

A Primer on Planting and Managing 'Push-Pull' Fields for Stemborer, Fall Armyworm and Striga Weed Control in Maize and Sorghum

A Step-by-Step Guide for Farmers and Extension Staff
3rd Edition



Z. R. Khan, J. A. Pickett, J. Pittchar, G. Genga, A. Ndiege, and D. Nyagol



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**Primer on Planting and Managing 'Push-Pull' Fields for
Stemborer, Fall Armyworm and Striga Control in Maize**

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by Z. R. Khan, J. A. Pickett, L. J. Wadhams, J. Pittchar, G. Genga, A. Ndiege, and
D. Nyagol

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Foreword

This handbook by *icipe* (International Centre of Insect Physiology and Ecology), with support from partners, has been published to serve two main purposes: first, as an easy-to-read but detailed reference for all those seeking information on push–pull technology, and second, as a do-it-yourself implementer’s guide targeting farmers and frontline extension staff on how to establish and manage a ‘push–pull’ plot.

This Primer contains guidelines to the two approaches of push–pull technology to support smallholder farmers in Africa in managing the most significant constraints (stemborers, parasitic *Striga* weed and poor soil fertility), namely conventional push–pull system and climate-smart push–pull for efficient production of staple cereal crops under hot, dry conditions.

We expect that this book will enhance the adoption of the technology and increase maize/sorghum and livestock productivity while improving soil fertility and conserving the environment. The Primer, based on the push–pull technology that *icipe* and partners developed over 20 years ago, can be one of the essential references for various technology transfer pathways currently in use. Recently, *icipe* modified the conventional push–pull method by incorporating drought-tolerant companion plants, while achieving similar control of the constraints, but with more extensive agroecological reach to areas affected by reduced and unpredictable rainfall as well as rising temperatures. Climate-smart push–pull provides a crucial factor in further upscaling the technology, in keeping with the Centre’s plans to expand this unique technology to

as many farmers as possible in different agroecological zones and farming systems in Africa.

Push-pull involves planting two types of companion plants.

Between the rows of cereal crops, farmers plant a legume (*Desmodium*), which emits chemicals that make the crops unattractive to stemborers (thus providing the 'push'). In the conventional push-pull system, farmers plant Napier grass as a trap crop. In the climate-smart push-pull system, farmers plant a drought-tolerant grass (*Brachiaria*) around the maize or sorghum plot as a trap crop. These plants emit chemicals that attract stemborer moths for egg-laying but allow only minimal larval survival (thus providing the 'pull'). The chemicals that the intercropped *Desmodium* roots secrete control the parasitic *Striga* weed and deplete the *Striga* seed bank in the soil. *Desmodium* is a nitrogen-fixing legume. It also improves carbon sequestration in the ground and grows year-round, thus protecting the soil from erosion, conserving soil moisture, improving soil organic matter, and enhancing the abundance and diversity of below- and above-ground beneficial insects, such as bees.

At present, more than 200,000 smallholder farmers have adopted push-pull and realised a threefold increase in their cereal crop yields. By the end of 2018, *icipe* had expanded push-pull to nine African countries (Ethiopia, Kenya, Tanzania, Uganda, Rwanda, Burundi, Malawi, Zambia and Zimbabwe).

However, why push-pull?

- The technology fits well with traditional mixed cropping systems in Africa; farmers can integrate beans into the system.
- The technology is economical and appropriate for resource-

poor African farmers; it is based on locally available plants and does not require expensive external inputs.

- Farmers can integrate crop and livestock farming activities, as the plants used in push–pull provide high-value livestock fodder, thus facilitating milk production and expanding farmers’ income sources, and solving the problem of shortage of livestock fodder.
- The technology improves gender equity, as women can quickly cut the fodder grasses.
- Push–pull has been found to control the fall armyworm (FAW), an invasive pest that has recently entered the continent.
- Push–pull provides integrated management of insect pests (stemborers and FAW), parasitic *Striga* weeds, and soil fertility.
- By reducing stemborers and FAW plant damage, it reduces maize ear rot and mycotoxins, such as aflatoxin and fumonisin (poisonous substances produced by fungi and which can contaminate cereals and similar crops).

This easy-to-read short 54-page Primer is filled with useful illustrations and contains frequently asked questions. We hope it will be a detailed but straightforward research-to-extension linkage, besides being a valuable learning resource for farmers and extension workers on this innovative technology. We believe that the groundbreaking climate-smart push–pull technology has the potential to improve livelihoods of smallholder farmers and rural families, increase agricultural productivity, and enhance environmental sustainability and resilience while lessening the effects of climate change.

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1 August 2019*

Stemborers, Fall Armyworm and Striga Weed

Stemborers, fall armyworm and striga weed are the three most destructive pests of cereal crops and can reduce yields of maize and sorghum on smallholder farms. These pests can cause yield losses of 30 to 100% if they are uncontrolled. Control of stemborers or fall armyworm by insecticides and control of striga weeds by herbicides is expensive for resource-poor farmers and is also harmful to the environment.

Stemborers

Stemborers are the most important insect pests of maize in Africa, and they also attack other cereal crops such as sorghum, millet and sugarcane. In eastern Africa, there are two species of stemborers that cause heavy damage to cereal crops:

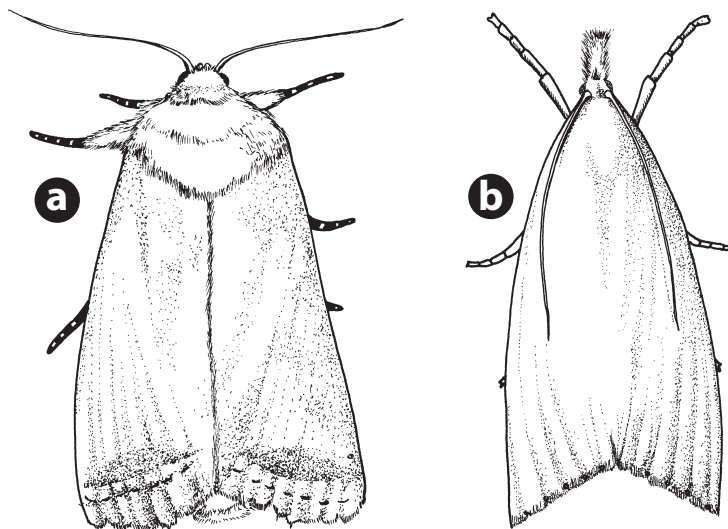


Figure 1. Adult stemborer moths of *Busseola fusca* (a) and *Chilo partellus* (b)

Busseola fusca (Figure 1a) and *Chilo partellus* (Figure 1b). *Busseola fusca* is indigenous to Africa and is present in high and mid-altitude areas (3500 ft [1077 m] above sea level and higher). *Chilo partellus* accidentally came to Africa from Asia in the 1930s. *Chilo partellus* is present in low and mid-altitude areas (zero to 4000 ft [1230 m] above sea level).

Damage is caused by the worm-like larvae, which first feed on young leaves (Figure 2), but soon enter into the stems.



Figure 2. Maize plant damaged by stemborer larvae

During the early stage of crop growth, the larvae may kill the growing points of the plant, resulting in deadheart (Figure 3).

At a later stage of growth, the larvae make extensive tunnels inside the stem (Figure 4). This weakens the stalk so that it breaks and 'lodges' (falls over). Damage caused by stemborers averages 20 to 40%, which means between 2–4 bags of maize are lost out of every 10 that could be harvested.



Figure 3. Deadheart caused by stemborer larvae feeding inside maize plants

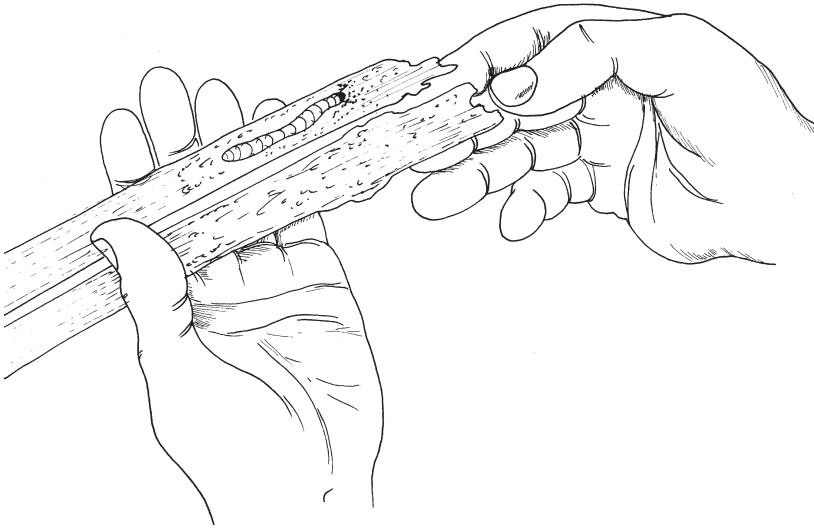


Figure 4. A stemborer larva feeding inside a maize stem

The adult moths of stemborers (Figure 1) are seldom seen in farmers' fields, as they are inactive during daytime. They become active after sunset and lay their eggs during the night.

Adult moths lay their eggs on maize plants; after the larvae emerge, they feed on leaves for two to three days and then enter inside the maize stem (Figure 4). *Busseola fusca* lays its eggs between the stem and leaf sheath, whereas *Chilo partellus* lays its eggs on the leaf surface in the form of egg batches (Figures 5 and 6). After the larvae bore into the maize stems, they feed and grow within the stems for 2–3 weeks.

When the larvae are fully grown, they pupate and remain inside the maize stem. After 7–14 days the adults emerge from the pupae and come out of the stem. They mate and lay eggs on the maize plants again and continue damaging the crop.

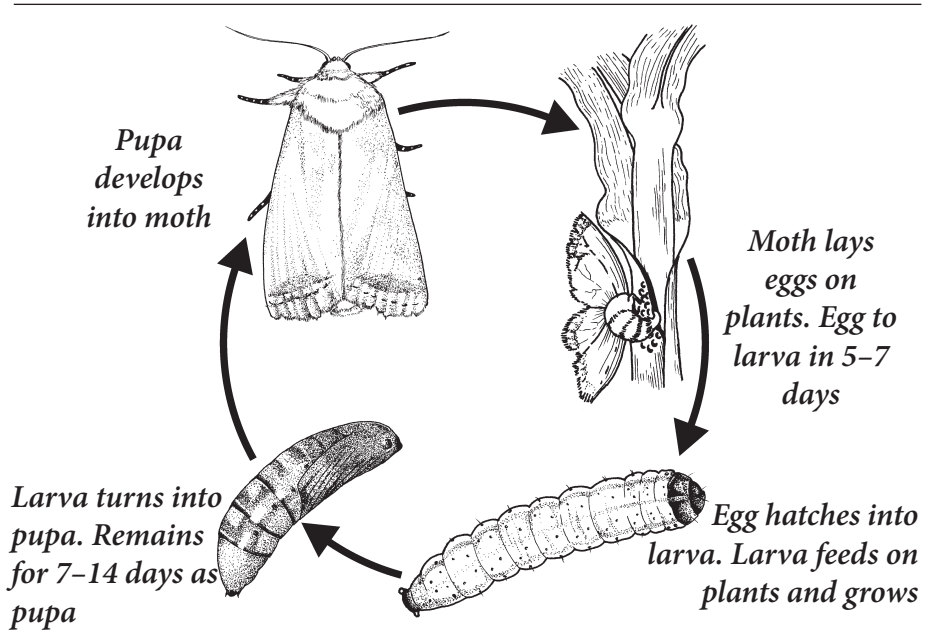


Figure 5. Life cycle of the stem borer *Busseola fusca*

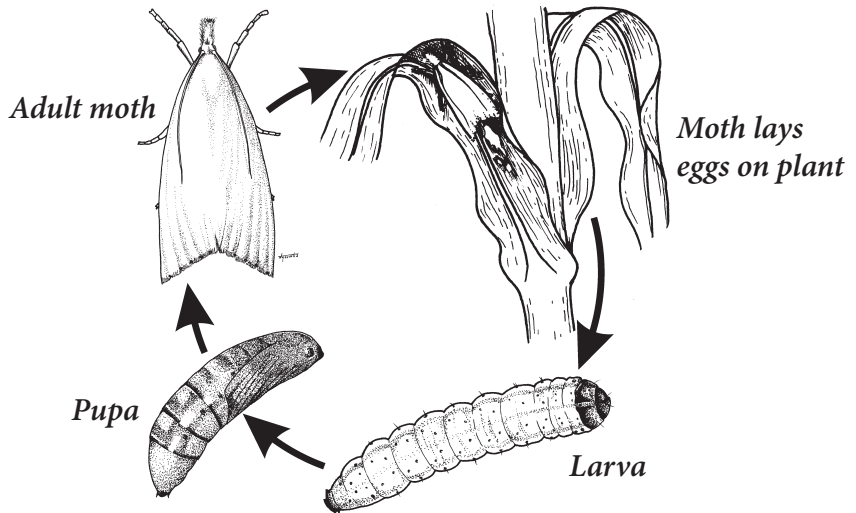


Figure 6. Life cycle of the stem borer *Chilo partellus* (the spotted stem borer)

Fall armyworm (*Spodoptera frugiperda*)

Fall armyworm (*Spodoptera frugiperda*), FAW, is a species of American origin. It is a heavy feeder; thus, it derives its name from its feeding habit. Once an 'army' of fall armyworm infests an area, they eat almost everything in the area, before moving to the next available food source.

How to identify

- The fall armyworm (Figures 7–10) has a feature that distinguishes it from other armyworm species.

- Its head has a predominantly white inverted (upside-down) Y-shaped suture between the eyes.

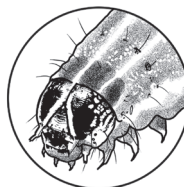


Figure 7. The inverted Y-suture on a FAW head

- Newly hatched larvae are greenish and have black heads. They move in a looping motion.

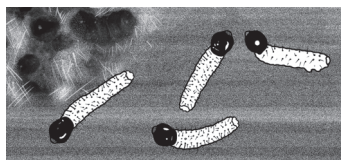


Figure 8. Newly hatched FAW larvae

- Fall armyworm has four dark spots arranged in a square on top of the eighth abdominal segment.

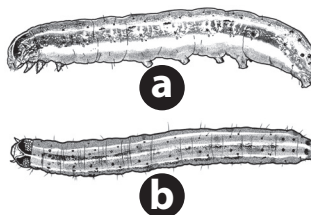


Figure 9. FAW lateral view (a) and top view (b)

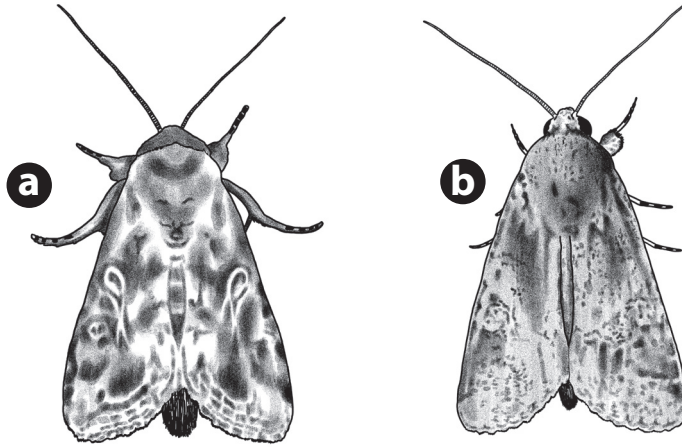


Figure 10. Adult fall armyworm Male (a) and Female (b)

Feeding habits

The fall armyworm has a voracious appetite and is a heavy feeder. It feeds on more than 80 varieties of crops. The fall armyworm feeds any time of the day or night. However, it is most active early in the morning or late in the evening. They crawl in vast armies to adjoining fields. They can also fly over 100 kilometres a day assisted by the wind; thus, they can spread fast.

Small fall armyworm larvae infest and feed on leaves, causing windowpane type feeding before moving to the leaf whorl. In the whorl, the larvae feed on tender leaf tissues until full-size. This feeding leaves the plant stunted and unproductive. When leaves unfurl (unfold), irregular, elongated feeding areas or a row of holes across the leaves are visible. When the caterpillars near maturity, they can destroy an entire crop in a few days.

Life cycle

The fall armyworm is an insect labelled as an incredibly successful invasive species. Its life cycle (Figure 11), ability to spread and reproduce quickly differentiates it from those that farmers are used to, such as the African armyworm (*Spodoptera exempta*), a less destructive species. The fall armyworm is a fertile insect, laying up to 2000 eggs in a lifetime. The adult females lay eggs in batches of 100 to 200 on the underside of leaves. The eggs are white, pinkish or light green and dome-shaped. The female also deposits a layer of greyish scales between the eggs and over the egg mass. The scales give the eggs a hairy or mouldy appearance. The eggs take about 3 to 5 days to hatch. The larvae emerge and migrate to the whorl.

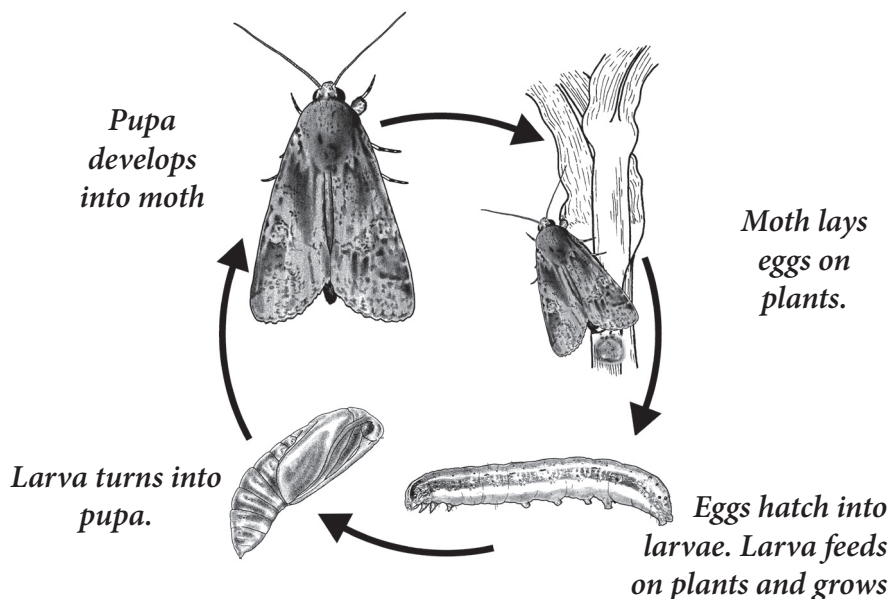


Figure 11. Life cycle of the fall armyworm

The destructive larval stage takes 14 to 28 days, after which the pest climbs down from the plant to the soil near the plant

for pupation. The pupation process takes place, ranging from 1 to 2 weeks. The adult moth emerges from the pupa and begins the egg laying cycle after 3 to 4 days.

Striga weed

Striga or 'witchweed' are parasitic weeds that affect cereal crops in many parts of Africa, reducing production from 30 to 100%, which is a complete loss of the crop. If maize plants are attacked by both stemborers and striga weed, the yield loss is often 100%. In East Africa, there are two common species of the witchweed, *Striga hermonthica* (Figure 12) and *Striga asiatica*. *Striga hermonthica* is common around the Lake Basin, while *Striga asiatica* is mainly found in the coastal areas. The most affected crops are maize, sorghum, rice and sugarcane.



Figure 12. A maize field infested with Striga hermonthica

When a farm is infested with striga, the affected plants seldom grow more than one foot (30 cm) tall. The weed does not put roots into the soil so as to grow on its own, but grows by attaching itself onto the host (e. g. maize) plant (Figures 13 and 14).

Each striga plant can produce up to 20,000–50,000 seeds, which lie dormant in the soil until a cereal crop is planted again. This dormancy can last for over 15 years. As striga germinates, its roots grow towards the host crop. They penetrate that crop's roots and start to draw nutrients from the host. This causes severe stunting of the host crop and yield loss.

The peculiar nature of striga seeds requires that farmers control them before the weed emerges above the soil. The reason for this is that the weed will have caused much of the damage to the maize by the time it emerges.

Although various control methods have been proposed, they are usually unsuccessful. For example, although manual removal of the striga reduces re-infestation, it is considered uneconomical, since most damage is done even before the weed emerges. Therefore, any control strategy has to begin within the soil.



Figure 13. Striga weed attached to maize roots



Figure 14. Striga flower

Control of Stemborers, Fall Armyworm and Striga Weed, Using a Push–Pull Strategy

What is push–pull?

icipe and partners have developed an effective, low-cost and environmentally friendly technology known as ‘push–pull’ to control stemborers and fall armyworm and to suppress striga weeds in maize and sorghum.

There are two options of the push–pull strategy as outlined below:

1. Conventional push–pull, a cropping strategy, whereby farmers use Napier grass and desmodium legume (silverleaf and greenleaf desmodium) as intercrops, for areas with reliable rainfall.
2. Climate-smart push–pull strategy, a cropping strategy, whereby farmers use *Brachiaria* spp. (a drought-tolerant grass) and desmodium legume (drought-tolerant greenleaf desmodium is recommended) as intercrops to efficiently produce staple cereal crops and fodder under hot, dry conditions.

Desmodium is planted in between the rows of maize. It produces a smell or odour that stemborer moths dislike. The smell ‘pushes’ away the stemborer moths from the cereal crop.

Conventional push–pull:- Use of clean Napier Stunt Disease-resistant Napier grass (*Pennisetum purpureum*) cultivars (such as Ouma II and South Africa cultivars) is recommended. The Napier is planted around the maize crop as a trap plant. Napier grass is more attractive to stemborer moths than maize and it ‘pulls’ the moths to lay their eggs on it (Figure 15). But Napier grass does not allow stemborer larvae to develop on it. When

the eggs hatch and the small larvae bore into Napier grass stems, the plant produces a sticky substance like glue which traps them, and they die (Figure 16). So, few stemborer larvae survive and the maize is saved because of the 'push-pull' strategy.

Climate Smart push-pull:- Desmodium legume is planted between the rows of cereal crops; it makes the cereal crops unattractive to stemborers due to the chemicals Desmodium emits (which provides the 'push'). A drought-tolerant grass *Brachiaria* sp. is planted around the maize or sorghum plot as a trap crop, due to the chemicals it emits, it attracts stemborer moths for egg-laying, but allows only minimal larval survival (which provides the 'pull').

In addition, a ground cover of desmodium (*Desmodium* spp, Greenleaf or Silverleaf), interplanted among the maize or sorghum, reduces striga weed. Research has shown that chemicals produced by the roots of desmodium are responsible for suppressing the striga weed. Therefore, striga does not grow where desmodium is growing. Being a legume, desmodium also fixes nitrogen in the soil and thus acts to enrich the soil.

Research has shown that, the chemicals Desmodium emits (which provides the 'push') also serves to repel the both the fall armyworm moths and larvae, from the desmodium cereal intercrop. Investigations are still going on to explain this mechanism of control.



Note: - *If the prevailing cropping conditions are favourable, either of the cereals (maize or sorghum), can be planted in any of the Push-pull options.*

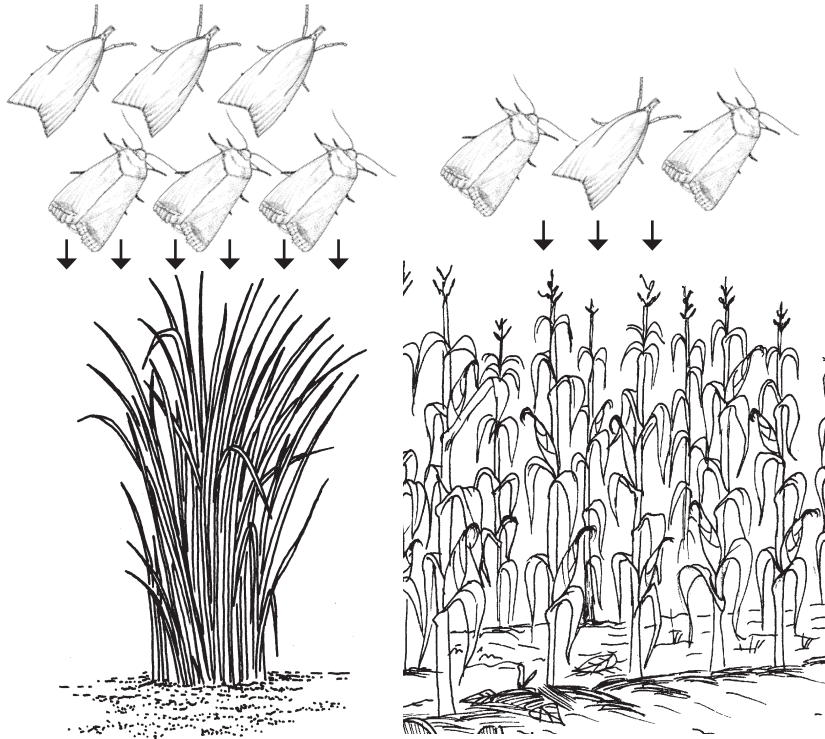


Figure 15. More stem borer moths are attracted to Napier grass than to maize. Napier, therefore, acts as the 'pull' in push-pull

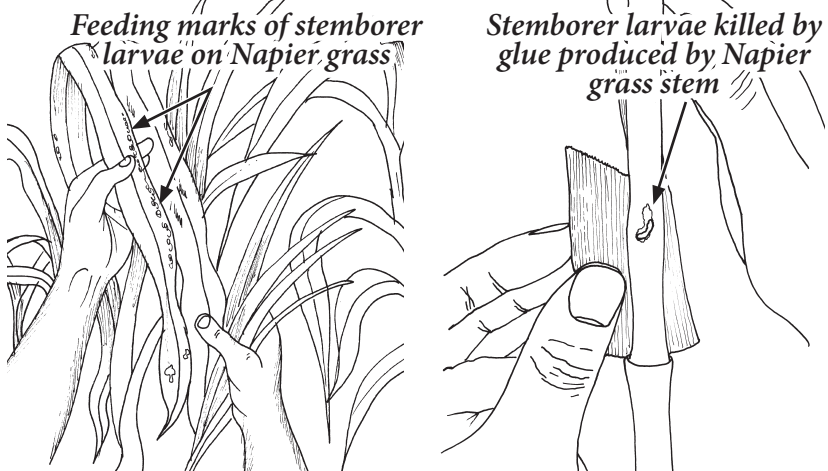


Figure 16. Napier leaves attacked by stem borer larvae (a). The larvae are killed by the sticky substance produced from Napier grass (b).

Benefits of adopting a push–pull strategy

When you adopt the push–pull strategy you will:

- Increase maize yield by 25–30% in the areas where stemborers are the only problem. Where both stemborers and striga are problems, you can double your maize yields.
- Protect your crop from fall army worm invasion and damage.
- Increase the supply of cattle feed from harvesting Napier grass and desmodium.
- Increase the quality of animal feed by increasing protein from desmodium.
- Fix nitrogen into your farm soil by desmodium legume, so you save on fertiliser costs.
- Protect soil from erosion, as desmodium acts as a cover crop.
- Retain soil moisture, as desmodium acts as mulch.
- Earn money from the sale of desmodium seed at an attractive price of US\$ 30 to US\$ 40 per kg. (Kshs. 3000 to 4000).
- Earn money from the sale of fresh brachiaria forage and desmodium, also sales income of hay from both plants
- Make more money from increased milk production and sales due to the quality feeds of brachiaria/Napier and desmodium.
- Save on farm labour, as you do not have to manually remove striga weed from the farm.
- Protect maize from strong winds, by surrounding it with the Napier grass.

For the farmer who wants to have Napier grass option, the establishment shall be the Conventional ‘Push–Pull’ system whereby, Napier grass is used as a trap or pull crop.

The following facts are important in the growing of Napier grass (*Pennisetum purpureum*,). It is an essential livestock

fodder in western Kenya, and Napier stunt (Ns) disease negatively affects Napier grass yields.

Facts about Napier stunt disease

What is Napier grass?

Napier grass (*Pennisetum purpureum*) is a high-yielding fodder grass that tolerates frequent cutting. These qualities make it the most important fodder grass in East Africa. The majority of the region's smallholder dairy and cereal farmers grow it.

What is Napier Stunt Disease?

NSD is a disease that affects Napier grass. Its symptoms are visible in the re-growth that happens after the grass has been cut or grazed. One can recognise affected plants by the severe stunting and yellowing, and lush growth of shrivelled, unhealthy new plant shoots. Often the whole stool is affected, and dies. NSD also attacks other fodder grasses such as *Cynodon dactylon* and *Hyparrhenia rufa*.

What causes it?

NSD is caused by a specialised bacterium called phytoplasma, which stops the grass from taking up the nutrients it needs to grow. The phytoplasma that causes NSD is a member of a phytoplasma group, 16SrXI, already known to cause stunting in rice and Bermuda grass.

How is it transmitted?

The phytoplasma is carried from plant to plant by the leafhopper *Maiestas banda* Kramer, which draws its food from the part of the Napier grass that is infected by phytoplasma.

High population densities of *Maiestas banda* Kramer on field sites in western Kenya confirmed the identification of the leafhopper as the principal insect vector for NSD.

The phytoplasma is also spread through the common practice of propagating split roots of Napier grass for multiplication.

After rigorous research trials, *icipe* selected and released two Napier varieties that are resistant to the Napier Stunt Disease for the technology transfer. These are Ouma II and South Africa cultivars, which *icipe* released to farmers for an integrated disease management approach. Research on other resistant cultivars is still going on.

How to Establish a Push–pull Plot

The push–pull technology embraces the conservation agriculture principles. The conservation activities are mostly applied in the subsequent seasons, and the practical benefits are fully realised after the proper establishment.

Step 1. Land preparation

- Clear your land during the dry season.
- Plough and harrow your land to a fine tilth (until the soil has no large lumps) before the onset of the rains. Why?
- Desmodium/Brachiaria seeds are small; therefore, the soil should be carefully prepared so that it is as fine and clean as possible, to maximise germination.
- Measure out your push–pull plot to a maximum size of 50 by 50 m (Figure 17).
- If you wish to layout a push–pull plot on land that is larger than 50 by 50 m, then measure out those pieces of land into plots of maximum 50 × 50 m size.
- If your land is less than 50 by 50 m, the Push–pull technology

will still work; however, do not plant push-pull in plots less than 15 by 15 m, as the Napier grass will have a shading effect on the maize crop.

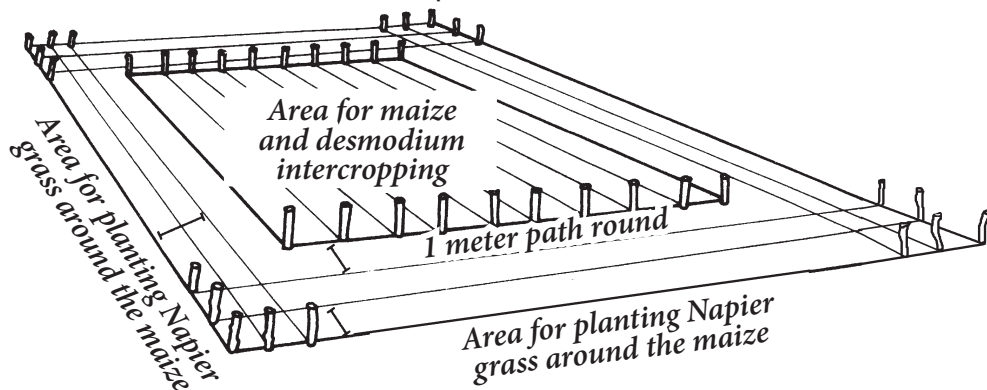


Figure 17. Layout of a push-pull plot

The outlined land clearing process is necessary for trying to ensure the total and successful establishment of the fine desmodium and *Brachiaria* seeds, which are also expensive.

Step 2: Planting material

Ensure that you have all the needed viable planting material:

- Maize/Sorghum seed
- Desmodium seed
- Napier grass root splits or canes (Figure 18). Use of clean Napier Stunt Disease resistant Napier grass (*Pennisetum purpureum*) cultivars (like Ouma II and South Africa cultivars) is recommended (Figure 19). Ensure that planting material is uninfected with Napier grass diseases
- *Brachiaria* (Mulato) seeds or splits if using the climate-smart option
- Triple superphosphate or single superphosphate fertiliser or farmyard manure.

Sources of planting material

- **Napier grass:** Agricultural Research Centres, Ministry of Agriculture, Animal Industry and Fisheries, other farmers.
- **Brachiaria:** (Mulato) stockists, via *icipe* directions
- **Desmodium:** Western Seed Company Ltd, Kitale, Kenya.
- **Cereal:** Seed companies, and appointed stockists.



Figure 18. Clean Napier grass root splits and cane cut into nodes for planting



Figure 19. Healthy Napier grass

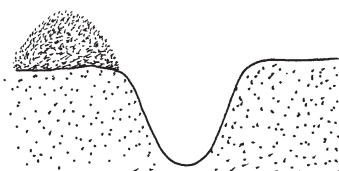


Figure 20. Diseased Napier grass

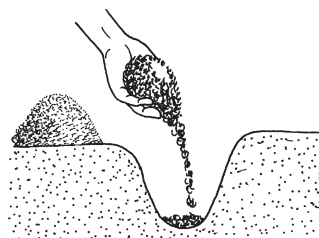
Diseased Napier grass plants are yellowish, stunted plants with short internodes (Figure 20). The leaves are narrow. The disease is carried by a microorganism (phytoplasma) and is transmitted by an insect vector, which is known as *Maiestas banda* Kramer on field sites.

Step 3. Planting the push-pull crops

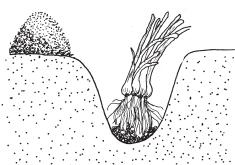
- Plant Napier grass (use clean and healthy planting material, preferably Napier stunt disease resistant cultivars, e.g. Ouma II or South Africa varieties) in a border around the maize plot as shown in Figures 17 and 22.
- Plant at least three rows of Napier all round the maize field. The spacing should be 75 cm between rows and 50 cm between Napier grass plants within a row (Figure 21).



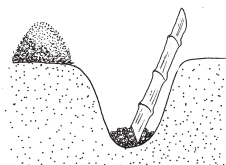
Hole ready for planting



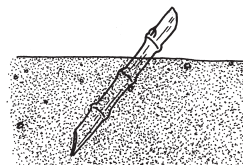
Put in one teaspoonful of TSP fertiliser or two handfuls of farmyard manure



Planting splits



Place cane in the hole



Cover cane with soil after planting

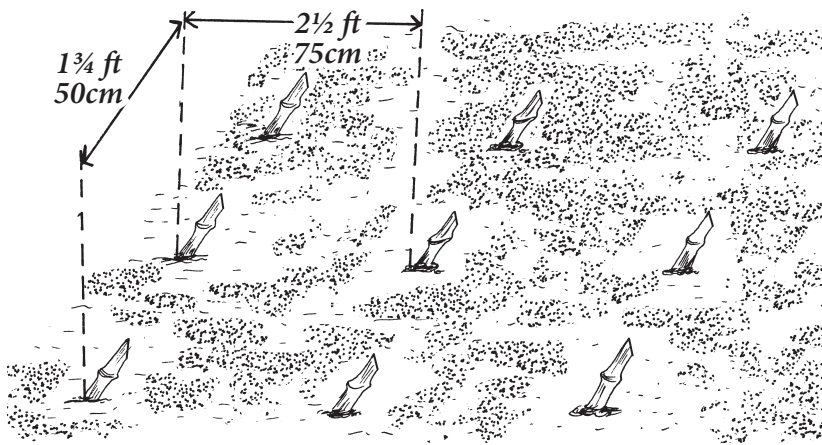


Figure 21. Newly planted Napier grass field

- Apply one teaspoonful of triple superphosphate (TSP) fertiliser or two handfuls of well decomposed farmyard manure in each hole before planting Napier grass (Figure 21).
- Place a three-node cane into the ground, ensuring that two of the nodes are covered, or place the root splits into the planting holes and cover with soil (Figure 21).
- In the first year, plant Napier grass before the rains so that it has a start on the maize. The stemborer moths will like the larger Napier grass for laying their eggs even more than the maize.

Planting maize

Plant your maize in the field already surrounded by Napier grass.

- Ensure that the 1st row of maize is 1 m away from the inner row of Napier grass.
- The recommended spacing for maize is 75 cm between rows and 30 cm between hills in a row.
- Apply one teaspoonful of triple superphosphate or two

-
- teaspoonfuls of single superphosphate per hole.
- Plant two maize seeds per hole and then thin to one plant per hill after the first weeding.



Note: *Napier rows should be planted so that they alternate with maize rows (Napier should not be planted in the same row with maize), so that ploughing of the field in the next season will be easy (Figure 22).*

Planting Brachiaria grass

Planting brachiaria grass *Brachiaria* cv. Mulato II is the best variety of brachiaria grass for Climate-smart push–pull.

Follow these steps when planting brachiaria grass in your Climate-smart push–pull plot.

Step 1: Dig a shallow pit about 1 cm, at each peg on the border of the marked plot (Fig. 17).

Step 2: Apply one teaspoonful of DAP or NPK fertiliser or a handful of well-decomposed farmyard manure in each hole and mix it well with the soil.

Step 3: Drop 5 – 6 seeds into each hole.

Step 4: Cover with light soil ensuring planted seeds are sparsely well-covered.

Step 5: Repeat steps 1 to 4 for the rest of the rows, ensuring that the rows are 75 cm apart and 30 cm between the plants for the rows running alongside the desmodium.

The spacing of 75 cm should be maintained at the head of the crop rows.

When complete, you will have three rows of brachiaria grass all round the sorghum field. If you are using root splits, place them upright into the planting holes and cover with soil (Do not shake off the soil clods from the roots.)

Note:

- Some farmers prefer to establish brachiaria grass in the short rains. The greenleaf desmodium and sorghum intercrop are established in the subsequent season. This helps to control stemborers and fall armyworm in the first season of the full Climate-smart Push–pull establishment.
- Brachiaria grass can also be established in a nursery and the root splits used in the actual lay out field.

This extra effort ensures germination and good plants surrounding the field. Plant all vegetative (splits) materials with the rains for maximum establishment.



Figure 22. Diagram of maize and Napier grass not planted in the same rows

How to intercrop desmodium

- You will need 1 kg of desmodium seed for 1 acre (0.4 ha) of land.
- Desmodium is drilled in between the maize rows so that the distance between the maize rows and desmodium rows is 75 cm. Maize/sorghum is planted first, followed by desmodium.
- Using a strong pointed stick, make a furrow 1–2 cm deep in the middle of the space between the rows of maize/sorghum or in the space where the maize/sorghum will be planted (Figure 23).
- Mix the desmodium with superphosphate fertiliser (about one handful of seed and two handfuls of fertiliser). If you cannot afford fertiliser, then mix seed with fine sand (Figure 24).
- Sow the seed–sand or seed–fertiliser mixture into the furrows you have made and cover lightly with a small amount of soil (Figure 25).
- A single row of desmodium should also be drilled on all sides of the outer rows of maize at an inter-row spacing of 37.5 cm between the outermost maize row and the outer desmodium row.

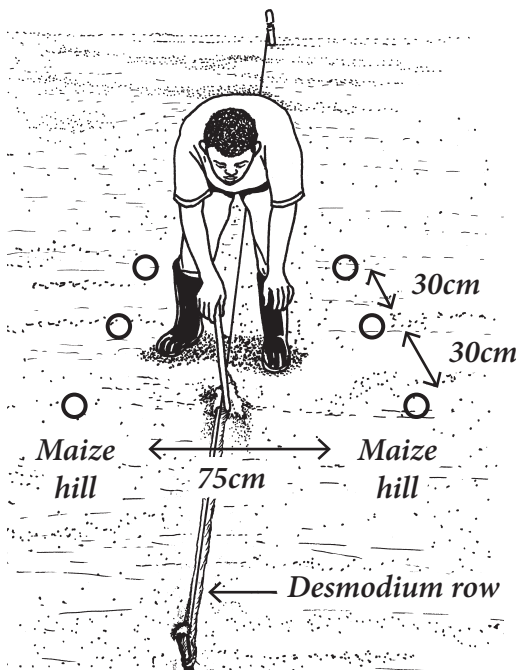


Figure 23. A farmer making rows for drilling desmodium seeds

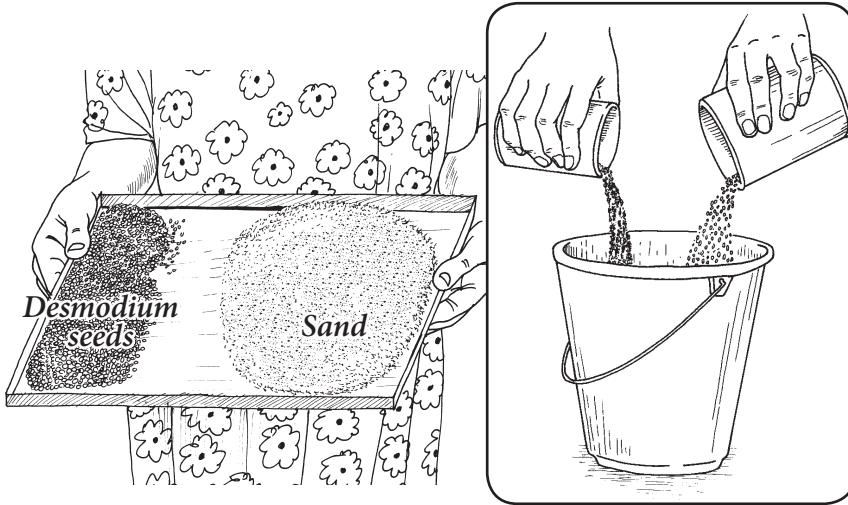


Figure 24. A farmer mixing desmodium seed with dry soil or sand for drilling. Use the ratio of 1 part seed to 3 parts sand

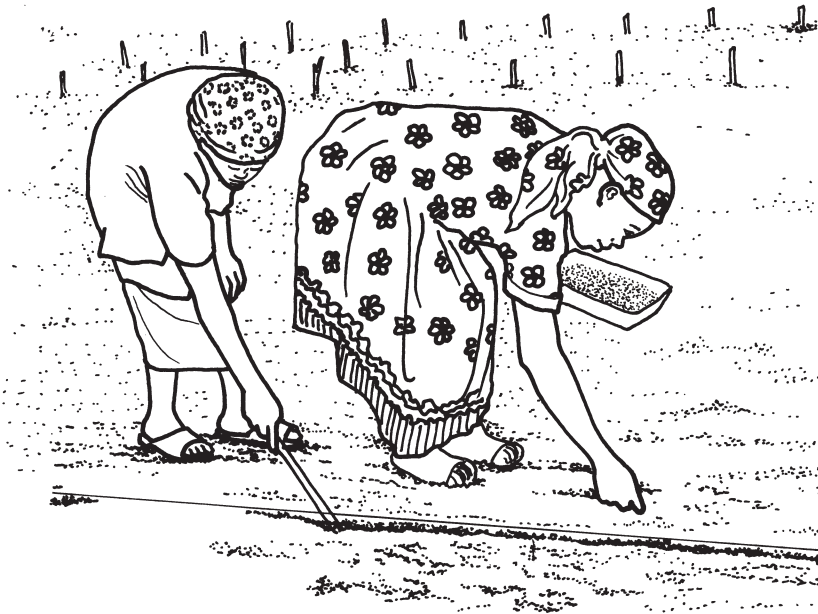


Figure 25. Farmers drilling and covering the desmodium seeds

-
- Plant desmodium with the rains for maximum germination.
 - In areas where striga weed is NOT a problem, farmers can plant desmodium after every 3 or 5 rows of maize, and use the other rows to plant beans. Stem borers will still keep away from the maize.
 - In case you do not find desmodium seed, then you can use desmodium root splits or cuttings from any neighbouring farm. Plant the splits or cuttings when there is enough soil moisture to ensure good establishment.
 - To make a desmodium cutting, cut the stem of the mother plant so that it has at least two internodes.

Step 4. Weeding

1st weeding and crop management

- Early weeding is important for the successful establishment of a push-pull plot.
- The first weeding should be carried out when the maize is 3 weeks old (Figures 26 and 27).
- It is important to know the difference between desmodium and weeds. If in doubt, consult the nearest extension staff. Figures 28 and 29 show young desmodium plants.
- Take care when weeding the drilled desmodium line. Hand-picking of weeds in the line is recommended at this stage (Figure 26).
- Thin maize to one plant per hill.
- In striga-infested areas, apply nitrogen fertiliser (CAN) to the maize at the rate of one teaspoonful per plant after the first weeding.
- Napier grass rows should also be weeded.



Figure 26. One-week-old silverleaf desmodium (left) and greenleaf desmodium (right) plants

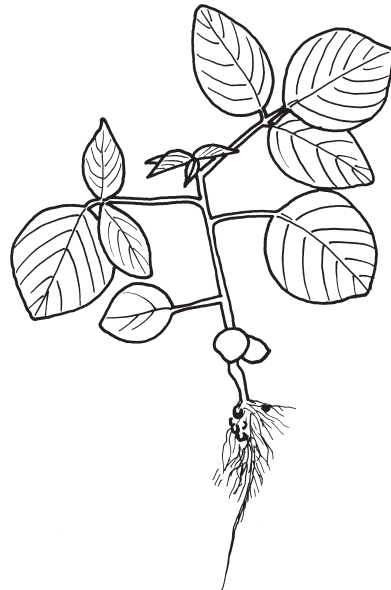


Figure 27. Three-week-old silverleaf desmodium (left) and greenleaf desmodium (right) plants



Figure 28. Hand weeding desmodium rows and weeding the space between maize and desmodium with a hoe



Figure 29. A push-pull plot after the first weeding

2nd weeding

- The second weeding should be done when the maize/sorghum is 5 weeks old (Figure 30).
- Take care to distinguish between desmodium and weeds (Figure 31).
- Napier/Brachiaria grass rows should also be weeded again.
- Top-dress the maize/sorghum and Napier/Brachiaria grass with CAN fertiliser at the rate of one teaspoonful per plant.



Figure 30. Push-pull plot after second weeding



Figure 31. Five-week-old silverleaf desmodium (left) and greenleaf desmodium (right) plants

Step 5a. Management of Napier grass

- You can start harvesting Napier grass when it is 3 months old or 1–1.5 metres high after planting (Figure 32).
- Start with the inner row nearest the maize and harvest this row around the field first. Leave a stem height of 4 inches (10 cm) from the ground at harvesting to encourage it to re-grow quickly (Figures 32 and 33).
- Feed this to your livestock. One dairy cow requires about 50–70 kg of green Napier grass per day.
- Always chop the fresh harvested Napier grass and desmodium to reduce wastage while feeding it to the livestock.



Figure 32. Farmers start harvesting Napier grass when it is 3 months old



Figure 33. Cutting of the inner row of Napier grass while leaving the two outer rows

- After the first forage has been harvested from the inner row, you can start harvesting the second row. This gives time for the inner row to grow again.
- The third row should be harvested only when the inner row is again 1–1.5 m high. This will ensure that there is always Napier grass of approximately 1–1.5 m high to trap the stemborers.
- The inner row can be harvested again when it reaches 1–1.5 m high, which means a period of 6–8 weeks between cuts.

Step 5b. Management of brachiaria grass

- You can start harvesting brachiaria grass when it is 5 months old just before flowering, and cut at 2–3 cm above ground after planting. Harvest the next crop, after every 3–12 weeks, good conditions prevailing.
- Start with the inner row nearest the maize/sorghum and harvest this row around the field first. Leave a stem height of 1.5 inches (2–3 cm) from the ground at harvesting to encourage it to re-grow quickly. The third row should be harvested only when the inner row is between 0.5–1.5 m high. This will ensure that there is always brachiaria grass of approximately 0.5–1.5 m high to trap the stemborers.
- The inner row can be harvested again when it reaches 0.5–1.5 m high, which means a period of 8–12 weeks depending on rainfall, soil fertility and management. Where farmers cut and carry to feed the animals, the grass is ready for the next cut in about 45–50 days during the rainy season. At this stage, the grass has higher nutrient content, especially protein, than Napier.

Farmers are advised to carry out routine top dressing after every cutting or grazing, using well-matured compost, farmyard manure and rock phosphate. The grass has thick leaves, which makes it difficult for weeds to thrive. The grass can persist up to 20 years with good management.

Step 6a. Harvesting of maize

- Harvest the maize once it attains maturity.
- Maize stover (stalks) left over after crop harvest can be used as livestock feed, particularly during the dry season. Always store the maize stover in a dry place to minimise spoilage.

Step 6b. Harvesting of sorghum

- Harvest the sorghum once it attains maturity, once kernel moisture reaches 25 percent. In most sorghum-growing

regions maturity often coincides with the start of the dry season, and the crop may be left standing in the field to dry for a number of weeks before harvest.

- Sorghum stover (stalks) left over after crop harvest can be used as livestock feed, particularly during the dry season. Always store the sorghum stover in a dry place to minimise spoilage.

Step 6c. Management of desmodium

- After harvesting your maize crop, desmodium can either be harvested as forage for livestock (Figure 34), or left to produce seed before it is harvested for forage (Figure 35).



Figure 34. Harvesting desmodium forage after harvesting maize from the field



*Figure 35. Flowering/podding desmodium
after harvesting maize*

Step 7a. Harvesting desmodium for forage

- When harvesting for forage, always cut the desmodium vines so as to leave a stubble height of 6 cm above the ground to encourage re-growth.
- Chop the harvested desmodium and mix with Napier grass to reduce the wastage when feeding it to livestock.
- When forage is in short supply, particularly during the dry season, chop the desmodium, Napier grass and maize stover and mix them before feeding to your livestock.
- Caution: Never, never bring your livestock to graze in a push-pull field as they will destroy the desmodium.

Step 7b. Leaving desmodium for seed production

- If your desmodium is flowering and podding, you may leave it for seed production.
- After harvesting the seed, you can harvest desmodium forage for livestock feed.
- A farmer can get between 600–800 kg of green forage from a 1-acre (0.4 ha) push-pull plot.
- In areas where the dry season is not severe, only cut enough desmodium needed for your livestock each day. However in areas where the dry season is severe or long, cut the whole field and make hay. Consult your agricultural extension officer on how to make good quality hay.

Step 8. *Harvesting and processing desmodium seed*

- When and how to harvest the seed:

Harvest the seed weekly once the pods have turned brown. Hand-strip (Figure 36) the ripe pods and place seeds in a tin.

Sun-dry and then thresh the desmodium pods using a stone and an old rubber shoe sole (Figures 37 and 38).

Winnow to get clean seed (Figure 39).

Store in dry, clean tin or airtight container (Figure 40).

- One acre (0.4 ha) of well-managed and adequately harvested desmodium seed crop can yield 50–60 kg of seed. Desmodium seed can earn a farmer between Kshs 30,000 to 50,000 (US\$ 400 to 670) when sold at the current market price of Kshs 600 to 800 per kg of seed.



Figure 36. Harvesting of desmodium pods

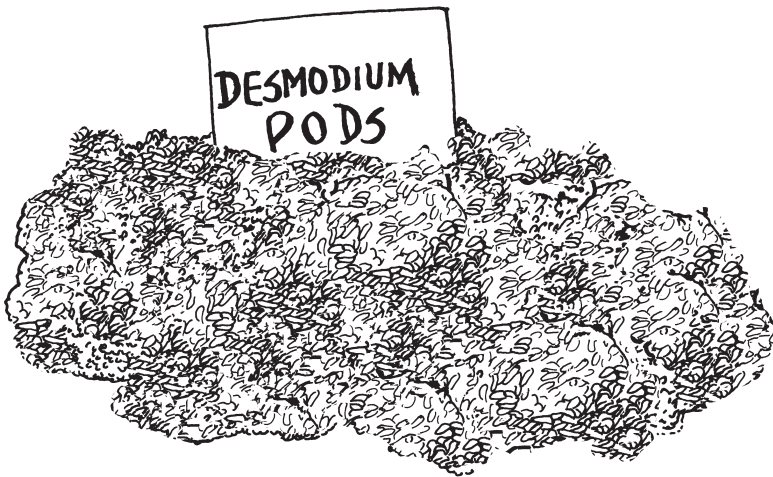


Figure 37. Sun drying of desmodium seeds



*Figure 38. Threshing of desmodium seeds
on a stone using an old slipper*



Figure 39. Winnowing desmodium seeds

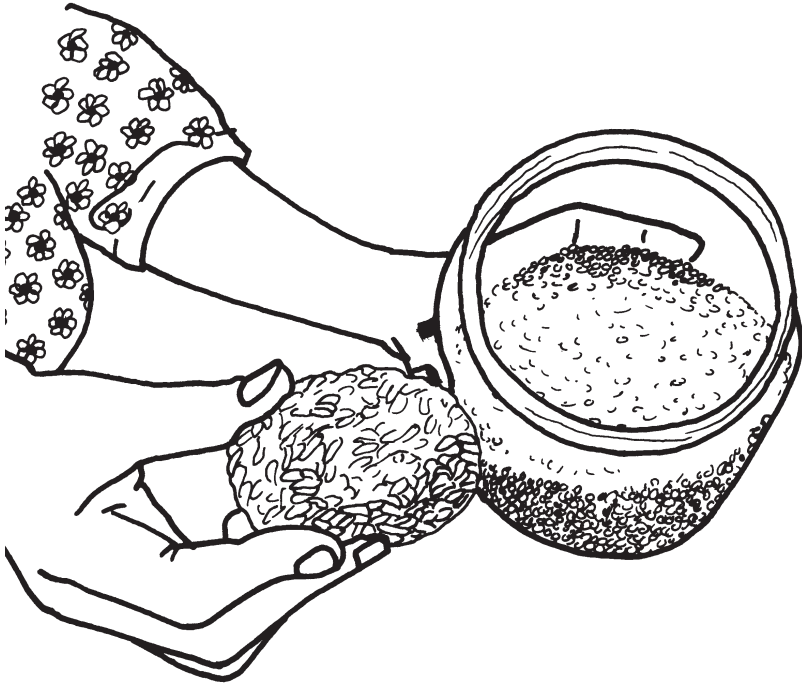


Figure 40. Store desmodium seed in a clean tin or airtight container

- In areas where moles and rats (rodents) are a problem, after the first season's harvesting, cut all the desmodium and Napier after harvesting the maize and feed to your livestock.

Planting Push–Pull during the Second and Subsequent Seasons

Step 1. Land preparation

- Continue cutting and utilising Napier grass, starting with the inner row as before and weeding the cut Napier lines.

If Climate-Smart option: Continue cutting and utilising Brachiaria/Mulato grass, starting with the inner row as before and weeding the cut Brachiaria/Mulato lines.

- Apply farmyard manure or CAN fertiliser after cutting and weeding.
- Cut back the desmodium and feed to livestock. Clear the land of maize/sorghum stover and feed to livestock.
- Before planting maize, dig or plough between the rows of desmodium. Care should be taken not to disturb/uproot the desmodium lines as desmodium is a perennial crop (Figure 41). (Minimum or zero tillage options outlined below.)



Figure 41. Push-pull plot ready for planting maize during the second season

Step 2. Planting the second crop of push-pull

- Plant maize in between desmodium rows at a spacing of 75 × 30 cm (Figure 42).
- Apply TSP or DAP fertiliser on the maize at the rate of one teaspoonful per hill as top dressing.



Figure 42. Newly planted push-pull plot during the second season

Planting the 2nd season Climate-smart push-pull

Step 1: Cut back the greenleaf desmodium leaving a 6-cm stubble above the ground to encourage regrowth. (Keep and feed the desmodium to livestock).

Step 2: Hand weed the desmodium.

Step 3: Dig or plough well between the rows of greenleaf desmodium. (Optional choice, one can practice zero or minimal tillage –see below)

Step 4: Weed the brachiaria grass.

Step 5: Plant sorghum in between greenleaf desmodium rows at a spacing of 30 cm. Apply 1 teaspoonful or soda bottle top of TSP or DAP fertiliser. You may also use a handful of well-decomposed manure per hole. Plant your cereal in rows between the desmodium lines in your field surrounded by brachiaria. Weed the field at least 3 and 6 weeks after planting. (Weeding could be done earlier if weed levels are high.)

Planting the 2nd season (Zero or minimum tillage)

If one opts to practice zero or minimal tillage, the following must be observed. The practice is best on a Push–pull field or desmodium bulking plot that has had a good ground cover establishment for at least 2 seasons.

Step 1: Cut back the greenleaf desmodium leaving a 6-cm stubble above the ground to encourage regrowth. (Keep and feed the desmodium to livestock).

Step 2: a) If zero tillage. Plant the cereal seeds along the initial line of the previous season between the rows of greenleaf desmodium. The desmodium should be trimmed and cut back regularly, from the base of the

cereal crop until after the second weeding. This is to avoid the smothering effect.

Step 2: b) If minimum tillage. Plant the cereal seeds only along the initial cereal line of the previous season. Dig or plough well between the rows of greenleaf desmodium, along the initial line of the previous season. Plant the cereal seeds, within this dug area.



Note: *For both options, in the subsequent seasons the desmodium should not be allowed to overgrow in between the maize or sorghum crops, until after the second weeding)*

Step 3. Weeding

1st weeding

- Weed the maize/sorghum when it is 3 weeks old. Napier/brachiaria grass and desmodium should also be weeded at this time.
- Desmodium at this stage can smother maize if not trimmed.

It is recommended that you trim it when the maize is 3 weeks old.

- Thin maize to one plant per hill.
- In striga-infested areas, top-dress the maize with CAN fertiliser at the rate of one teaspoonful per hill.

2nd weeding

- The second weeding should be done when the maize is 5–6 weeks old.
- Desmodium should be trimmed again at this stage.
- Top-dress the maize with CAN fertiliser at a rate of one teaspoonful per hill.

Step 4a. Management of Napier grass

- Continue harvesting Napier grass for your livestock 6–8 weeks after the onset of the rains.
- Start cutting the inner row, followed by the middle row, then the outer row.
- Always maintain a 1-metre high row of Napier grass surrounding the tender maize, and be sure to give time for the previously cut row to grow before cutting the next.
- Caution: Leaving maize without a Napier grass border or row of 1-metre high will encourage stemborers to attack your maize.

Step 4b. Management of Brachiaria/Mulato II grass

After sowing, the grass takes about 21 weeks to flower and this is the most suitable stage for feeding livestock. Regrowth takes about 3 weeks. Harvest the first crop five months after planting by cutting at a height of 5 cm above the ground. Harvest the next crop after every 3–12 weeks depending on rainfall, soil fertility and management.

Start cutting the inner row, followed by the middle row, then the outer row.

Always maintain a 1-metre high row of Brachiaria/Mulato II grass surrounding the tender maize, and be sure to give time for the previously cut row to grow before cutting the next.

Caution: Leaving the cereal without a Brachiaria/Mulato II grass border or row of 1-metre high will encourage stemborers to attack your maize.

Step 5. Management of desmodium

- After the second trimming (5–6 weeks after planting maize), leave the desmodium to grow until the maize is harvested.
- The rest of the management practices are similar to those for the first season.
- If you follow a good management regime for Napier grass and desmodium, you could benefit from your push-pull plot for 5 or more years.

Feeding Your Cow

- Chop the harvested Napier/Brachiaria grass and desmodium to reduce wastage while feeding it to your cow (Figure 43).
- During the dry season, chop the maize stover into small pieces and mix with the chopped Napier/Brachiaria grass and desmodium.
- Napier grass mixed with desmodium in the ratio of 3:1 is recommended for higher milk production of your cows and goats (Figures 43, 44 and 45).
- Two acres (0.8 ha) of a well managed push-pull plot can give enough Napier grass and desmodium for one dairy cow for one year, if supplemented with maize stover or other feeds during the dry season.
- Always remember to give your cow the recommended mineral supplements.



Figure 43. Chopping Napier and desmodium forage for feeding cows and goats

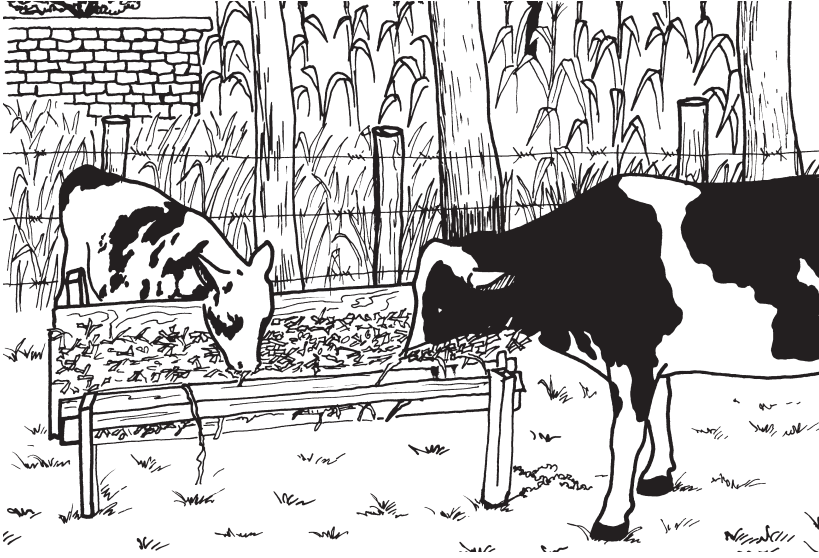


Figure 44. Cows feeding on chopped Napier mixed with desmodium forage. Mixing the small-leaved desmodium with Napier reduces wastage of the former



Figure 45. Dairy goats with chopped Napier mixed with desmodium in a trough

Things Not To Do

1. Do not trim desmodium during the first season.
2. Do not graze livestock in the push-pull plot, because animals will destroy the Napier/*Brachiaria* grass and desmodium.
3. Do not intercrop desmodium with Napier/*Brachiaria* grass in the same row.
4. Do not plant any other crop with the Napier/*Brachiaria* grass.
5. Do not allow desmodium to spread into the maize rows in the second and subsequent seasons until the maize is 6 weeks old. This reduces the competition between the two crops.
6. Never cut all the three rows of Napier/*Brachiaria* together. This avoids 'windowing'. Always cut one row all around your maize/sorghum at a time.
7. Do not let Napier/*Brachiaria* grass over-grow because it will seed and be ineffective in controlling stemborers and fall armyworm, and will become hard and coarse for cattle to feed on.
8. Do not plough under the desmodium rows. Replanting the desmodium is expensive and is unnecessary, as it can grow for up to 5 years or more.

Frequently Asked Questions

Q1. What is the maximum and minimum size of the push-pull plot?

Answer:

A push-pull plot can range from 50 × 50 m (maximum) or be used on any size farm provided the fields are demarcated into 50 × 50 m sections using border row pull crops of either Napier or Brachiaria grass.

Q2. What is the minimum width of a push-pull plot?

Answer:

Not less than 15 metres (50 ft).

Q3. How long can the push-pull plot be kept?

Answer:

If well managed, you can benefit from your Push-pull plot for 5 or more years.

Q4. Can I graze my cattle directly in the push-pull plot?

Answer:

No. Grazing destroys desmodium and Napier grass.

Q5. Can I practise push-pull, if I don't have livestock?

Answer:

Yes, because you can sell the Napier and desmodium forage and seed to your neighbours and desmodium can improve the fertility of your soil.

Q6. Can I intercrop other crops and trees in the push-pull plot?

Answer:

Yes, you can successfully intercrop beans into your Push-pull plot; these can be interplanted in the same hole or in between the maize/sorghum crop in the same line. The integration of other crops or trees into the push-pull plot may introduce new pest challenges and compromise the effectiveness of the technology. New crops would require research.

Q7. Are there alternatives to Napier grass and desmodium?

Answer:

*Yes. A drought-tolerant grass *Brachiaria* sp. can be planted around the maize or sorghum plot as a trap crop, as it is an excellent trap and forage alternative. Another alternative is wild sorghum such as Sudan grass (*Sorghum vulgare sudanense*), which can also be used to trap stemborers instead of Napier grass. Molasses grass (*Melinis minutiflora*) can be used to repel stemborers instead of desmodium. Molasses grass does not control striga weed, hence can be used in striga-free areas.*

Q8. How long can desmodium survive in a prolonged drought?

Answer:

Desmodium can always regenerate after a drought. However you are advised to plough and re-establish a push-pull plot in case of a prolonged drought or when desmodium fails to regenerate.

Q9. Can I plant maize first, then Napier grass after a few weeks?

Answer:

No. You are advised to plant Napier grass before planting maize, or if planting late, plant both crops at the same time.

Q10. When do I start reaping the benefits of the push-pull plot?

Answer:

You can reap benefits during the second cropping season in areas where farmers plant maize twice in a year, and during the second year in areas where farmers plant only once in a year. However, the benefits are noticed and have been acknowledged immediately upon proper establishment and management by technology users during the first season. For fall armyworm, the is immediate upon proper establishment and management of the technology.

Q11. Can I use push-pull technology on sorghum?

Answer:

*Yes. Intercrop green leaf desmodium (*Desmodium intortum*) with sorghum to repel stem borers and control striga weed. This is often encouraged under the climate-smart push-pull whereby, the green leaf desmodium (which is hardy and can do well in low rainfall areas), is intercropped with the cereal and surrounded by *Brachiaria-Mulato II* trap crop*

Q12. Is push–pull effective against other weeds and insect pests?

Answer:

Desmodium in the push–pull strategy if managed well can reduce most weeds by smothering them, but both Napier grass and desmodium may not reduce other insect pests. This tested technology is most effective against stemborers and striga weed. A recent significant finding is the control for fall armyworm by this technology. Studies and field findings show that control is effective when maize is intercropped with drought-tolerant greenleaf desmodium and Brachiaria is planted as a border crop around this intercrop.

Q13. Where can I obtain Napier grass, Brachiaria and desmodium seeds?

Answer:

Obtain Napier grass from neighbouring farmers or reputable bulking sites (clean Napier stunt resistant cultivars like Ouma II or South Africa) Desmodium seed is sold by Western Seed Company Ltd, Kitale, Kenya. Obtain brachiaria from established root splits during the wet season and its seed sources can be confirmed through local agriculture and icipe advisory staff.

Q14. What can I do if I don't get desmodium or Brachiaria seeds?

Answer:

Use desmodium root splits or cuttings from your neighbour. Brachiaria also can be obtained from established root splits during the wet season However ensure that you plant them immediately and when there is adequate soil moisture.

Q15. How effective is push-pull against stemborers, fall armyworms and striga weed?

Answer:

Push-pull is effective. It is even better than insecticides for the control of stemborers and better than manual removal of striga weed, both in terms of cost and labour. Push-pull is the most effective control method. The climate-smart Push-pull (desmodium and Brachiaria) has proved effective in inhibiting fall armyworm access and damage to the crops.

Q16. Can I be given a dairy animal if I establish a push-pull plot?

Answer:

No. But you can qualify for applying to various projects on dairy animals. Also the income generated from sales of fodder and other by-products can help in purchasing your own animal.

Q17. If I don't have desmodium seed, can I plant only Napier grass in my push-pull plot?

Answer:

Yes. If you plant only Napier grass, you will be able to reduce stemborers on maize, but you will not be able to control striga weed. However, using both Napier and desmodium gives the best results.

Q18. Can the push-pull technology work in all parts of Kenya or Africa?

Answer:

Yes, but only in areas recommended for growing desmodium, where rainfall and climate allow cropping with low risk of the crop. Consult your agricultural extension staff.

Q19. Can I use other varieties of Napier grass other than Bana grass?

Answer:

Yes, but it is strongly recommended that one should use clean and Napier stunt disease-resistant varieties. iCipe approved cultivars are Ouma II and South Africa. Field sanitation and hygiene are essential, whereby you should rouge out any traces of the disease.

Q20. Can I use other species of desmodium other than silver leaf?

Answer:

*Yes. You can use greenleaf desmodium. The results with silverleaf (*Desmodium uncinatum*) intercropped with maize is the best. Greenleaf desmodium can be used in drier areas and is often used with a sorghum cereal crop. Research on African desmodium varieties is on for possible integration.*

Glossary

CAN	calcium ammonium nitrate
DAP	diammonium phosphate
deadheart	destruction of the growing bud in the plant whorl can result in a 'deadheart' (drying, stunting, and complete loss of yield by a plant)
drilling in	to sow seeds in a furrow or trench in rows
emergence	the process of emergence of a plant from seed
ft	feet
greenleaf	greenleaf desmodium (<i>Desmodium intortum</i>)
host	an animal or a plant that maintains a parasite
indigenous	a plant or animal originating (native to) in an area
infestation (of striga)	penetration of germinating seeds of striga into the host root
internodes (for Napier or desmodium)	part of stem between two nodes
larva (pl. larvae)	newly hatched worm-like forms of insects that feed on plants
leafsheath	the basal or lower part of the leaf enclosing the stem
lodging	damaged plants due to heavy winds
m	metres
manual	by hand
molasses grass	<i>Melinis minutiflora</i>
node	an enlarged point on a stem where a leaf, bud, or other organ is attached
parasite	a plant or an animal that grows, feeds and is sheltered on or in a different plant or animal called the 'host'

pupa (pl. pupae)	inactive stage in the life cycle of stemborers, following the larval stage
silverleaf	silverleaf desmodium, <i>Desmodium uncinatum</i>
stover	dried stalks and leaves (of a cereal crop used as a fodder after grain has been harvested)
top dressing	applying fertiliser to the surface of the soil
TSP	triple superphosphate (fertiliser)
witchweed	parasitic weed such as <i>Striga hermonthica</i>

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This easy-to-read primer shows farmers how to manage some of the major pests of maize/sorghum (stemborers, fall armyworm and striga weed), in the eastern and southern Africa region without the use of chemical pesticides. The 'push-pull' strategy is a novel system of intercropping designed to manage the agroecohabitat for higher maize yields, while at the same time providing fodder, enriching the soil and conserving biodiversity.

Push-pull can also be adapted for sorghum and millet fields and is an affordable, appropriate and socially acceptable technology for use by Africa's farmers.



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