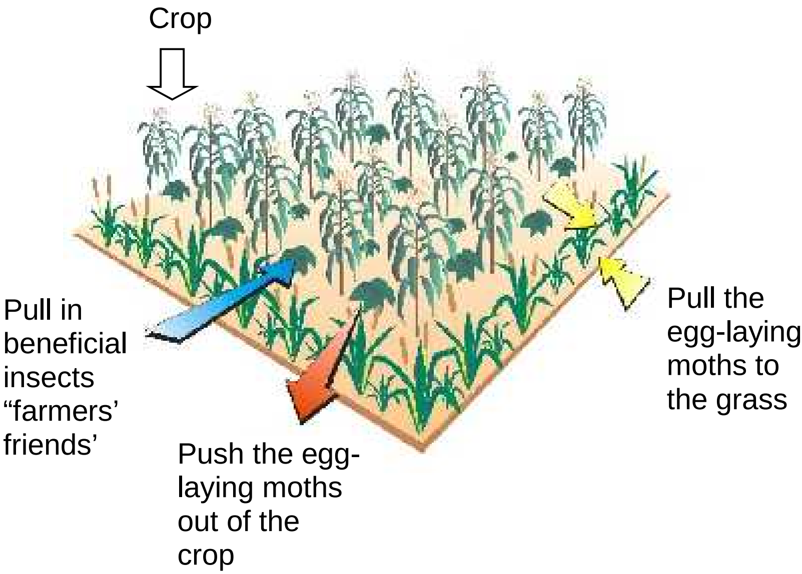
Push-Pull Technology: An ecological and safe way to control stem borers and striga in Ethiopia



By

Institute for Sustainable Development (ISD)

Addis Ababa
2014

Published by:

Institute for Sustainable Development (ISD)

P.O. Box 171–1110, Addis Ababa, Ethiopia

Tel: +251-(0)911-246046 / +251-(0)116-186774

e-mail: sustaindeveth@gmail.com

Website: www.isd.org.et

ISD gratefully acknowledges the financial and technical support received from ICIPE, Kenya, through the EU financed project, ADOPT

Cover diagram, with thanks, from Rothamstead Research Institute, UK, with labels edited.

Contents

Acknowledgements

This manual records the experiences of: Arefayne Asmelash[1], Berihu Araya[1], Endris Mohammed[1], Fentaw Ejigu[1], Hailu Araya[1], Hailu Legesse[2], Haileselassie Gebremariam[3], Sara Misgina[1], Sue Edwards[1], and Teshager Teshome[4], with inputs from the farmers Ayal Abera[5], Eshetu Mekonnen[6], Gebreyesus Tesfay[7], Gebreyohannes Tewolde[7], Haregu Gobezay[8], Sisay Bogale[6], and Zewdie Seid[5], and researchers Abreha Hailu[9], Abreham Gebremichael[9], and Kifle Gereziher[10]. A first draft was developed in Tigrinya by Hailu Araya during a Write Shop process involving most of the people referred to above. Berihu Araya translated the draft into English for editing by Sue Edwards and Tewolde Berhan Gebre Egziabher.

Many of the photos were taken during the making of a documentary on Push-Pull Technology by Eminence PLC in November 2012. Others were taken by Alemu Asfaw, Endris Mohammed, Haileselassie Gebremariam, Hailu Araya and Sue Edwards.

---

[1] Institute for Sustainable Development
[2] Tahtai Maichew Wereda/District Agriculture Office, Tigray
[3] Aksum University, Tigray
[4] Kola Tembien District Agriculture Office, Tigray
[5] Tehuledere Wereda, South Wollo, Amhara
[6] Ambasel Wereda, South Wollo, Amhara
[7] Tahtai Maichew Wereda, Tigray
[8] Mereb Lekhe Wereda, Tigray
[9] Tigray Region Agriculture Bureau
[10] Mai Tsebri Research Center, Tigray

The final draft was commented on by Jimmy Pitchar of icipe Mbita campus in Kenya and subsequently improved including ISD's experiences from the 2014 main growing season.

ISD thanks everyone for their contributions to this manual, and hopes that further comments will be forwarded in the future to improve a second edition.

This manual also complements the manual in Amharic *የአባራሪና አጥማጅ ቴክኖሎጂ የትግበራ መመሪያ*, produced by the staff of Melkassa Agricultural Research Station (MARC).

1. Introduction

Ethiopia's economic development is based on agriculture. Accordingly, many efforts have been made to increase yield to eliminate poverty and provide food security for the estimated 90 million people living in Ethiopia in 2014, over 80% of whom are rural. Maize and sorghum are the 2nd and 4th most widely grown cereal crops in the country. However, the optimum yield cannot be obtained from these crops due to their vulnerability to pests, diseases and weeds, although they give better yield in comparison with the other crops. The areas where they are grown also suffer from low soil fertility, shortage of rainfall, and the impacts of weather variability caused by climate change that also reduce yields.

Most of the damage to maize and sorghum is caused by stem borer pests and the parasitic *Striga* weed, both of which have been causing major crop losses in recent years. These problems occur mostly in the middle and lower altitude areas of the country, i.e. below 1900 m above sea level (asl). These problems are familiar to the farmers in Ethiopia but they have not been able to overcome them.

A new practice, Push-Pull Technology, has been found to be an appropriate crop management system to minimize both stem borer and striga infestations. Using Push-Pull Technology results in female stem borer moths being *pushed* out of the crop by particular 'smells' given off from Desmodium, a legume, grown between the crop rows. 'Smells' from a border of Napier/ Elephant or Mulatto/Brachiaria grass *pull* the moths out of the field to lay their eggs there. However, the young caterpillars get mechanically trapped by the sticky sap produced by the Elephant grass, also called Napier grass, and die. At the same time, chemicals from the roots of the Desmodium cause *Striga* seeds to germinate and then die in the soil before they can attach themselves to the roots of the crop. This technology does not use any toxic chemicals: it only needs farmers' willingness to undergo training and plant the legume and grass in their fields of maize and sorghum. Once in use, farmers claim that the technology increases the yield from their fields by around 50 and even up to 90 percent.

Figure 1: Demonstration plot of Push-Pull Technology in Kalu, Kombolcha, after harvest of maize in November 2012

1.1 Objective of this Manual

The objective of this manual is to introduce Push-Push Technology to the experts and development agents, as well as interested researchers working directly with the farming communities of Ethiopia where stem borer pests often combined with striga infestation are posing very serious challenges to farmers growing maize and/or sorghum as their main cereal crops. The technology is based on scientifically proven ecological interactions. These need to be well explained so that experts, farmers, policy makers and other partners can understand the management methods involved so that the Push-Pull Technology can become sustainably and widely practiced.

2. The Uses of Sorghum and Maize in Ethiopia

Sorghum and maize are cereal crops that belong to the grass family. Sorghum cultivation originated in Africa more than 5000 years ago. In drier areas, it gives better yields than maize because it is able to grow where rainfall is scarce and it can tolerate dry periods in the growing season. In addition to their grain, the stalks of these crops are needed and used in many places by farmers for animal feed, fuel, and fencing, as well as in house construction for thatching and walls. Maize is widely grown in the moister western and south western parts of the country as a food crop while it is grown in home gardens and with irrigation to be eaten as a snack when it is fresh in the northern and eastern parts.

2.1 Sorghum and Maize Production Systems in Ethiopia

Until 2010, farmers would sow nearly all their field crops by broadcasting the seed across the field using high seed rates that resulted in dense plant populations with intense competition between the plants. Once established, this system could partly suppress the growth of weeds, but the crops were vulnerable to drought and the stems could be weak so that they easily fell over in high winds and rain storms, especially when the seed head developed.

Starting from 2003, ISD has worked with farmers and local extension experts to encourage farmers to change to planting their long growing season crops, i.e. finger millet, sorghum and traditional maize varieties, by transplanting seedlings giving sufficient space between the plants for good root and shoot development and minimizing competition. In 2009, the technology was extended to planting crops in rows, either with transplanted seedlings or by direct sowing giving sufficient space between the plants within the row as well as between the rows. This improved system of crop management is called System of Crop Intensification (SCI) internationally; in Ethiopia, the farmers call it 'planting with space'. Changing to row planting has made it possible for farmers to get dramatically increased yields from their crops. For example, SCI for teff has increased average yield from 10 quintals to 25 quintals or more per hectare, and finger millet from around 13 quintals to 30 quintals or more per hectare.

Both maize and sorghum can be grown in rows either by transplantation or direct sowing resulting in improved yields, particularly of sorghum. Farmers explain that the young root of the maize is easily damaged during transplanting resulting in low survival rates. Hence, maize is better grown by direct sowing in rows. Farmers prefer a spacing of around 50-75 cm between rows and 30-50 cm between plants in the row for both crops: 75 cm is also the recommended spacing between crop rows for the push-pull technology.

Some of the advantages of growing crops in rows are:

- Reduces the amount of seed required for planting;
- Decreases the competition among the crop plants for water, nutrients and sunlight;
- The roots get space to spread out and down giving a strong support for the stems as well as reaching more water and nutrients;
- The plant can produce more productive tillers that give increased yield;
- Weeding is quicker and easier among the rows — even improved hand tools can be used that cut the roots of the weeds and aerate the soil leaving the dying weeds as a mulch on the soil surface; and
- Both chemical and organic fertilizers, such as compost, can be applied directly to the plants at sowing or transplanting. [When fertilizer is scatted by broadcasting, much of it is wasted as it doesn't necessarily come in contact with the roots of the crop plants.]

2.2 Problems from Stem Borers

Stem borers are the larvae / caterpillars of moths that bore their way inside the thick stems of grasses, such as sorghum and maize, feeding on the soft nutrient transporting tissues of the plant. The female moths lay their eggs on the undersides of leaves in batches (*Chilo*) or rows (*Busseola*). They do this at night when farmers and insect eating birds cannot see them. When the eggs hatch, the very small larvae first feed on the leaves of the sorghum or the maize leaving many small holes in the leaves. Then the larvae move to the growing point of the plant where the leaves and stem are soft so that they can bore into them. The damage they can cause to the growing point is called ’dead heart’, as the plant often stops growing. Later in the season, larger larvae can move from one stem to another using a silk thread to swing across the gap. They then bore directly into the stem leaving a small hole. Parts of the crop stem damaged by stem borer larvae often show red streaks and patches. If a damaged stem is opened, evidence of stem borer larvae is seen in their dark red droppings called ’frass’.

Figure 2: Stem borer holes and stems colored red from the frass of the larvae

Figure 3: Stem borer larva and its ‘frass’ inside a maize stem

There are several species of stem borers. However, the ones that cause most damage to sorghum and maize in Ethiopia are *Chilo partellus*, the spotted stem borer, and *Busseola fusca* with cream-colored larvae. The life cycle of each species is shown in Figures 4 and 5.

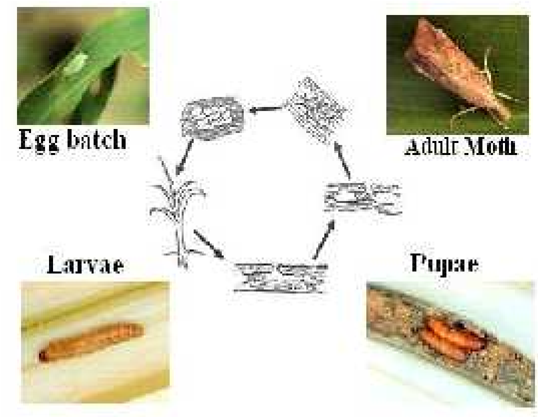


Figure 4: Life cycle of *Chilo partellus*

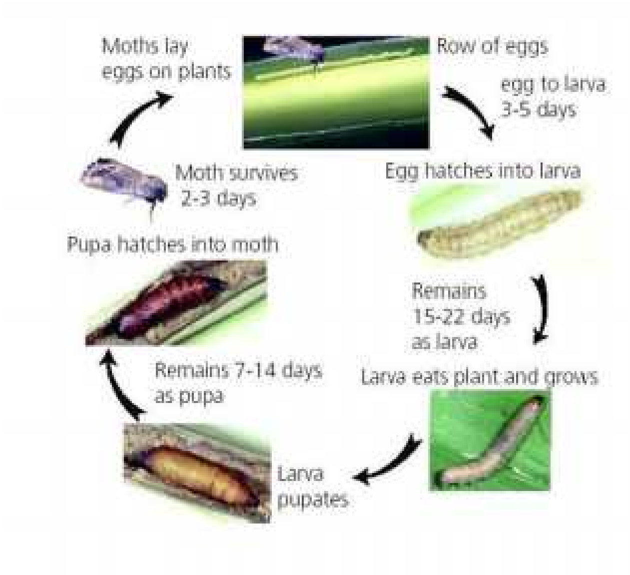


Figure 5: Life cycle of *Busseola fusca*

Agricultural officers and farmers have tried to protect their maize and sorghum crops using toxic pesticides, but sometimes the required chemicals are expensive, and not available at the required time when the very young larvae are still on the leaves and before they have bored into the crop's stem. Farmers also are reluctant to use pesticides as they kill beneficial insects like bees.

Some of the methods used by farmers and experts to try and control stem borers have been as follows:

Early sowing time: Some studies have indicated that yield improvement is possible in Hawassa and Gambela by using an early sowing time as this coincides with lower stem borer infestation. However, this is not seen in other parts of the country. For example, the Sirinka Agricultural Research Center in North Wollo showed that early sowing exposes the crops to the worst damage by stem borers.

Handling of stalk residues: During the dry season, stem borers hibernate (go into diapause) either as fully grown larvae or pupae mostly inside stalk residues but also in the soil and under stones. Farmers store the stalks for animal feed and fuel by gathering them together in vertical stooks in their farms, but the stalks are not adequately exposed to sunlight and dry air that can kill the insects. Of course, feeding the stalks to domestic animals and burning them destroys some of the hibernating larvae and pupae. But the majority remain until the coming of rain triggers them to complete their lifecycle and emerge as adult moths to start infesting the farmers' fields again.

Figure 6: Farmers' storage of sorghum stalks/stover

Figure 7: Storage of maize stalks/stover in Kalu

Farmers can use the following methods to kill some of the hibernating larvae and pupae. But none of these methods are as effective as the Push-Pull Technology.

- Laying the stalks down so that they can be fully exposed to sunshine and get very dry;
- After the maize or sorghum stalk is cut, the remaining part with the root can be dug up and used as fuel or plowed back into the soil;
- Plowing the land during the dry season can expose the hibernating larvae and pupae in the soil to sunshine that kills them; and
- After the crops are sown or transplanted, the soil can be hoed or dug over again between the rows in order to expose the pupae to sunshine that kills them.

Intercropping / Mixed Crops Sowing: Sowing of maize or sorghum with haricot bean or cowpea or groundnut is practiced by many farmers. This practice has a valuable contribution to improving soil fertility and food security; it also shelters the natural enemies of the pests.

Use of Chemical Fertilizers: Using nitrogen, phosphorus and potassium (NPK) fertilizers can help reduce the damage to crops by pests and diseases by improving the growth of the plants. However, over usage of nitrogen fertilizer can make the leaves and stems of the plants 'soft' and more susceptible to damage by pests and diseases.

Use of Medicinal Plants / Biopesticides: Well-known medicinal plants such as endod, wild gourd, tobacco, ginda, chili pepper, and others have traditionally been used by farmers to try and protect their crops from stem borers, other pests and microorganisms. Powdered Neem seed has been reported as effective if the powder is put into the bore holes made by the larvae, but this system requires a lot of skilled labor (Tsedeke Abate, personal communication).

Use of chemical pesticides: Chemical pesticides can be effective if they are sprayed when there are newly laid eggs on the leaves of the plants and before the newly hatched larvae enter into the stems. The pesticides reported by the Agricultural Inputs Agency to be used against stem borer pests in some places include 5% endosulfan 8 g per hectare, 5% carate EC liquid 310 ml by mixing with 400 liters of water for one hectare. It should be noted, however, that endosulfan is now recognized as a banned toxic substance under the Stockholm Convention on Persistent Organic Pollutants (POPs) to which Ethiopia is a signatory.

Some farmers have said that they have used powder formulations of insecticides by putting pinches by hand into the growing points of the crops. However, this has not been found to be very effective: it is also time consuming and needs much labor. Using toxic chemicals to protect against pests also has negative impacts on people as the chemicals can be absorbed through the skin and then enter the liver and other important organs via the blood stream. Toxic chemicals also kill beneficial organisms such as bees, praying mantids, lacewings, lady bird beetles and tiny wasps that control pests by laying their eggs inside caterpillars and pupae. Furthermore, the chemicals are washed off by rain and can then pollute water sources causing health problems for people as well as domestic and aquatic animals thus negatively affecting the biodiversity and the environment in general.

2.3 Problems from Striga

Striga is a very dangerous parasitic weed that has been reducing yields of maize and sorghum for many years in Ethiopia. It can cause 100% crop loss. In some parts of South Wollo Zone and Tigray Region, farmers have been forced to abandon sorghum production because of striga infestation. In some places, striga also attacks finger millet and also teff.

Figure 8: Striga infestation in sorghum in Humera, western Tigray

As a parasitic weed, striga attaches its roots to those of its host taking from it the nutrients and water it requires to emerge, flower and set seed (figure 9). It thus grows at the expense of its host crop with 60% of the damage occurring before it appears above the ground. It can cause 100% crop loss. Striga seed is stimulated to germinate by chemicals coming from sorghum or maize roots so that its own roots grow towards and then tightly attach themselves to and put 'suckers' into the fibrous root systems of the sorghum or the maize, its host. It produces very large numbers of minute black seeds looking like soot (figure 10) that can remain dormant in the soil for 15 or more years.

Figure 9: Striga roots attaching themselves to the roots of maize

Figure 10: Striga seeds and capsules

There are several species of Striga, but the most important ones that cause great damage on crops are *Striga asiatica* and *Striga hermonthica*. *Striga hermonthica* possesses purple or pale pink colored flowers and needs cross pollination to set seed. It also has a thin coarse stem with four edges. On the other hand, *Striga asiatica* possesses red flowers and is self-pollinated. The most important and widely occurring species in Ethiopia is *Striga hermonthica.*

Striga mostly occurs in areas that have shortages of rainfall and the soils have poor fertility. Both maize and sorghum can appear to grow well where striga also appears if the season has enough rainfall and the soil is fertile.

According to a study conducted by Professor Gebisa Ejita and his assistants, striga causes 65-70% yield reduction in Ethiopia in places where sorghum is grown. Studies conducted in the Tigray region also revealed that it causes 20-100% crop loss.

Striga has been known for a long time in Tigray, but it spread rapidly, particularly in the 1980s following the Great Ethiopian Drought and Famine of 1983 to 1985. Some of the reasons that striga has expanded across the country include:

- The great difficulty in seeing the seed, which looks like dust, so it can easily be carried unnoticed on sorghum seed and stalks, as well as being picked up by the feet of people and animals as well as car tires when farmers spread the weed on roads and tracks thinking that this will kill the weed. But, unintentionally, this has made it possible for the seeds of striga to be spread widely throughout the country.
- The ability of one plant to give many very tiny seeds (up to 10,000 seeds from one flowering stem), and the ability of the seeds to stay viable inside the soil for 15 years or longer.
- The rapid decline in soil fertility and the farmers' discontinuation of crop rotation, particularly over the last 30 years, as striga flourishes in poor soil where the crops are weaker.

Some strategies used to combat striga: Some of the strategies used to try and combat striga are: removal of damaged crops, water harvesting to provide water to the crop during dry periods during the rainy season, mixed cropping–especially with legumes, application of manure or chemical fertilizer (particularly nitrogen) to improve soil fertility, crop rotation, use of herbicides, use of integrated pest management (IPM) and use of striga tolerant crop varieties (e.g. a sorghum variety called Gobiye Meshela).

3. The Meaning and Advantages of Push-Pull Technology

3.1 What is Push-Pull Technology?

Push-Pull Technology (PPT) is an ecological system for protecting two major cereal crops, maize and sorghum, from damage by both the larvae of stem borer moths and the parasitic weed, striga, particularly in areas where rainfall is erratic, dry spells are frequent, and the soil is poor. The crops are grown with two drought resistant companion plants: a forage grass and the forage legume, Desmodium. The original PPT developed by *icipe*[11] with and for farmers growing maize in the sub-humid region of western Kenya used Napier/Elephant grass and Silver Leaf Desmodium *uncinatum*.

Ethiopian farmers in semi-arid environments such as eastern parts of Amhara (Oromia Special Zone, South Wollo and North Wollo Zones), Pawe of BeniShangul Gumuz Region, East and West Haraghe in eastern Oromia, the Central and South Zones of Tigray grow sorghum as their preferred cereal. They also grow maize. These areas are prone to periods of drought and increasingly erratic rainfall. ICIPE has identified the forage grass, *Brachiaria* variety Mulatto II and Green Leaf Desmodium *intortum* as the companion plants for a drought resistant type of PPT, and this is the preferred

[11] *Icipe* is the International Centre for Insect Physiology and Ecology, with its motto, *African Insect Science for Food and Health*

PPT package now being promoted in partnership with the Extension service of the Ethiopian Ministry of Agriculture.

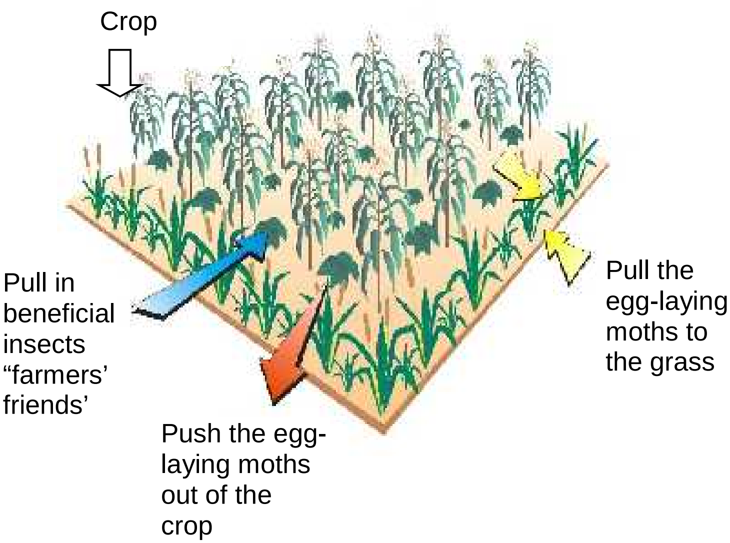


Figure 11: Diagram showing the push-pull effects of Desmodium and the border forage grass

The maize or sorghum are planted in rows 75 cm apart with the Desmodium between the rows of the crop. Desmodium produces a smell that the stem borer moths do not like. The smell ‘*pushes*’ the stem borer moths away from the maize/sorghum crop. The Brachiaria or Elephant grass is planted as a border around the maize or sorghum field to act as a trap plant. The smell of the grass is more attractive to stem borer moths than maize or sorghum so it '*pulls*' the moths to lay their eggs on it. But the grass does not allow stem borer larvae to develop. The sharp hairs on the stems and leaves of the Elephant grass pierce the larvae. Again when the eggs hatch and the small larvae bore into the grass stems, they produce a sticky substance like glue which traps them, and they die. So, few stem borer larvae survive to develop into adult moths and the maize/sorghum is saved because of the ‘push-pull’ strategy of the two companion plants.

In addition, a ground cover of Desmodium planted between the maize or sorghum reduces infestation by striga weed. Research has shown that chemicals produced by the roots of Desmodium are responsible for stimulating the striga seed to germinate but then it dies before it can reach the roots of the crop plant. Striga is not found where Desmodium is growing. Research in Kenya has shown that when Desmodium is grown as a companion crop with maize for five seasons or years, almost all the striga seed in the soil is killed. Being a legume, Desmodium also fixes nitrogen and thus helps to improve the fertility of the soil. Research by *icipe* in Kenya has shown that only Desmodium has the ability to suppress striga infestation. Other legume crops, such as haricot bean, cowpea and mung bean, are legumes like Desmodium that can also fix nitrogen. But these crops do not have the same effect on either striga or stem borer as Desmodium.

Brachiaria and Elephant grass do not have any relationship with striga, but Sudan grass, *Sorghum sudanense*, is related to sorghum. *Icipe* has demonstrated that Sudan grass stimulates and supports the growth of striga. Hence, Sudan grass cannot and should not be used as a substitute for Elephant grass.

Maize and haricot bean

Maize and mung bean

Maize and cowpea

Maize and Desmodium

Figure 12: Long Term Trials with Maize-Legume Intercrops in *icipe* Mbita campus (Khan et al. 2007. Crop Science 47: 730-734)

It is possible to avoid the problem of striga, in the absence of the any problem of stem borer, by planting only Desmodium in between the rows of the crops. But it is essential to plant either Brachiaria or Elephant grass as well as Desmodium to protect the crop plants from the problem of stem borers.

There are two types of Desmodium: Green Leaf and Silver Leaf (figure 13). Their easily seen difference is that the Silver Leaf Desmodium has a white/silver color down the middle (midrib) of its leaves whereas the green leaf Desmodium has completely green leaves. Green Leaf is also more drought resistant than Silver Leaf. Silver Leaf now grows wild in many places in Ethiopia and has been found in hedges and nursery sites in South Wollo where it easily flowers and produces seed. Green Leaf can only be grown by farmers sowing the seed or raising seedlings or taking and planting cuttings from already established plots. In 2013, the researchers from Melkassa Agricultural Research Center (MARC) and the farmers in Mechara Wereda of Western Haraghe Zone collected seeds of Green Leaf Desmodium from their demonstration plots. Seed of Green Leaf Desmodium was also successfully produced in 2014 in Farmers' Training Centers (FTCs) and also farmers' fields in both Central Zone of Tigray and South Wollo Zone of Amhara. Farmer Haregu in Rama regularly produces seed of Silver Leaf that she sells for ETB 500/kg. She says that producing the seed is difficult requiring skilled labor and time.

Figure 13: Leaves of Silver Leaf (left) and Green Leaf (right) Desmodium

3.2 Advantages of Adopting Push-Pull Technology

While the main advantages of using the Push-Pull Technology (PPT) is to control the problems of stem borer pests and striga weed, it also has several other benefits. Some of these are:

- Increase maize/sorghum yields by 25-30% in the areas where stem borers are the only problem. Where both stem borers and striga are problems, farmers can double or even treble their crop yields;
- Increase the supply and quality of animal feed by farmers harvesting Brachiaria or Elephant grass and Desmodium;
- As a legume, Desmodium improves soil fertility by fixing nitrogen in the soil. It can add up to 110 kg of nitrogen per hectare in the soil in a year, and so save farmers from the costs of buying chemical fertilizer. Avoiding the use of nitrogenous chemical fertilizer also reduces the release of the most damaging greenhouse gas, nitrous oxide, to the atmosphere, thus contributing to the mitigation of climate change;
- Protects the soil from erosion, as Desmodium acts as a cover crop (figure 14);
- Retains soil moisture, as Desmodium acts as a mulch;
- Farmers can earn money from the production and sale of Desmodium seed;
- Productivity of cattle, sheep and goats would be improved providing more milk for children and butter, milk and meat for sale in local markets;

- Reduces the time needed for weeding, as the Desmodium acts as a smother crop; and
- Protect maize/sorghum plants from strong winds, by surrounding the fields with Elephant grass that can act as a wind break.

Figure 14: Green Leaf Desmodium forming ground cover under maize

4. How to Practice the Push-Pull Technology?

At the outset, it is important to identify both farmers and local extension experts who are willing and interested to be committed to do their best to implement the technology, and also to share their experiences with their neighbors and colleagues as well as with other local stakeholders and policy makers.

4.1 Site selection, materials and land preparation

The area selected for implementing the Push-Push Technology should be where maize and/or sorghum are important crops and stem borer and striga, both or either of them, occur. Moreover, it should have a place with water for irrigation where Desmodium can be maintained and multiplied during the dry season for distribution to farmers in the following year. Desmodium can also be raised in nursery beds in Farmers' Training Centers (FTCs) or pots to be ready for transplanting as seedlings into fields when maize or sorghum is sown at the start of main rainy season.

The materials needed for planting a Push-Pull field or demonstration plot are

- ✓ farm tools,
- ✓ Desmodium seed, cuttings or seedlings — either Green Leaf or Silver Leaf,
- ✓ Brachiaria seed or root splits,
- ✓ Elephant grass root splits or stem cuttings each with 3 or 4 nodes,
- ✓ Chemical or natural (compost/farmyard manure) fertilizer,
- ✓ A measuring tape, rope, small sticks, to mark out the border rows, and the rows and places for the crop and Desmodium to be planted. If the PPT is to be on a farmer's field, the rows to be planted can be marked by making furrows and putting in small sticks where crop seeds or grass splits are to be planted.

Land preparation and plowing is very important for good establishment of PPT fields or demonstration plots because the Desmodium seed is very small, similar in size to teff. Rows should be marked out for planting the border grass, maize/sorghum and Desmodium. If it is to be a demonstration plot, the preferred size is 50 m x 50 m. But if it is on a farmer's field, it should be his/her decision on the size because he/she can expand it if he/she gets a good result. The fields of many farmers are often smaller than 50 m x 50 m. In fact, they are usually rectangular rather than square in outline with a width of less than 50 m. However, demonstration plots should not be smaller than 10 m x 10 m.

4.2. Preparing a demonstration plot for the Push-Pull Technology (PPT)

Farmers Training Center (FTC) compounds and fields of model farmers are preferred for establishing demonstration plots. The layout for a PPT demonstration plot in Dura FTC, Tigray, is show in figure 15, while that of a standard PPT plot in Mbita campus of icipe is shown in figure 16.

In order to establish a PPT demonstration plot, the land needs to be prepared as follows:

- During the dry season, clear away crop residues grown during the previous season.
- Plow and harrow the land to produce a fine tilth (until the soil has no large lumps) before the onset of the rains. Desmodium has very small seeds, therefore the soil should be as fine and clean as possible. The same care as that given to a field to grow teff should be used to prepare a PPT demonstration plot.

Figure 15: PPT demonstration plot for maize in Dura in 2011 with Napier grass cuttings in the border rows

Figure 16: Standard PPT plot for maize in *icipe* Mbita campus with Brachiaria established in the border rows

- Measure out the area for the push-pull plot: the smallest size can be 10 m x 10 m and maximum size 50 m x 50 m.

- If your plot is less than 50 m x 50 m, the push pull technology will still work; however, do not plant PPT in plots less than 10 m x 10 m as the grass can have a negative shading effect on the maize/sorghum crop.

4.3 Planting / sowing grasses, maize/sorghum and Desmodium

4.3.1 Planting Brachiaria or Elephant grass before the crops

Brachiaria or Elephant grass should always be sown before the crops. If it is the first growing season for a PPT demonstration plot or field, the grass should be planted 1-2 months earlier in order for it to become established and start attracting the stem borer moths when the maize/sorghum is sown. But if it is the second growing season for a PPT demonstration plot or field, the Brachiaria or elephant grass and Desmodium should already have been established. Therefore, only the appropriate rows for the maize or sorghum need to be prepared for sowing. Care should always be taken, especially outside the main growing season, to prevent grazing animals trampling on the Brachiaria or Elephant grass as the growing points of these grasses that are at soil level will be crushed and dry out.

The grasses need to be sown or planted in 3 rows around the border of the plot. If only one row is planted, there will be too little grass to attract the egg laying moths and gaps will be left after the grass is cut for forage. There will also be less forage available to feed the domestic animals.

To plant/sow the grasses:

- ✓ Root splits of Brachiaria grass are dug up and covered or put in a plastic bag to keep them moist until they are planted. Stems of Elephant grass should be cut, each having 3 or 4 nodes. They should also be covered or put in a plastic bag so they do not dry out before they are planted.
- ✓ The 3 border rows of the demonstration plot or field should be marked out as follows:
  - o Ropes should be stretched along the rows by putting sticks at the corners of each row with a distance of 70-75 cm between each row and the position for each root split or stem marked out along the row at 30-50 cm intervals.
- ✓ For root splits, dig holes 10-20 cm deep and put a handful of compost, farmyard manure or dry animal dung in each hole. The holes need to be deep enough for the roots to go straight down and not be bent upwards. Fill the hole with soil making sure the bottoms of the shoots are also covered.
- ✓ For Elephant grass stem cuttings, dig holes 10-15 cm deep and put a handful of compost, farmyard manure or dry animal dung in each hole. Put one cane in each hole so that the bottom 2 nodes can be covered by soil and the cane placed at an angle of about 45°. If the soil is soft, the canes can be pushed into the ground at 45° angle making sure that the bottom 2 nodes are below the soil surface. Although this method is quick and does not need a digging tool, pushing the canes into the soil can often cause them to split apart so that they dry up and do not establish.

- ✓ Brachiaria seed should be sown in shallow furrows, 1-2 cm deep, but not deeper, that are made along the line of the rope. In order for the seeds to be spaced out, they should be well mixed in the ratio of 1/3rd Brachiaria seed with 2/3rd of sand, or fine soil, or dry compost.
- ✓ After the root splits or stems have been planted, or the Brachiaria seed have been sown, the border rows should be watered to help the materials to start growing.
- ✓ After the Brachiaria seedlings have emerged, careful digging up and transplanting can be done to move seedlings from places where they are dense to fill gaps in the rows.
- ✓ If possible, the grasses should be planted during the small rains or about 1-2 months before the main growing season is expected to start and be watered regularly so that they will have begun to grow well when the crop is planted. This can help *pull* the newly emerged female moths to lay their eggs in the border rows rather than in the young crop plants.

4.3.2 Sowing or planting Desmodium *and maize/sorghum*

The following procedure should be followed for sowing alternate rows of maize/sorghum and Desmodium:

- ✓ Both the maize or sorghum and the Desmodium can be planted at the same time in a new PPT demonstration plot or field when the rains have started.

- ✓ The rows for planting the maize or sorghum in the demonstration plot should be marked out as follows:
  - o Ropes should be stretched across the plot/field with a distance of 70-75 cm between each row and the position for sowing the maize/sorghum marked at 30-50 cm intervals along each row.
  - o A gap of about 1 meter should be left between the border rows of forage grass and crop growing part of the field. This gap makes it easy for farmers to harvest the forage grass from the inner border row as well as get into the crop field for weeding and monitoring the growth of the crop and Desmodium.
  - o In the middle between each row of the crop, a very shallow furrow only 1-2 cm deep should be made for the sowing of the Desmodium seed.
- ✓ Before sowing Desmodium seed, it can be pre-treated by adding it to warm water and leaving it to soak overnight. In the morning, the water should be drained off and the seed left to dry in a shade, NOT in the sun, before sowing. This pre-treatment increases the germination rate from about 60% to over 90%. This innovation was developed by a woman farmer, named Ayal Abera, in Tehuledere who had previously worked in a tree nursery.
- ✓ Before sowing, the Desmodium seed should be mixed in the ratio of 1/4 seed with 3/4 compost, or fine soil, or sand and then spread evenly along the furrow.

- ✓ After sowing, the furrow should be filled with light and fine soil.
- ✓ Desmodium seed is very small, only slightly bigger than teff seed. If the furrow for the Desmodium is too deep or the soil covering too thick and heavy, the germinating seedlings die before they can reach the soil surface.

Using cuttings: To fill gaps in rows of Desmodium, and/or expand PPT to another field or demonstration plot, Desmodium can be planted using cuttings, as follows:

- ✓ The rows for planting the crop should be marked out with 75 cm between each row, and a 2-3 cm deep furrow for planting the Desmodium cuttings made midway between each crop row.
- ✓ Cuttings are taken from the creeping stems of Desmodium that have started to produce roots at some of the lower nodes. Each cutting should have 3-4 nodes, or even more, up to the end of the stem, but the oldest 1-2 nodes should have started to develop roots. The cuttings dry up very quickly so the root-producing nodes should be wrapped in a damp cloth or leaves and put in a plastic bag to keep them moist until they are planted.
- ✓ The cuttings are laid down in the furrow and the nodes with young roots covered with soil, but the top part of the cutting should be on top of the soil.
- ✓ The best time for taking and planting cuttings is after the rains have started and the soil is moist.

- ✓ If the soil is dry, the cuttings need watering regularly until the rains start and the cuttings have started to produce new leaves.

Figure 17: Green Leaf Desmodium producing runners that can be used as cuttings to fill gaps in the Desmodium rows

Using seedlings: Desmodium can be sown in nursery beds, or in old pots 4-6 weeks before the rainy season is expected to start. The seedlings can be planted at the same time as the maize or sorghum is sown. They can also be used to fill gaps in rows of Desmodium, and/or expand PPT to another field or demonstration plot.

- ✓ If the soil is dry, the seedlings need watering regularly until the rains start and they can be planted out.
- ✓ The rows for planting the crop should be marked out with 75 cm between each row, and a 3-5 cm deep furrow for planting the Desmodium seedlings made midway between each crop row.

- ✓ Seedlings of Desmodium need to be handled carefully so that the roots are not broken. The seedlings can dry up very quickly so they should be wrapped in a damp cloth or leaves and put in a plastic bag to keep them moist until they are planted.
- ✓ A hole for each seedling should be made with a stick and the roots put straight down into the hole, leaving the leafy stem above the top of the soil.
- ✓ The best time for taking and planting seedlings is after the rains have started and the soil is moist.

Planting the maize or sorghum: Maize should be planted by putting 2 seeds in each hole with the holes 30 cm apart along the row. Farmyard manure, and/or compost and/or chemical fertilizer should be put in the holes when the seeds are sown. Compost or manure is preferable in a place where there is shortage of rain and/or the soil is poor. Where both seeds germinate, one of the seedlings can be pulled up at a convenient time for the farmer to use to feed his cattle, or to dig up carefully and plant in a gap in the row.

- ✓ Sorghum can also be planted by putting 2 seeds in each hole with a handful of farmyard manure or compost, and then thinning to 1 plant per hole, as for maize. However, for long season varieties of sorghum, seedlings can be raised in nursery beds and then transplanted to holes in the PPT field or demonstration plot when the rains start. This is the 'planting with space'/SCI method that many farmers in Tigray and South Wollo have taken up.

- ✓ Maize/sorghum should germinate in 5-10 days. If there are gaps in the crop row where seeds have not germinated, or transplanted seedlings have died, additional seeds or seedlings can be planted in holes to fill the gaps in the rows.

4.3.3 Weeding

In order for the crop and Desmodium plants to grow well, weeding should be done on time.

- ✓ The first weeding should be done when the maize/sorghum is 3 weeks old. The difference between weeds and *Brachiaria* and Desmodium seedlings should be known by all members of the farmers' family during the weeding time (figure 18). Local extension experts and experienced farmers should be asked to teach everyone how to recognize these seedlings and young Desmodium plants. Using sharp tools is good for removing the weeds by cutting through their roots, but weeding by hand pulling is better for small weeds in the rows with the Desmodium to avoid cutting through its roots.
- ✓ The second weeding should be done when the growing maize/sorghum has reached 5 weeks old or when it has grown to knee height.

4.3.4 Using the grass and Desmodium *for animal feed*

Brachiaria and Elephant grass can be cut at regular intervals throughout the growing season, and even during the dry season, to be used as animal feed, as follows:

- ✓ The three rows of the grasses should NOT be cut at the same time. The inner row should be cut first, and then the middle row and lastly the outer row. This sequence of leaving two rows while one row is cut, makes sure that the grass performs its duties in the PPT of pulling egg laying moths to it.

Figure 18: Brachiaria seedlings (left) and Desmodium seedlings (down center) being raised in an old bucket

- Brachiaria grows fast and the inner row can start to be cut first when its leaves have reached 60-80 cm in length, or 8-10 weeks after being sown. Then the second row can start to be cut 4-6 weeks later, and the third row 4-6 weeks after that. Not all of a row needs to be cut at the same time. The farmer should only cut what she or he needs to feed to her or his animals.

- o The Brachiaria/Mulato or Elephant grass should be cut leaving stems about 5-10 cm tall above the ground.
- o The second cut can be made 6-7 weeks after the first cut in the rainy season, or 8-12 weeks after the first cut in the dry season depending on how well the Brachiaria Mulato or Elephant grass has regrown.
- o Elephant grass grows more slowly than Brachiaria. Therefore, the first cut should not be made until it is 1-1.5 m tall or about 3 months after planting. Then the second row can start to be cut. The third row should not be cut until the first row has regrown to 1-1.5 m tall to maintain the pull effect of the grass on the female stem borer moths.
- o <u>These instructions are given as a guide</u>. Generally using the biomass of the grass depends on the personal observation and need of the farmer, how well the grasses grow and the amount of biomass in the row. In practice, farmers in Ethiopia have been found only planting one row of the grass and not harvesting from it until the dry season when there is a shortage of animal feed.

- ✓ Desmodium should be trimmed if it grows very vigorously and starts to smother the crop plants.
- ✓ In the second and following PPT growing seasons, Desmodium can be cut for animal feed and to prevent it smothering the crop. It should be cut

leaving about 6 cm of stem for the plants to regrow.

- ✓ Both the grass and the Desmodium should be chopped up before being given to the animals as this minimizes wastage. While mixing the animal feed, it should be 3/4 of the grass with 1/4 of Desmodium. Chopped up stalks of maize or sorghum can also be added to the animal feed.

4.3.5 Post harvest management of Desmodium for forage and seed production

Both the grasses and the Desmodium are perennial plants that should be kept in the PPT field or demonstration plot so that they are available to grow and provide protection against stem borer pests and striga weed in the next growing season. However, in Ethiopia, farmers are not familiar with keeping such kinds of companion and cover plants in their fields over the dry season. The traditional practice is to allow domestic animals to graze in harvested fields, and also plow the whole field in preparation for the next growing season. Farmers also rotate the crops they grow as well as select the crop according to the weather.

However, some farmers who have access to water to irrigate their fields for growing a second crop in the dry season are starting to maintain their rows of Desmodium through the dry season. These farmers have found that Desmodium appears to suppress another parasitic weed, *Orobanche* or Broom Rape. This is a parasitic weed that attacks tomato, other vegetable crops and faba bean.

The following information is for farmers who want to make good use of Desmodium after the maize or sorghum has been harvested.

- When the main crops have been harvested, Desmodium can either be cut for making animal feed or left to continue growing and flowering in order to produce seeds.
- If it is for animal feed the stems should be cut at about 6 cm above the ground in order to enable the plants to grow again.
- Both Brachiaria/Elephant grass and Desmodium should be cut, chopped up and mixed together to give to the animals in feeding troughs in or near their sleeping area.
- Taking animals to and allowing them to graze on the PPT fields or plots has to be completely forbidden, because if the cattle graze on the plants in the field, they trample on and destroy both the stems with their roots.

Production of* Desmodium *seed

- If the Desmodium starts to flower and produce pods, it should be left to go on growing in order to produce mature seed. Mature pods are brown and dry, and easily break up into square one seeded units. After the mature pods are collected, the stems can be used as animal feed.

Figure 19: Desmodium **almost mature seed pods – they are 1-seeded sections of the original seed pod**

- When the Desmodium seed pods turn from green to brown, the mature pods should be collected by hand and put into paper bags or other types of container, but not into plastic bags. In plastic bags, moisture from the pods collects as condensation and then the pods can get moldy and the seeds will die.
- Since the pods are covered in sticky hairs they easily stick on clothes and skin. Therefore, the people assigned to collect the mature pods should wear plastic raincoats, or they should wrap plastic around their trousers or skirts to prevent the ripe seed pods sticking to their clothing.
- Collected mature pods should be thoroughly dried by spreading them out on a cloth exposed to sunlight but protected from wind.

- The dry pods are threshed / broken to release the seeds / by grinding them gently on a stone using a sole of an old plastic slipper (flip-flop). A stone should NOT be used as it will break both the seeds and the pods.
- The broken pods and seeds should then be separated by winnowing them in the wind and/or on grass trays - the same grass trays that women use to gently winnow and clean crop seeds.

Figure 20: A ball of sticky nearly mature Desmodium pods and a jar with the threshed seed

5. Using the same PPT demonstration plots for the following years

When the border rows of the forage grass and the Desmodium rows in the crop field can be maintained, the amount of work needed to use a PPT demonstration plot or field in the following 2-5 years is greatly reduced.

- As long as the grasses and Desmodium continue to grow, they can be cut for animal feed at regular intervals throughout the year. They also need to be weeded regularly and even watered if possible to keep them growing.
- If there is enough water, compost or chemical fertilizer can be added to the Brachiaria/Elephant grass plants in order to encourage them to grow after being cut for animal feed.
- Do <u>not allow</u> animals to graze in the PPT demonstration plot or field during the dry season as they will destroy the plants.
- For land preparation to sow the maize/sorghum, only the rows between those of the Desmodium need to be cleaned of old crop residue and dug, and then the maize/sorghum seed or seedlings can be planted when the rains begin.
- One bottle cap of chemical fertilizer or two handfuls of properly prepared compost should be added in each hole with the crop seed.
- The first weeding should be carried out when the main crop reaches 3 weeks old. Weeding should also be done for Desmodium and the grasses at the same time, and the Desmodium cut back so it does not smother the young crop plants.
- The maize/sorghum need to be thinned to one plant every 30 cm along a row.
- Collecting water for supplementary irrigation both during the dry season as well as during dry gaps

in the rainy season is very useful for helping the Desmodium and grass survive.

6. Recording information from PPT demonstration plots and farmers' fields

Regular follow-up and recording of information from PPT demonstration plots and farmers’ fields is important for good participatory monitoring and evaluation of this technology both among and with the farmers and their local experts as well as with higher officials. Each PPT demonstration plot should have the following information recorded:

- ✓ Sowing and emergence dates of Brachiaria or Elephant grass, Desmodium and maize/sorghum
- ✓ Date of the start of the main rainy season
- ✓ Date of the end of the main rainy season
- ✓ Dates when Brachiaria or Elephant grass and/or Desmodium were cut for animal feed
- ✓ The level of damage by stem borer and/or striga at the beginning, middle and end of the growing season - a table for recording this information is given in Annex 1
- ✓ Type and name of the crop variety - or varieties if the farmers mix maize and sorghum in the same field
- ✓ Date of crop flowering
- ✓ Date of crop maturation

- ✓ Yield of crop grain and stalk residue obtained from the PPT demonstration plot and a 'normal' plot to provide a control
- ✓ Challenges faced and their solutions

7. Important Points for Consideration

1. To reduce problems from shortage of moisture, the PPT needs to be integrated with general soil and water conservation practices, and particularly with water harvesting and storage.
2. As much as is possible, 'nurseries' to produce Brachiaria and Elephant grass planting materials as well as the production of Desmodium seeds, seedlings and cuttings should be established in every PPT implementing wereda/kebele to avoid the shortage of these materials when farmers want to establish their own PPT fields or demonstration plots.
3. To make farmers confident to implement PPT, it needs to be started in demonstration plots in farmers' training centers (FTCs) and model farmers' fields in order to create understanding among neighboring farmers, local experts and development agents and to carry out experience sharing visits involving all local stakeholders.
4. Model farmers following the government's '1 to 5' networking (technology dissemination policy) should be given priority in establishing PPT demonstration plots on their own fields.
5. The activities and the human resources required for establishing PPT demonstration plots and fields need to be planned ahead of time along with the required

budget to carry them out. If there is a shortage in the budget, every effort should be made to find a timely and reliable source for the needed money.

6. To improve the germination of Desmodium, the seeds need to be soaked in warm water over night and then dried off under shade before mixing with sand, compost or soil before sowing.

Annex 1: Field assessment of Push Pull Technology

The following is a guide. The information is best collected by the farmers, including their children, with the help of their development agents.

Date when information collected: ____________________

Name of Farmer / FTC / research station: _____________________

Address: Region ______________ Wereda _______________ Kebele _____________

Plot / field history:

Last year's crop, ______________________________

Inputs: (enter Yes or No) chemical fertilizer ___; compost ___; animal dung ____; none ______

Most important weed and/or pest in previous year(s)

____

____

This year's history and yield

Plot/field size: ____________________________ in timad / sq m?

Type of crop and name of variety used this year:

sorghum ________________________ ;

maize __________________________

Dates (day/month) from present growing season for PPT plot / field

Plant type and variety		When sown	When 50% germinated	When weeded	When flowered	When harvested
Desmodium						
Grass border						
Maize						
Sorghum						

GL = Green Leaf; SL = Silver Leaf; E = Elephant/Napier; B = Brachiaria; O = Other type; N = none

Number of grass border row(s) planted: (tick for the number, or none): 3 _____, 2 _____, 1 _____, 0 (none) ______

Input type used: None ____; Manure _____: Compost ______; chemical fertilizer ____ (enter Yes or No)

Harvested area: __________________________ timad or sq m

Weight of: grain ____________; straw ___________

Experience of stem borer and / or striga

Your previous experience on the degree of striga weed and/or stem-borer infestation, as % estimate, in your field(s) / FTC / research station. Which year, _________

Level of infestation	No infestation (0%)	Low (20%)	Medium (50%)	High (80%)	Very serious (90%)
Striga					
Stem-borer					

Your experience this year on the degree of striga weed and/or stem-borer infestation, as % estimate, in your field(s) / FTC / research station in this year ___________

Level of infestation	No infestation (0%)	Low (20%)	Medium (50%)	High (80%)	Very serious (90%)
Striga					
Stem-borer					

For the following questions, give the number or tick the box as appropriate

Striga count per square meter: Plot 1 [___], Plot 2 [___], Plot 3 [___]; Average of 3 [___]

Stem-borer count per square meter: Plot 1 [___], Plot 2 [___], Plot 3 [___]; Average of 3 [___]

Maize/sorghum plant count per square meter at harvest: Plot 1 [___], Plot 2 [___], Plot 3 [___]; Average of 3 [___]

Plant height (an average of 5 plants) in cm at harvest: ______________________

Number of cobs for 5 maize average /number of heads/tillers (sorghum) _________

Nodules on Desmodium root (average of 5 plants): none visible [___]; a few [___]; many [___]

Soil moisture condition at harvesting:

In PPT field / plot: dry [____]; moist [____] tick appropriate box

In a normal field / plot without PPT; dry [____]; moist [____] tick appropriate box

Name of data recorder: _______________ Signature: _______________ Date: ______________