Evaluation of Push-pull technology for pest and soil fertility management on maize in north western Ethiopia.

Mesfin Abate (maf19200614@gmail.com)
Debre Markos University College of Agriculture and Natural Resource
Getenet Atnafu
Berhanu Alemu
Abiyot Molla
Gizaw Gebremariam
Yentila Alemneh
Messeret Taddese

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Abstract

Aims

The aims of the study were (i) to evaluate the effectiveness of the push-pull technology against stemborer and striga infestation, (ii) to investigate the impact of the push-pull technology on improving grain yield, and (ii) to assess effect of the push-pull technology on soil fertility.

Methods

The study was conducted in 2017 and 2018 cropping seasons in 3 districts in north western Ethiopia. Three farmers from each district were randomly selected for the study. Each farmer had a set of two treatments (plots): a push-pull and maize monocrop treatments. Data were collected on percentage of maize plants damaged by stemborers, number of emerged striga plants, plant height, grain yield, available phosphorus (P), available potassium (K), total nitrogen (TN), organic carbon (OC), organic matter (OM) and bulk density (BD).

Results

There were significant reduction in stemborer damage (2.8%) and striga count (4.1 Striga plants/m^2) in the push-pull compared to maize monocrop plots (15.4% and 21.8 striga plants/m^2, respectively). Maize plant height (2.34 m) and grain yield (5.3 t/ha) were significantly higher in the push-pull plots as compared to sole crop (1.9 m and 3.0 t/ha, respectively). Similarly, there were significantly higher P (20.06 mg/kg soil), K (406.86 mg/kg soil), TN (2.5 g/kg soil), OC (42.9 g/kg soil), OM (73.8 g/kg soil) and BD (0.92 g/cm^3) levels rating from moderate to high fertility status in the push-pull as compared to monocrop plots (11.17 mg/kg soil, 347.93 mg/kg soil, 1.6 g/kg soil, 29.8 g/kg soil, 0.95 g/cm^3 and 51.2 g/kg soil, respectively) which is rated from low to moderate soil fertility level. Moreover, BD was significantly lower in PPT (0.92 g/cm^3) than in MC (0.95 g/cm^3) plots.

Conclusions

Therefore it can be concluded that push pull technology is better in improving soil fertility status which results in better grain yield.

Introduction

Maize (Zea *mays* L.) is the most important cereal crop cultivated widely in north western Ethiopia. Maize contributes the most important share of grain crop production in Ethiopia. Annually, 18% of cropped area (2,274,306 ha) is planted with maize and produces 29% (96,357,34.5 tons) of grains in Ethiopia (CSA, 2018). Maize is the second crop after teff in cropped area and first in grain production (CSA, 2018).The productivity of maize is, however, very low (< 4.2 t/hac) due to stemborer (*Busseola fusca)*, the parasitic weed striga *(Striga hermontica*) infestation and low soil fertility (CSA, 2018). In sub-Saharan Africa, due to striga an annual loss of US $7 billion was estimated, which affects the livelihood of over 100 million people (BaduApraku & Akinwale, 2011). In Ethiopia, crop losses of 65–100% are common in heavily striga infested fields (Ejeta et al., 2002). Mesfin et al. (2017) reported that in north western Ethiopia 44% yield reduction in sorghum is recorded in striga infested conditions. In some areas, farmers have become unable to grow maize and they have either abandoned their land or switched to other less important crops (Ejeta et al., 2002). Stemborer insects cause maize grain yield losses ranging from 20–40% (Kfir et al., 2002). When the two pests occur together they resulted in destroying entire harvests (Kanampiu et al., 2002).On the other hand, soil fertility depletion is one of the challenges to crop production in Ethiopia .This low soil fertility status is mainly caused by high cropping intensity, especially monocropping with limited practice of intercropping maize with legumes (Amede et al., 2021). Even though farmers are applying high rate of fertilizers in nutrient depleted soils, the nutrient use efficiency and the return is very low (Amede, 2020) making these soils non-responsive (Vanlauwe et al., 2008).

To overcome these challenges, the 'push-pull' technology (PPT) is important to intercrop maze with Desmodium that repel (push effect) and attract (pull effects) stemborer (Khan et al., 2014; Pickett et al., 2014). Napier grass (*Pennisetum purpureum*) has a particular ingenious way of defending itself: when the larvae bore into the stem, the grass secretes a sticky gum, physically trapping the borer and preventing most larvae from completing their life cycle (Ahmed et al., 2007). Desmodium (*Desmodium intortum*)root exudates hinder germination of striga seeds and fail to develop and attach on to the host roots (Midega et al., 2010). Desmodium is also essential in enhancing soil fertility status through biological fixation of atmospheric nitrogen (N2) and N mineralised from legume residues (Giller, 2001) and the addition of organic matter, practically eliminating soil erosion and suppressing weeds. The technology provides also additional benefits through providing high-quality livestock forage that increases animal health and milk production, which contributes to improved incomes and nutritional security in smallholder households.

Push–pull technology is a novel cropping system for integrated pest, weed and soil fertility management in cereal based farming systems. Hence, the technology is appropriate to smallholder farmers as it effectively addresses the major production constraints, and is economical as it is based on locally available plants, not expensive external inputs. It also fits well with traditional mixed cropping system in Ethiopia (Khan et al., 2014). Therefore, we conducted a two season study in farmer managed fields with three objectives;

i. To evaluate the effectiveness of push-pull technology against stemborer and striga weed infestation on maize crop
ii. To investigate the impact of push-pull technology on maize grain yield, and
iii. To assess effect of push-pull technology on soil fertility.

Materials And Methods

Study sites

Field experiments were conducted in three districts (Gozamin, Hult eju enesie and Jabitenan) in North western Ethiopia in 2017 and 2018 cropping seasons. These are sites where push-pull technology is being introduced for adoption by small holder farmers. The study districts were selected on the basis of being relatively hotspots for striga and stemborer pests. However, in Gozamin district, no striga was observed in both years. The study sites are characterized by a monomodal, long, and dependable rainy season occurring from May to October with an average of 180 days during 2017 and 2018 growing seasons (MOA, 2018). In all study sites mixed crop and livestock farming is the predominant mode of agricultural production. Maize, sorghum, and teff are the major cereal crops, together with pulses and oil crops. Detail description of the study sites is indicated in Table 2. The study sites receive an average rainfall of 900, 1000 and 1200 mm during 2017 and 2018 production seasons (June to November) in Huleteju enessie, Jabitenan and Gozamin districts, respectively. The average temperature of the study sites is 30, 28 and 25°C while altitude of the study sites ranges between 1800 and 2250 m.a.s.l. (MOA 2020)

Table 1
Soil chemical properties at the beginning of the study (before sowing in 2017 season) in three districts in north western Ethiopia.

Soil physic-chemical property	Districts				Mean rating
	Gozamin PP MC	Hulet eju enessie PP MC	Jabitenan PP MC	Mean PP MC	
pH	5.0 5.0	4.8 4.6	4.7 4.7	4.5 4.7	Strongly acidic (Jones, 2012)
Available P (mg/kg)	15 15.7	11 11	13 15	13 13.9	Low (Olsen et al. 1994)
Available K (mg/kg)	557.6 550	201 210	307 305	355.2 355	Very high (Landon 1991)
Organic carbon (g/kg)	45 47	31 35	29 29	35 37	Moderate (Tekalign *et al.* 1991)
Organic matter (g/kg)	62 60	57 60.2	50 49.7	56.3 56.7	Moderate (Tekalign *et al.* 1991)
Total N (g/kg)	2 1.7	2.5 2.5	1.75 2.0	2.08 2.06	Moderate (Tekalign *et al.* 1991)
Bulk density (g/cm^3)	0.92 0.65	0. 8 0.75	0. 95 0.9	0. 9 0.76	High (Jones, 2012)

Table 2
Mean (± S.E.) Percentage damaged by stemborer larvae and emerged striga /m^2 at 10 weeks after crop emergence in push-pull technology (PPT) and maize monocrop (MC) plots in North western Ethiopia .

Districts	Mean stemborer damage (%)						Mean emerged striga (count/m^2)					
	2017			2018			2017			2018		
	PPT	MC	P-value	PPT	MC	P-value	PPT	MC	P-value	PPT	MC	P-value
Gozamin	1.5 (± 0.3)	10.7 (± 0.9)	0.001	1.0 (± 0.4)	11.9 (± 0.7)	0.0001	-	-	-	-	-	-
Hulet eju enessie	4.7 (± 0.6)	17.1 (± 1.3)	0.0001	2.5 (± 0.4)	13 (± 0.6)	0.0003	5 (± 5.0)	23.2 (± 5.90)	0.0002	4 (± 4.2)	17 (± 5.7)	0.0001
Jabitenan	5.0 (± 0.5)	17.8 (± 1.2)	0.001	2.1 (± 0.5)	22.1 (± 0.1)	0.0001	6 (± 6.5)	27 (± 14.8)	0.0001	1.4 (± 2.2)	20 (± 13.7)	0.0003

Plot Layout, Planting And Experimental

Each districts, **3** small holder farmers with a total of 9 farmers in three districts who were within their first season of adoption of the push-pull technology were randomly selected to participate in the study. Each of the farmers had two adjacent plots, a push-pull (PP) and and maize monocrop (MC) plot, having the same fertility status at the time of establishment. The PP plot had maize intercropped with desmodium (Khan et al., 2008) which was planted through a drilling system in furrow between the rows of maize and three rows of Napier grass (Khan et al., 2008) planted around intercrop at a spacing of 50 cm within and 50 cm between rows. The inner most row of Napier grass was spaced 1m from the first row of maize (Khan et al., 2008). In both PP and sole maize treatments, during planting 2 maize seeds were planted at 80 and 40 cm inter and intra row spacing, respectively. Two week after planting, the seedlings were thinned to one plants per hill.. Farmers planted hybrid maize variety (BH 540) which was susceptible to both stemborer and striga in North Western Ethiopia. Urea (46% N) and DAP (18% N and 46% P2O5) were applied at a rate of 50 kg urea ha-1 and 100 kg DAP ha-1, equivalent to 27 kg N and 46 kg P2O5 ha-1. The whole amount of DAP (100 kg ha-1) and 25 kg of urea (first split of N) were applied at planting, while the remaining 25 kg urea (second split of N) was top dressed at vegetative stage. The plot size for PP and maize monocrop plots was 10 x 10 m^2. Farmers maintained equally all crop management practices (planting, weeding, fertilizer application and harvesting) throughout the study period.

Stemborer And Striga Infestation

Stemborer infestation levels were assessed non-destructively at 10 weeks after crop emergence (Khan et al., 2008). At 4 weeks after maze emergence thirty (30) maize plants were randomly selected in each PP and sole maze plots and tagged for subsequent observations. The tagged plants were inspected in each PP and sole maize plots and counting the number of plants with window-paned, pin-holed leaves and dead hearts arising from stemborer larvae feeding was recorded (Kfır et al., 2002). The data was expressed as percentage of maze plants damaged by stem borer per plot (Khan et al., 2008). At 10 weeks after maize emergence, striga count was done from each PP and maize monocrop plots through counting all shoots of striga per m^2 in average of 5 samples per plot (Mesfin et al., 2017).

Plant Height And Yield Of Maize

At physiological maturity, height of each of 30 plants was measured and data recorded as average plant height per plant. All the maize plants in each treatment were harvested and cobs sundried separately until it reach 12% moisture content for each treatment. The grain weight were measured per treatment area harvested and data converted in to t/ha.

Soil analysis Prior to planting (beginning of 2017), composite surface (0–30 cm) soil samples were collected from 5 points in both PP and maize monocrop treatments separately and analyzed for soil chemical properties. Similarly, at the end of the experiment (end of 2018 cropping season) soil samples were collected from 5 points in each PP and maize monocrop treatments and analyzed for soil chemical properties. Soil samples were mixed, homogenized, air dried in shade, ground and passed through a 2 mm sieve, and analyzed for soil pH, available P, available K, total nitrogen, organic carbon, organic matter and bulk density. Soil pH was measured potentiometrically in the supernatant suspension of a 1:2.5 soil: water mixture using a pH meter according to method outlined by Sahlemedhin and Taye (2000). Available P was determined following the method of Olsen et al. (1954). Total nitrogen was determined by the micro-Kjeldahl, distillation and titration method as described by Jackson (1958). Organic carbon was analyzed following the wet digestion method as described by Walkley and Black (1934). Potassium was measured by using flame photometry (Toth and Prince, 1949). Bulk density was determined by taking soil samples at 0–30-cm soil depths by using a standard core sampler (4-cm-long and 8-cm in diameter) and oven-dried at 105 ^oC for 48 h. The following equation was used to calculate the soil bulk density:

BD = Wd/V

Where: BD = soil bulk density (g cm − 3), Wd = sample oven dry weight (g), and V = sample total volume (cm^3).

At the beginning of 2017 cropping season, the result of preplanting soil analysis showed that the soil was strongly acidic in reaction with the pH value of 4.7 to 5. The available P (11–15 mg/kg soil), available K (201- 557.6 mg/kg soil), Organic carbon (29–45 g/kg), total nitrogen (1.75–2.5 g/kg), Organic matter (50–62 g/kg) and bulk density (0.75–0.9 g/cm^3) which had rating low to moderate nutrient content due to continuous monocropping (Table 3). However at the end of the experiment significant increase of soil fertility status (moderate to high) was observed in push-pull than maize monocrop plots due to addition of nitrogen nutrient thorough nitrogen fixation of desmodum and addition of legume residues inside the soil (Table 4)..

Table 3
Mean (± SE) plant heght (m) and grain yield of maize (t/ha) crop in push-pull technology (PPT) and maize monocrop (MC) plots in each district of north western Ethiopoia in combined 2017 and 2018 cropping seasons.

Districts	Growth and yield parameters					
	Plant height (m)			Gran yield (t/ha)		
	PPT	MC	P-value	PPT	MC	P-value
Gozamin	2.5 (± 0.2)	2.0 (± 0.4)	0.04	4.5 (± 2.94)	2.95 (± 2.1)	0.05
Hulet eju enessie	2.2 (± 0.3)	1.8 (± 0.2)	0.007	4.3 (± 2.7)	2.75 (± 2.0)	0.03
Jabitenan	2.4 (± 0.22)	1.7 (± 0.2)	0.01	4.0 (± 2. 8)	3.4 (± 2.5)	0.02

Table 4
Soil chemical properties in push-pull technology (PPT) and maize monocrop (MC) plots in 2018 cropping season in three districts in north western Ethiopia'.

Soil fertility parameters	Districts								
	Gozamin			Hulet eju enessie			Jabitenan		
	PPT	MC	P-value	PPT	MC	P-value	PPT	MC	P-value
Available P (mg/kg)	18 (± 1.489)	13.6 (± 0.464)	0.01	27.13 (± 4.06)	9.9 (± 4.641)	0.0001	15.07(± 0.579)	9.91 (± 1.557)	0.001
Available K (mg/kg)	620.2 (± 17.282)	548.6 (± 10.310)	0.002	252 (± 28.783)	199.8 (± 3.701)	0.0001	348.4 (± 3.648)	295.4 (± 3.361)	0.05
Organic carbon (g/kg)	51.2 (± 0.744)	33.4 (± 0.763)	0.02	41.1 (± 0.694)	30.8 (± 0.428)	0.01	36.4 (± 0.250)	25.1 (± 0.501)	0.03
Total nitrogen (g/kg)	2.5 (± 0.032)	1.5 (± 0.043)	0.01	2.9 (± 0.032)	2.3 (± 0.019)	0.05	2.5 (± 0.016)	1.3 (± 0.040)	0.005
Organic matter (g/kg)	88.1 (± 1.280)	57.5 (± 1.312)	0.005	70.7 (± 1.196)	53.1 (± 0.733)	0.004	62.7 (± 0.428)	43.2 (± 0.858)	0.001
Bulk density (g/cm^3)	0.75 (± 0.021)	0.95 (± 0.017)	0.05	0.93 (± 0.021)	0.95 (± 0.017)	0.05	0.90 (± 0.013)	0.96 (± 0.008)	0.003

Data analysis

The two years data in three districts were analyzed using general linear model of SAS computer package, version 9.4. The measured data were analyzed for each of PP and maize monocrop plots. Data were recorded for each treatments, cropping season and districts. Analysis of variance using a general linear model was used to test for difference among treatments with regard to stem borer infestation, striga infestation, plant height, grain yield, available P, available K, total nitrogen, organic carbon, organic matter and bulk density. Because of high variability observed for striga counts, $\log 10\,(n+1)$ transformation of the original data was performed (Mesfin et al., 2014). Similarly, the data on percentage of maize damaged by stem borer were subjected to arcsine transformation before analysis. Statistical results were considered at $\alpha = 0.05$. Untransformed means are presented in tables and figures throughout the text whereas transformed means are used only for analysis purpose.

Result

Effect of Push-pull technology on stemborer and striga infestation

The ANOVA result revealed that significant difference was observed in stemborer infestation between push-pull and maize monocrop plots in each districts and cropping seasons (Table 2). The proportion of stemborer damaged plants were generally low (1–5%) in the push-pull as compared with maize monocrop plots (10.7–22.1%) in each study districts and seasons (Table 2). Push-pull plots recorded the lowest stemborer infestation (1%) in Gozamin district during 2018 cropping season whereas maize monocrop plots recorded the highest stemborer infestation (22.1%) in Jabitenan district in the same cropping season (Table 2).

Significant difference in striga count was observed between push-pull and maize monocrop plots in each study districts and seasons (Table 2). There were significantly ($P < 0.0001$) lower striga counts in push-pull plots as compared to maize monocrop plots in each study sites and cropping seasons except Gozamin district which was no emerged striga count in both seasons (Table 2). The highest number of emerged striga (27 and 20 striga plants/m^2) was recorded in maize monocrop plots in 2017 and 2018 cropping season in Jabitenan district, respectively (Table 1). Conversely, lower (1.4–6 striga plants/m^2) and higher (17–27 striga plants/m^2) number of striga counts were recorded in push-pull and maize monocrop plots, respectively in each districts and cropping seasons (Table 1). In each seasons, in Huleteju enessie and Jabitenan districts there were a 4 fold reduction in striga count in push-pull plots except Jabitenan district which was 20 fold reductions in 2018 cropping season.

Effect Of Push-pull On Plant Height And Crop Yield

The ANOVA result showed that significant difference in plant height and grain yield were observed between push-pull and maze monocrop plots in each districts but were not significant on both parameters among seasons (Table 2). Plant height ranged between 2.2 to 2.5 m and 1.7 to 2.0 m in push-pull and maize monocrop plots, respectively in each district and combined seasons (Table 2). The highest plant height (2.5 m) was recorded in the push-pull plots while the lowest (1.7 m) was registered in maize monocrop plot in each district and combined cropping seasons (Table 2). Similarly, grain yield was higher (4.0–4.5 t/ha) in push-pull than in maize monocrop plots (2.75–3.4 t/ha) in each districts and combined seasons (Table 2). In the push-pull plots grain yield was highest (4. 50 t/ha) in Gozamin district and lowest (4 t/ha) in Jabitenan district during combined cropping seasons. However in the maze monocrop plots highest grain yield (3.4 t/ha) was recorded in Jabitenan dstrct and the lowest was recorded (2.75 t/ha) in Hulet eju enesse district in combined cropping seasons (Table 2).

Effect Of Push-pull Technology On Soil Chemical Properties

At the end of the experiment in 2018 cropping season, there was significant increment in soil fertility status in push-pull plots as compared to maize monocrop plots in all study districts (Table 4). In all districts the push-pull plots had relatively better soil fertility status with values available phosphorus (15–27 mg/kg soil), available potassium (348–620 mg/kg soil), Organic carbon (36–51.2 g/kg), total nitrogen (2.4–2.9 g/kg), Organic matter (62.7–88.1 g/kg) and bulk density (0. 92 – 0. 93 g/cm^3) as compared to monocrop plots which rated as low soil fertility status with values 9.9–13.6 mg/kg soil, 199.8-548.6 mg/kg soil, 25.0–33.0 g/kg, 1.3–2.3 g/kg ,43.2–57.5 g/kg and 0. 95 – 0. 96 g/cm^3, respectively (Table 4). The fertility status of the push-pull plots was rated medium to high as compared to maze monocrop plots which scored low levels (London 1994). At the end of 2018 the push-pull treatments of all study districts had high total nitrogen, organic carbon, and organic matter content with medium phosphorus and potassium content.

Discussions

Push-pull technology is very effective for integrated pest, weed and soil management in cereal- based farming system (Khan et al., 2014). Considering this, we conducted a two year experiment to investigate the effect of PPT on controlling stem borer and striga infestation, improving soil fertility and grain yield with maize crop. The result of this study showed that the push–pull plots effectively controls *striga hermonthica*, resulted in increase plant height and grain yield in all study districts except Gozamin district with no striga occurrence. Even though striga was not emerged in Gozamin district in the push-pull and maze monocrop plots but still growth and yield of maize were increased in the push-pull plots. This is because N fertilizer has played vital role in enhancing vegetative growth and resulted in increment on plant height and grain yield (Sakatu, 2017). Ullah et al., (2018) also reported that as nitrogen increase cells protein content increase and size of plant cell increases, as a result of that leaf area and photosynthesis rate rises which ultimately make the plant taller and higher grain yield.

Similarly desmodium is a legume crop and essential in enhancing soil fertility status through biological fixation of atmospheric nitrogen (N2) and increase organic matter, practically eliminating soil erosion (Giller, 2001). The result of this study were consistent with those result observed in on farm studies conducted in eastern Africa where the technology is equally effective in controlling striga with increased growth and maize yield (Khan et al., 2008; Midega et al., 2015; Hailu et al., 2018; Khan et al., 2006; Asmare, 2014). These results corroborate earlier findings in western Kenya that reported effective control of striga through hindering striga seed germination by the released root exudates of desmodium (Midega et al., 2010). Desmodium contain root exudates which hinders germination of striga seeds (Tsanuo et al., 2003; Hooper et al., 2009, 2010). This provides a novel means of reduction of striga seed bank in the soil. These contribute to the importance of intercropping with desmodium in smallholder cereal based farming systems in north western Ethiopia. The significant reductions in the number of emerged striga in the push–pull plots observed in the current study across the study sites over the cropping seasons indicates stability of the striga control efficiency of desmodium and suggests that its use in smallholder farming systems in striga prone areas has potential to stabilize these systems.

Similarly, the result of this study showed that the push–pull plots effectively controls stemborer, resulted in increase plant height and grain yield in all study districts than monocrop plots. In push-pull plots stemborer control through companion cropping is mediated by green leaf volatiles emitted by the companion crops (Khan et al., 2010). Previous studies have shown that Napier grasses are preferred to maize for oviposition, and with minimal feeding and survival of stemborer larvae on Napier grasses (Midega et al., 2011). As compared to monocrop plots in push-pull plots low survival rates of stemborer larvae on Napier grass is favorable for conservation of the parasitoids by providing continuous shelter to natural enemies and therefore improving biological control of stemborer. Additionally, use of green leaf desmodium has been shown to repel stemborer moths resulting in effective control of stemborer (Khan et al., 2006a). Moreover in push-pull plots volatile organic compounds emitted by desmodium, including (E)-ocimene and (E)-4,8-dimethyl-1,3,7-nonatriene repel stemborer moths (Khan et al., 1997, 2000) and attract stemborer natural enemies and reduce stemborer attack in maize crop (Midega et al., 2009, 2014b). In addition to controlling pests, the present study also identified that Push-pull technology also enhances soil fertility and grain yield. The greater crop yields and productivity of push-pull plots relative to maize monocrops result from complementary use of resources for growth by the intercrop components (Willey, 1979; Ofori and Stern, 1987; Rao and Singh, 1990; Willey, 1990). The push-pull technology practiced in the study sites increased grain yield and soil fertility through different ways. Desmodium is an essential legume crop in enhancing soil fertility status through biological fixation of atmospheric nitrogen (N2) and increased organic matter, eliminating soil erosion (Giller, 2001). Desmodium is effective legume crop which can fix over 300 kg N/ha per year (Whitney, 1966). Even though the study was conducted for only two years still in push-pull plots there were significant increment in soil fertility status, growth and yield of maize because desmodium were added 300 kg N/ha per year through biological fixation (Whitney, 1966). This legume crop also improves soil organic matter content, nitrogen and conserves soil moisture which resulted in an increase in soil microbial diversity and activity (Midega et al., 2005; Khan et al, 2006a; Khan et al., 2002; Midega et al., 2008,2009). The differences in soil fertility status between push-pull and maize monocrop plots may be attributable to N2 fixation of Desmodium in push-pull plots as compared to maize monocrop plots. Our study showed that the inclusion of legumes is essential for soil fertility sustenance as they contribute to soil fertility enhancement through biological fixation of atmospheric nitrogen (N2) in the push-pull than maize monocrop plots.

Similarly available P, K, organic matter, total nitrogen and organic carbon were increased in the push-pull plots than maize monocrop plots. The cause of increment in push-pull plots and decrement in maize monocrop plots was due to desmodium increase nitrogen content. This nitrogen increment in low fertile soils (acidic soils) can leads to a release of phosphorus, potassium, organic matter, total nitrogen and organic carbon reserves inside the soil. In accordance to our result as Kas et al. (2016) and Giller, (2001) indicated that the increment of nitrogen through biological fixation resulted in a significant increase of phosphorus, potassium, organic matter, total nitrogen and organic carbon. Similarly Cong et al. (2016) revealed that presence of nitrogen nutrient in the soil system increased phosphorus and potassium content. This may be due to positive interaction balance of phosphorus and potassium in the soil system under increased mineral nitrogen at push-pull plots than monocrop plots. Push-pull technology that involves maize intercropping with desmodium and improves and maintains soil health has an important role in integrated soil fertility management strategy and in turn leads to increased growth and grain yield of maize (Altieri and Nicholls, 2003).

Conclusions

Most smallholder farmers in northwestern Ethiopia are prone to stemborer and striga infestation, and soil fertility depletion. Farmers have technological opportunities available to reverse pest attack and soil fertility depletion which threatens to undermine food security in the study area. The use of push-pull technology in cereal dominant farming system has been considered as a sustainable approach for controlling striga and stemborer infestation, improving soil fertility and crop productivity. The result of the current study indicates that there was significant reduction in stemborer and striga infestation and increased soil fertility status in push-pull plots than maize monocrop plots leading to increased growth and grain yield of maize. In all the study districts, the benefits of push-pull technology are grater under stemborer and striga infestation and low soil fertility conditions, apparently due to controlled pests through desmodium leaf contains volatile chemicals which are effective in repelling stemborer moths and root exudates which hinder striga parasitism. Similarly, soil fertility status increased through desmodium ability to fix atmospheric N_2 and nitrogen increment resulted in significant increase of phosphorus, potassium, organic matter, total nitrogen and organic carbon. These results therefore show that the technology has a potential to improve the livelihood of small holder farmers living in poor fertile soils, striga and stemborer prone areas. However, there is a need to compare other legume crops and evaluate on controlling stemborer and striga infestation and improving soil fertility for longer seasons in order to ensure continued effectiveness in the long term for sustainable maize production in north western Ethiopia.

Declarations

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