICIPE (2007) that stem borer, striga and poor soil fertility are three constraints to efficient production of cereals in sub-Sahara Africa.

Majority of the respondents (58%) declared that the use of PPT in enhancing moisture conservation in the farmland was very good which plays its role in increasing the productivity of sorghum. Regarding the use of PPT in increasing the soil fertility of the farmland, about 39% and 40% of the respondents declared that it is very good and good, respectively. The use of PPT to control soil erosion in the farmland was reported by about 48% of the respondents. Similarly, Wanyama et al. (2015) reported that over 80% of the farmers in Busia district, and over 50% in Bungoma, Migori, Suba and Teso improve soil fertility under the PPT because of reduced soil erosion and increased nitrogen fixation.

Contribution of PPT for livestock feed:

All the respondents (100%) replied that they have already experienced the use of PPT plants (*Desmodium* and *Brachiaria*) for their livestock. The result showed that almost all the respondents clearly agreed that the push pull plants (*Brachiaria*

and *Desmodium*) were used as feed source for their livestock.

About 46% of the respondents perceived that the quantity of milk increased by feeding PPT plants to animals was ranked to be high. This is result is in line with Wanyama et al. (2015) who indicated more than 50% of the farmers in Kisii, Suba and Trans-Nzoia districts reported an increase in milk production due to increased fodder production. Similarly, about 38% of the respondents replied that the PPT plants resulted in moderate milk production. None of the respondents believed that milk yield from PPT plants was low.

On the other hand, about 54% and 34% of the farmers believed that PPT contributed in increasing animal body weight were ranked moderate and high, respectively. None of the respondents believed that push pull plants resulted in low animal body weight.

Contribution of farmers research network on other technology adoption:

The majority of the farmers (98%) clearly showed that the network established among the farmers through FRN and farmers research group (FRG) contributed significant advantage on social and other related issues. As a result 97% of farmers responded that PPT through FRN increased their knowledge transfer and developed their capacity in technology adoption. This result is similar with report push–pull technology is dissemination methods, namely field days, farmer teachers, mass media, public meetings, printed materials and farmer field schools (Khan et al., 2008; Amudavi et al., 2009). About 96.4% of the farmers believed that participation in the PPT farmers' research net work improved their social interaction among them and helps to increase technology diffusion. Sydney (2010) also reported farmer teachers themselves were a widely used source of information by adopters (60%) and exposed farmers (100%).

On the same manner, about 96% of the respondents also believed that participating in the PPT created opportunities for the diffusion of other technologies. About 77% of the respondents agreed that participating in the PPT develop positive completion among the farmers during the implementation of both agricultural and non agricultural related activities. About 90% of the respondents agreed that the PPT helps them to contribute labor to support each other among the farmers. However, very limited number of farmers replied that PPT has some disadvantages such as time consuming due to late comers of participants (0.6%). It takes much time to create awareness among farmers or to reach to common consensus on some issues.

The respondents also mentioned other advantages which were gained from FRN. These include the following: It helps to known each other and increase relationship among farmers; Strengthen weak farmers through consultation and feedback within and among groups; Creates opportunity for the farmers to save money; Creates self confidence of the individual farmers and the groups; Encourage female headed farmers to be a leader; and Learn from the weakness during practical evaluation of each ones performance on their push pull plot.

Advantage of PPT over application of pesticides:

Majority of the respondents (89±16.56) agreed that PPT is safer for human health as compared to application of pesticides to control stem borers and striga in sorghum field. Similarly, the respondents perceived that pull technology is environmentally friendly (89±16.56) as compared to pesticides. This indicated that majority of the farmers perceived that pesticides are pollutants to their environment as well as have direct toxic effect on human being. Most farmers perceived that the use of PPT is safer to the environment and to the human beings relative to pesticides. This result is in line with Midega et al. (2008) who reported environmental benefits of the PP technology include soil and moisture conservation, improved soil health, enhanced biodiversity while eliminating pesticide usage.

The majority of farmers (88±15.37) also believed that PPT is affordable for them as compared to the pesticides. This could be associated to the high cost of pesticides in comparison to the push pull technology. Push pull strategy is relatively low cost technology and farmers incur very low cost for it. This result similar with the findings of Fischler (2010) that the push–pull technology described 'the single most effective and efficient low-cost technology for smallholders in Eastern Africa. Most farmers in the study area are with low income and cannot afford the current high cost of herbicides. Hence, the use of push pull in the farming system of South, North Wollo and Oromia special zone will be more sustainable in the long term. On the other hand, about 86.31% of the farmers perceived that the use of PPT does not affect beneficial insects in the crop field where as pesticides have the potential to completely devastate beneficial insects in their field. Similar to this finding, Midega et al. (2008) mentioned pull push technology is important roles played by companion crops and beneficial insects in the system. The other reasons that mentioned by the farmers for the preferring of the PPT as compared to pesticides are the Desmodium and Brachiaria plants are becoming major sources of feed for their animals. In addition, such plants can suppress weed

infestation particularly of striga and increased soil fertility through nitrogen fertility. Such plants are tolerant to low moisture stress and do not have effect on honey production and animal health.

In conclusion, stem borers and striga damages were significantly reduced and thereby sorghum yield was increased. Moreover, farmers noted that PPT-FRN provides a good source of livestock feed, increases soil fertility, reduces soil erosion and suppresses other weeds. These findings suggest that the technology could be practically desirable option for livelihood improvement in sorghum-growing smallholder farmers and using FRN approach for learning agricultural technologies was found the best choice for farmers of the study area. Dissemination of the PPT using FRN approach to non push pull practitioners of the area is therefore very useful.

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REFERENCES

Amudavi, D., Khan, Z.R, Wanyama J.W., Midega C., Pittchar, J., Nyangau, M., Hassanali, A., & Pickett, J.A. (2009). Assessment of technical efficacy of farmer teachers in the uptake and dissemination of push pull technology in western Kenya. *Crop Protection, 28 (11)*, 987-996.

Asmare, D. (2014). On-farm Evaluation of Push-Pull System for Stem borers and Striga Management on Sorghum in Northeastern Ethiopia. *Biopesticides International, 10 (2)*, 176-183.

Asmare, D., Emana, G., Ferdu, A., & Amare, A. (2011). Efficacy of some botanicals on stemborers *Busseola fusca* and *Chilo partellus* on sorghum in Ethiopia. *Biopesticides International, 7 (1),* 24-34.

Butler, G. W., & Bathurst, N.O. (1956). Tropical Grasslands. *Australian Journal of Experimental Agriculture and Animal Husbandry, 5 (2)*, 89–98.

Crowder, L.V., & Chheda, H.R. (1982). Tropical Grassland Husbandry. Longmans, London, England.

EMA (2016). Report of Ethiopian Meteorology Agency of the year 2016. Addis Ababa, Ethiopia.

Fischler, M. (2010). Impact Assessment of Push Pull Technology in Eastern Africa. Inter cooperation, Switzerland, ICIPE Science Press, Nairobi, Kenya.

Hailu, A., Kifle, G., Dejene, A., Haileselassie, G., Fasil, R., Kidu, G., Sue, E., Hailu, L., Endris, Arefayne, M. A., & Sara, M. (2015). Evaluation of the piloting of push pull technology in controlling striga and stemborerin maize and sorghum areas of semi-arid northern Ethiopia. *AshEse Journal of Agricultural Science, 1 (7)*, 071-081.

Horrocks, R.D., & Vallentine, J.F. (1999). Harvested Forages. Academic Pres, Published by Elsevier Science Publishing Co Inc, USA.

ICIPE (2007). Push-Pull: Curriculum for farmers field schools. International center of insect.

ISD (2013). Annual Report for 2013. Institute for sustainable development, Addis Ababa, Ethiopia.

Kfir, R., Overholt, W. A., Khan, Z. R., & Polaszek, A. (2002). Biology and management of economically important Lepidopteran cereal stem borers in Africa. *Annual Review Entomology, 47*, 701–731.

Khan, Z. R, Amudavi, M., Midega, C., Wanyama, J. W., & Pickett, J. (2008). Farmers' perception of a push–pull technology for control of cereal stem borers and striga weed in western Kenya. *Crop protection, 27 (6)*, 976-987.

Khan, Z.R., Muyekho, F.N., Njuguna, E., Pickett, J.A., Wadhams, L.J., Pittchar, J.A., Ndiege, G. Genga, D., Nyagol, C. & Lusweti, (2005). A Primer on Planting and Managing 'Push-Pull' Fields for Stemborer and Striga Weed Control in Maize: A Step-by-Step Guide for Farmers and Extension Staff. International Centre of Insect Physiology and Ecology (ICIPE), Nairobi, P60. Kenya.

Midega, C.A.O., Khan, Z.R., Vanden, B., Ogol, C. K., Dippenaar-Schoeman, P.O., Pickett, J., & Wadhams, L.J. (2008). Response of ground-dwelling arthropods to a "push–pull" habitat management system: spiders as an indicator group. *Journal Application Entomology, 132*, 248–254.

Murage, A.W., Midega, C.A.O., Pittchar, J.O., Pickett, J.A. & Khan, Z.R. (2015). Determinants of adoption of climate-smart push-pull technology for enhanced food security through integrated pest management in eastern Africa. *Food Security, 7*, 709–724.

Oswald, A. (2005). Striga control technologies and their dissemination. *Crop Protection. 24 (4),* 333–342.

Rogers, E, M. (1995). Diffusion of innovations (4th ed.). New York: The Free Press.

Pyke, B., Rice, M., Sabine, B., & Zalucki, M.P. (1987). The Push-Pull Strategy-Behavioural Control of Heliothis. *Australian Cotton Grower*, *9*, 7-9.

Sydney, S. (2010). Analyzing the Impact of Push-Pull Technology, Gender, and Irrigation on Food Security in Rural Kenya. International Centre of Insect Physiology and Ecology, Mbita, Kenya.

Wanyama, J.W., Khan, Z.R, Amudavi, D., Nyangau, M., Midega C., & Pickett, J. (2015). Farmers' Perceptions and Adoption of a 'Push-Pull' Technology for Control of Cereal Stem borers and Striga Weed in Western Kenya. AIAEE Proceedings of the 23rd Annual Meeting, Polson, Montana, Kenya.