

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

**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
A Step by Step Guide for Farmers**

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 to all those who are looking for information on the push pull technology. Secondly as a do it yourself implementer's guide targeting farmers and frontline extension staff on how to establish and manage a 'push-pull' plot to control stemborer, fall army worm and striga weed.

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

It is expected that this book will enhance adoption of the technology and increase maize/sorghum and livestock productivity while improving soil fertility and conserving the environment. The primer can be one of the essential references for various technology transfer pathways currently in use. We have developed this primer on the push-pull technology that icipe (International Centre of Insect Physiology and Ecology)

and partners developed over 20 years ago. Recently, icipe modified the conventional push-pull method through incorporating drought-tolerant companion plants, while achieving similar control of the constraints, but now 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. Farmers plant a legume (Desmodium) between the rows of cereal crops, which makes the cereal crops unattractive to stemborers due to the chemicals Desmodium emits (which provides the 'push'). Farmers also plant a drought-tolerant grass (Brachiaria) around the maize or sorghum plot as a trap crop, which due to the chemicals it emits, attracts stemborer moths for egg-laying, but allows only minimal larval survival (which provides 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. Push-pull has been expanded to nine African

countries (Ethiopia, Kenya, Tanzania, Uganda, Rwanda, Burundi, Malawi, Zambia and Zimbabwe) by the end of 2018.

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 to 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 rots and mycotoxins, such as aflatoxin and fumonisin (which are poisonous substances that fungi produce that contaminate cereals and similar crops).

This easy-to-read condensed 50-page primer is filled with

useful illustrations and contains frequently asked questions. We hope that the primer will be an additional detailed and simple research to extension linkage, besides being a valuable learning resource for farmers and extension workers of this innovative technology. We believe that the groundbreaking climate-smart push-pull technology has 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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Director General & CEO, *icipe*,

Nairobi, Kenya

Stemborers, Fall armyworm and Striga Weeds

Stemborers, Fall armyworms and striga weeds are the three most destructive pests of cereal crops and can greatly reduce yields of maize and sorghum on smallholder farms. These pests can cause yield losses of 30 to 100% if they are not controlled. Control of stemborers or fall armyworms by insecticides and control of striga weeds by herbicides is very expensive for resource-poor farmers and is also harmful to the environment.

Stemborers

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

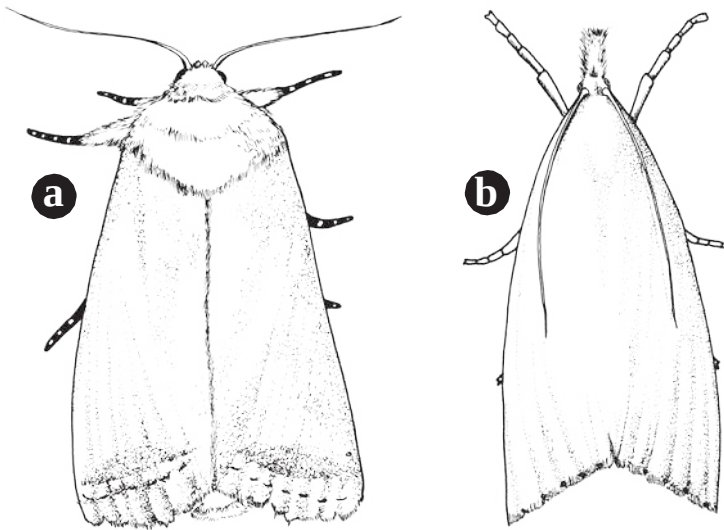


Figure 1. Adult stemborer moths of *Busseola fusca* (a) and *Chilo partellus* (b)

Busseola fusca (Figure 1a) and *Chilo partellus* (Figure 1b). *Busseola fusca* is indigenous to Africa and is present in high and mid-altitude areas (3500ft [1077m] 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 4000ft [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 dead heart (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

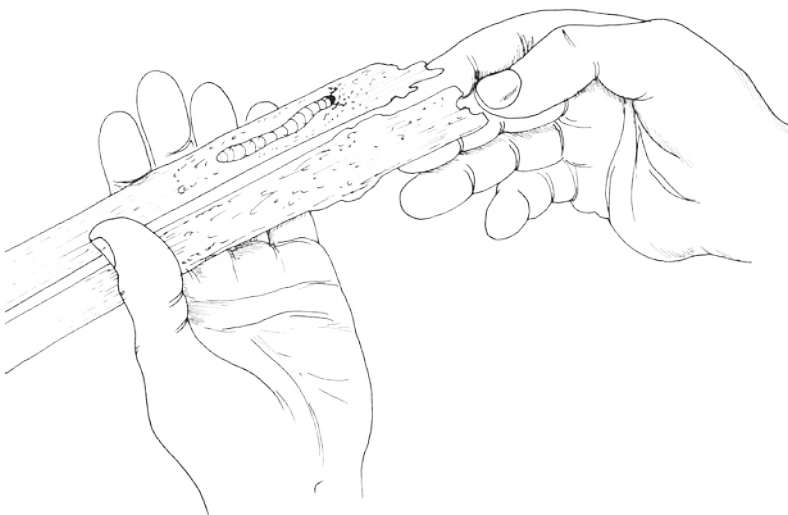


Figure 4. A stem borer larva feeding inside a maize stem

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 leafsheath, 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.

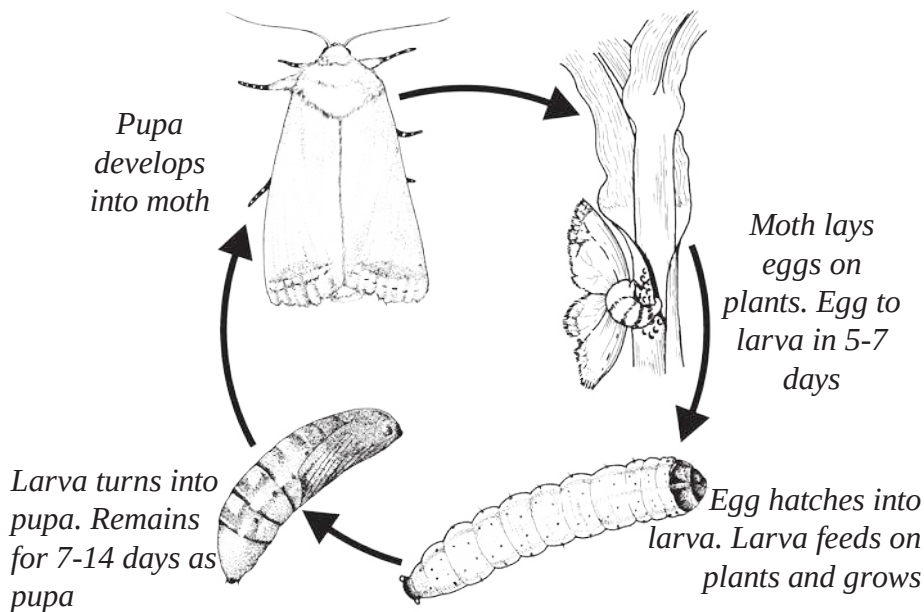


Figure 5. Life cycle of the stem borer *Busseola fusca*

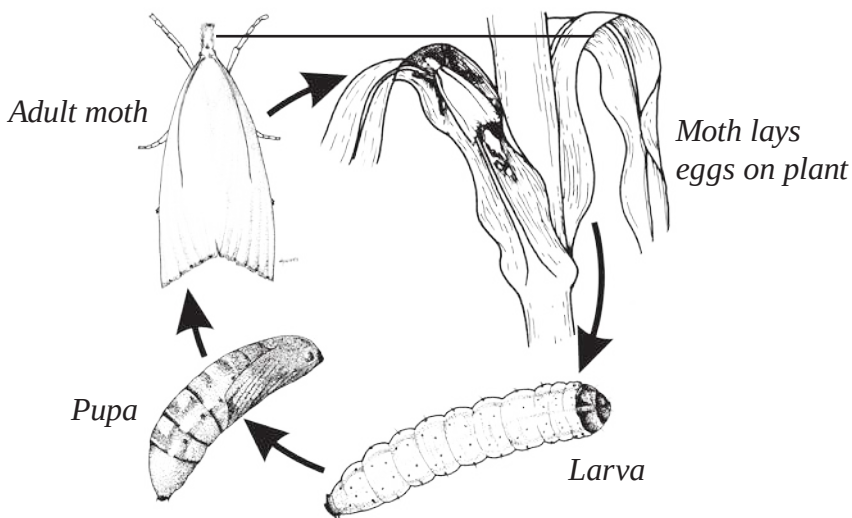


Figure 6. Life cycle of the stem borer ***Chilo partellus***
(The spotted stem borer)

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 armyworms infest an area, they eat almost everything in the area, before moving to the next available food source.

How to identify

The fall armyworm has a feature that distinguishes it from other army worm’s species.

- Its head has a predominantly white inverted (upside-down) Y-shaped suture between the eyes.
- Newly hatched larvae are greenish in colour and have black heads. They move in a looping motion.
- Fall armyworm has four dark spots arranged in a square on top of the eighth abdominal segment.

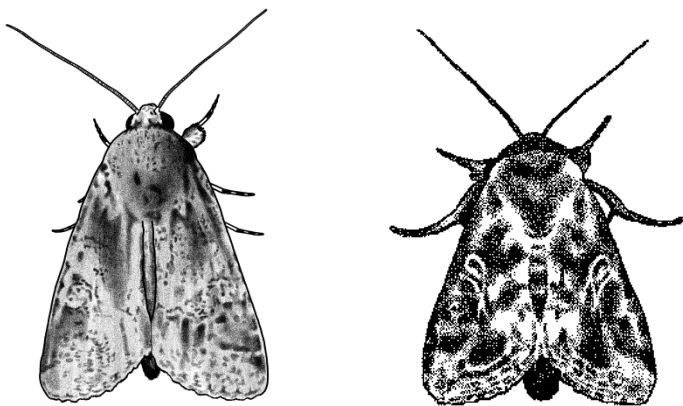


Figure :Adult Fall army worm Male and Females illustrations

Feeding habits

The fall armyworm has a voracious appetite and they are heavy feeders. It feeds on more than 80 varieties of crops. Fall armyworms feed any time of the day or night. However, they are most active early in the morning or late in the evening. They crawl in great armies to adjoining fields. They can also fly over 100 kilometres a day assisted by wind, thus they can spread very 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 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 completely destroy an entire crop in a few days.

Life cycle

The fall armyworm is an insect labeled as an incredibly successful invasive species. Its life cycle, 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 very fertile insect, laying up to 2,000 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 in colour and dome-shaped. The female also deposits a layer of grayish scales between the eggs and over the egg mass. This gives the eggs a hairy or moldy appearance. The eggs take about 3 to 5 days to hatch. The larvae emerge and migrate to the whorl. 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 pupa and begins the egg lay cycle after 3 to 4 days.

Striga weeds

Striga or ‘witchweeds’ are parasitic weeds that affect cereal crops in many parts of Africa, reducing production from 30 to 100%, or 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 7) 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.

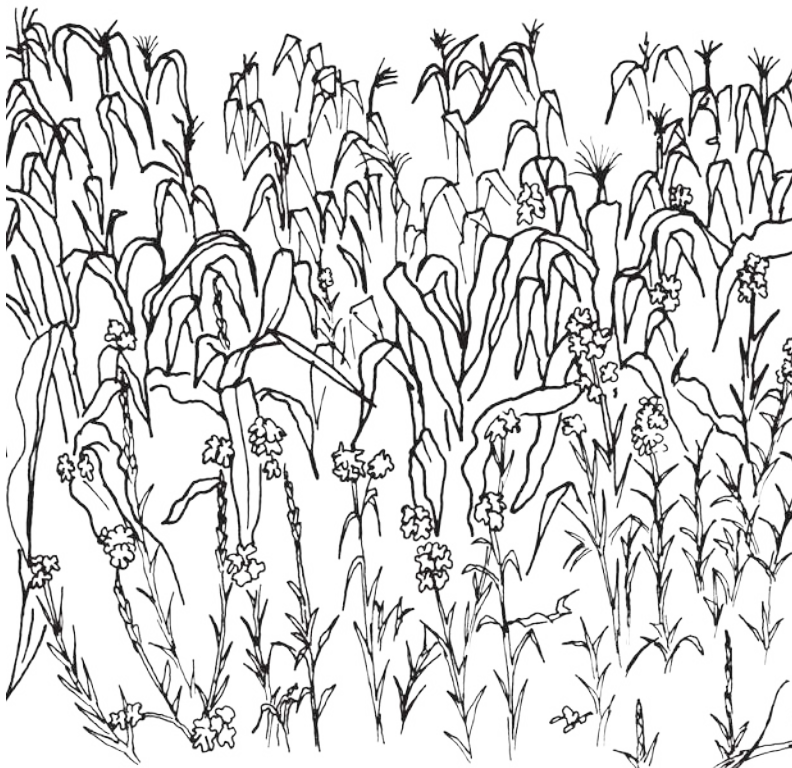


Figure 7. A maize field infested with *Striga hermonthica*

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 (Figure 8).

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.



Figure 8. Striga weed attached to maize roots

Taking into account the peculiar nature of striga seeds, farmers are advised to control it before the weed emerges above the soil. The reason for this is that by the time it emerges, much of the damage to the maize will have been caused.

Although various control methods have been proposed, they are usually not successful. 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.

Control of Stemborers, Fall armyworms and Striga Weeds, Using a Push-Pull Strategy

What is push-pull’?

ICIPE and her partners have developed an effective, low-cost and environmentally friendly technology known as ‘push-pull’ for the control of stemborers, fall armyworms and suppression of striga weeds in maize and sorghum.

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

- i) **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. C
- ii) **Climate-smart push-pull strategy**, a cropping strategy, whereby farmers use *Brachiaria spp* (a drought tolerant grass) and desmodium legume (drought tolerant greenleaf desmodium recommended) as intercrops to efficiently produce staple cereal crops and fodder under hot, dry conditions. C

Desmodium is planted in between the rows of maize. It produces a smell or odour that stemborer moths do not like. 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 (like Ouma2 and South Africa cultivars) is highly 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 9). 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 10). So, very 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 and allow either of the cereals (Maize or Sorghum), can be planted in any of the push pull options.*

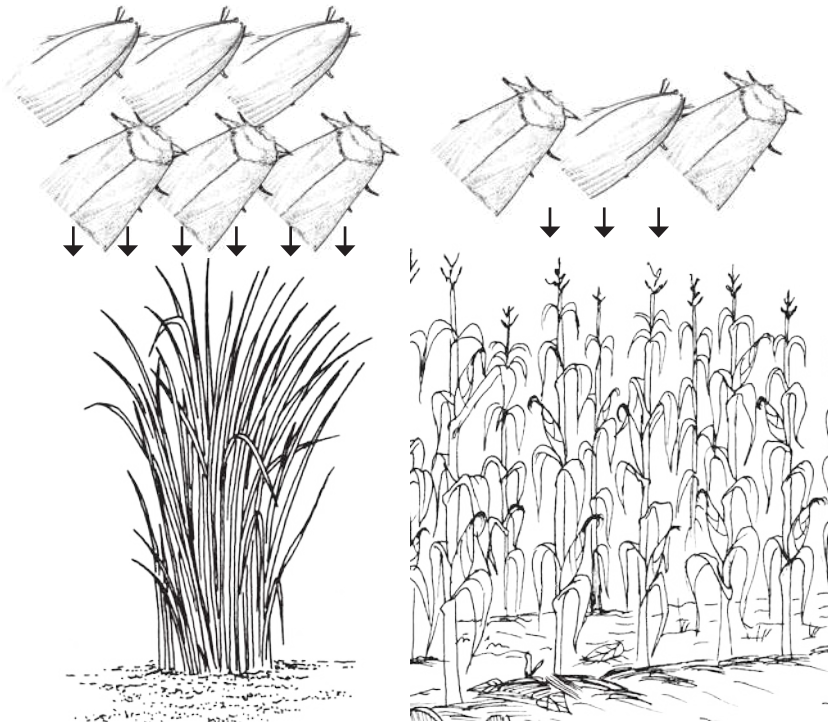


Figure 9. More stemborers moths are attracted to Napier or Brachiaria grass than to maize. Napier/Brachiaria therefore acts as the ‘pull’ in push-pull

Feeding marks of stemborer larvae on Napier grass



Stemborer larvae killed by glue produced by Napier grass stem



Figure 10. Napier leaves attacked by stemborer 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 \$ 40 per kg. (Kshs.3000 to 4000)
- Earn money from the sale of fresh Desmodium forage and Brachiaria, 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 the most important livestock fodder in Western Kenya, and is severely constrained by Napier stunt (Ns) disease. The 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 which tolerates frequent cutting. These qualities make it the most important fodder grass in East Africa. It is grown by the majority of the region’s smallholder dairy and cereal farmers.

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. Affected plants are recognized by severe stunting and yellowing, and a profuse growth of shriveled, 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 specialized 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 are carried from plant to plant by the leafhopper *Maistas banda* Kramer, which draws its food from the part of the Napier grass which is infected by phytoplasma. High population densities of *Maistas banda* Kramer on field sites in western Kenya confirmed the identification of the leafhopper as the principal insect vector for NSD.

The phytoplasma are also spread through the common practice of propagating split Napier grass roots for multiplication. After rigorous research trials, icipe selected and released two Napier varieties which are resistant to the Napier Stunt Disease for the technology transfer. Namely, these are Ouma II and South Africa cultivars, which were 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 effective benefits are fully realized 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 this: Desmodium/Brachiaria seeds are very small; therefore the soil should be carefully prepared so that it is as fine and clean as possible, to maximize germination.
- Measure out your push-pull plot to a maximum size of 50 by 50 m (Figure 11).
- 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 x 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.

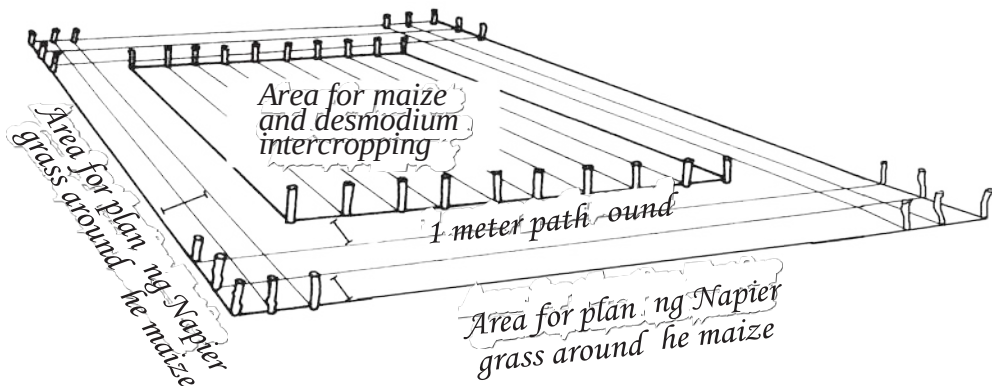


Figure 11. Layout of a push-pull plot

Step 2. Planting material

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

Ensure that you have all the needed viable planting material:

- Maize/Sorghum seed
- Desmodium seed
- Napier grass root splits or canes (Figure 12). Use of clean Napier Stunt Disease resistant Napier grass (*Pennisetum purpureum*) cultivars (like Ouma2 and South Africa cultivars) is highly recommended. Ensure that planting material is not infected with Napier grass diseases
- Brachiaria (Mulato) seeds or splits if using the climate smart option
- Triple superphosphate or single superphosphate fertilizer or farmyard manure.

Sources of planting material

- Napier grass.
- Brachiaria (Mulato)- stockists, via icipe directions
- **Desmodium:** Western Seed Company Ltd., Kitale, Kenya.
- **Cereal:** Seed companies, and appointed stockists.

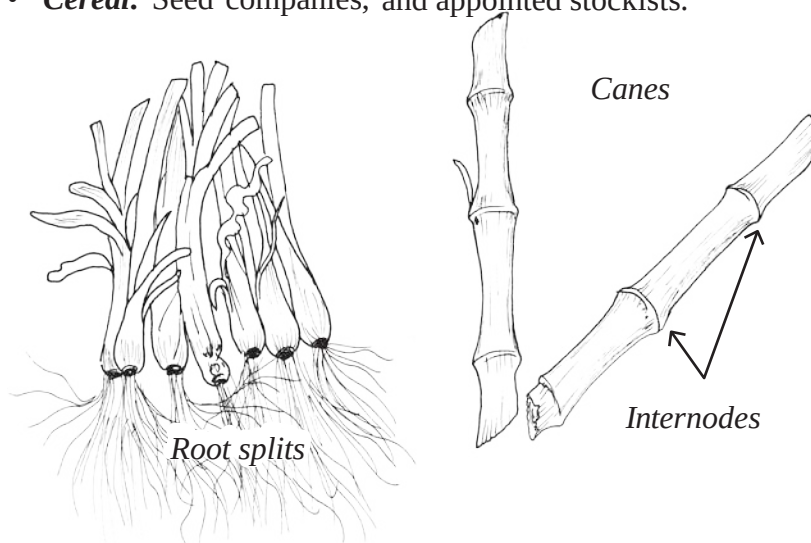


Figure 12. Clean Napier grass root splits and cane cut into nodes for planting



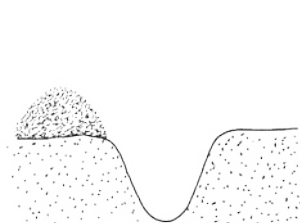
*Figure 13. Diseased Napier grass plants are yellowish, stunted plants with short internodes. The leaves are very narrow. The disease is carried by a microorganism (phytoplasma) and is transmitted by an insect vector, which is known as *Maestas banda Kramer* on field sites*

Step 3. Planting the push

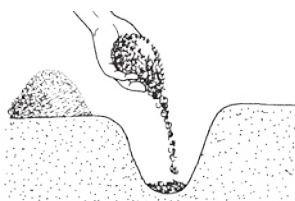
~~probs~~

Planting Napier grass

- Plant Napier grass (use clean and healthy planting material, preferably Napier stunt disease resistant cultivars e.g. Ouma2 or South Africa varieties.) in a border around the maize plot as shown in Figures 11 and 15.
- 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 14).



Hole ready for planting



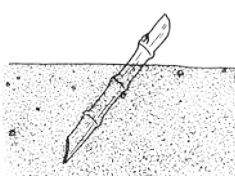
*Put in one teaspoonful of TSP
fertilizer or two handfuls of
farmyard manure*



Planting Splits



Place cane in the hole



*Cover cane
with soil after
planting*

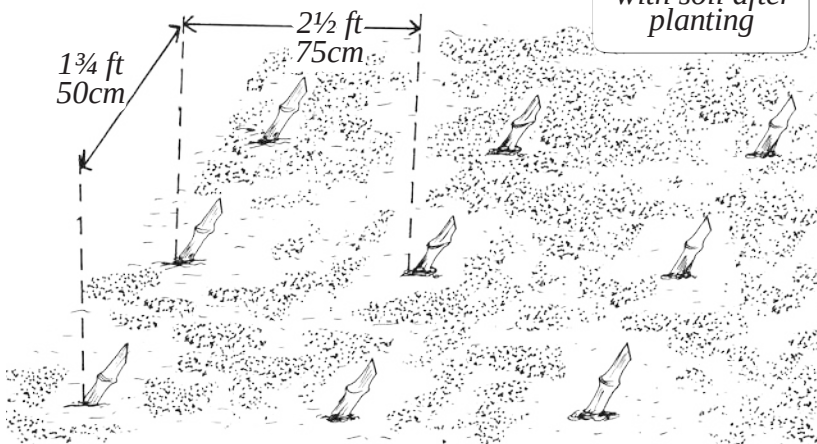


Figure 14. Newly planted Napier grass field

- Apply one teaspoonful of triple superphosphate (TSP) fertiliser or two handfuls of well decomposed farmyard manure in each hole before planting Napier grass (Figure 14).
- 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 14).
- 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.

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 15).

Planting Brachiaria grass

Planting Brachiaria grass Brachiaria cv. Mulato II is currently 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 soil.

Step 3: Drop 5 – 6 seeds into each hole

Step 3. Planting the push ~~-pull~~

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 armyworms 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 15. 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 16).
- 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 (Fig.17).
- Sow the seed-sand or seed-fertiliser mixture into the furrows you have made and cover lightly with a small amount of soil (Figure 18).
- 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.

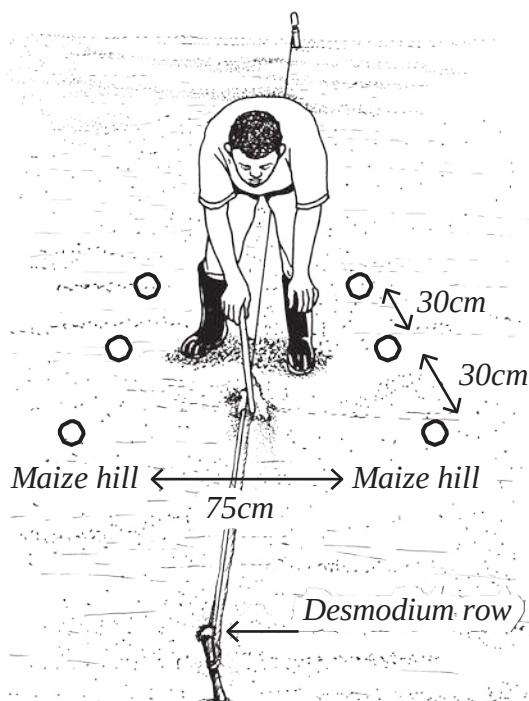


Figure 16. A farmer making rows for drilling desmodium seeds

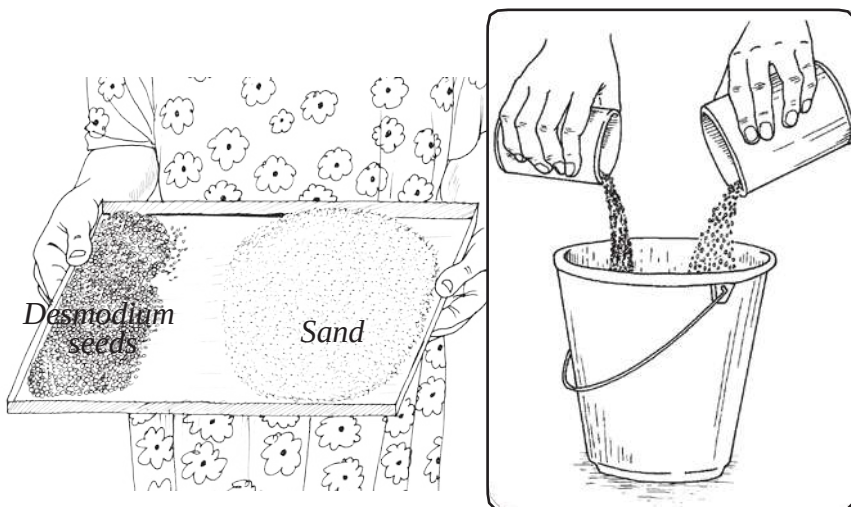


Figure 17. A farmer mixing desmodium seed with dry soil or sand for drilling. Use the ratio of 1 part seed to 3 parts sand



Figure 18. 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. Stemborers will still be kept 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. Planting of the splits or cuttings should be done 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 very important for the successful establishment of a push-pull plot.
- The first weeding should be carried out when the maize is 3 weeks old.
- It is important to know the difference between desmodium and weeds. If in doubt, consult the nearest extension staff. Figures 19 and 20 show young desmodium plants.
- Care should be taken when weeding the drilled desmodium line. Hand picking of weeds in the line is recommended at this stage (Figure 21).
- Thin maize to one plant per hill.
- In striga-infested areas, apply nitrogen fertilizer (CAN) to the maize at the rate of one teaspoonful per plant (Figure 22) after the first weeding.
- Napier grass rows should also be weeded.



Figure 19. One-week-old silverleaf desmodium (left) and greenleaf desmodium (right) plants



Figure 20. Three-week-old silverleaf desmodium (left) and greenleaf desmodium (right) plants



Figure 21. Hand weeding desmodium rows and weeding the space between maize and desmodium with a hoe



Figure 22. 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 23).
- Care should be taken again to distinguish between desmodium and weeds (Figure 24).
- 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 23. Push-pull plot after second weeding



Figure 24. Five-week-old silverleaf desmodium (left) and greenleaf desmodium (right) plants

Step 5. 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 25).
- 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 (Figure 26).
- 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 25. Farmers start harvesting Napier grass when it is 3 months old



Figure 26. 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 stem borers.
- 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 stem borers.
- 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, farm yard 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 6. 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 maize stover in a dry place to minimise spoilage.

Step 7. Management of desmodium

- After harvesting your maize crop, desmodium can either be harvested as forage for livestock (Figure 27), or Left to produce seed before it is harvested for forage (Figure 28).



Figure 27. Harvesting desmodium forage after harvesting maize from the field



Figure 28. Flowering/podding desmodium after harvesting maize

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.

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.

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 29) 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 30 and 31).
 - Winnow to get clean seed (Figure 32).
 - Store in dry, clean tin or airtight container (Figure 33).
- One acre (0.4 ha) of well managed and properly harvested desmodium seed crop can yield 50-60 kg of seed. This 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.

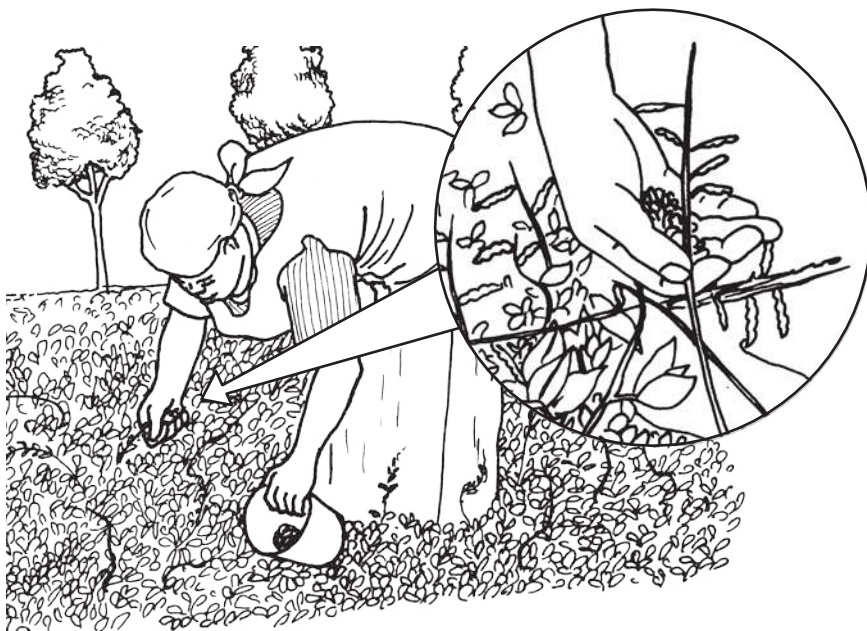


Figure 29. Harvesting of desmodium pods

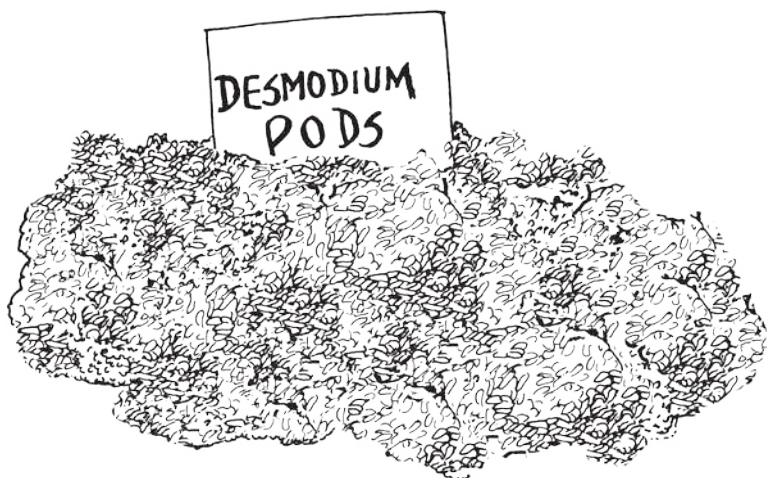


Figure 30. Sun drying of desmodium seeds



Figure 31. Threshing of desmodium seeds on a stone using an old slipper



Figure 32· *Winnowing desmodium seeds*

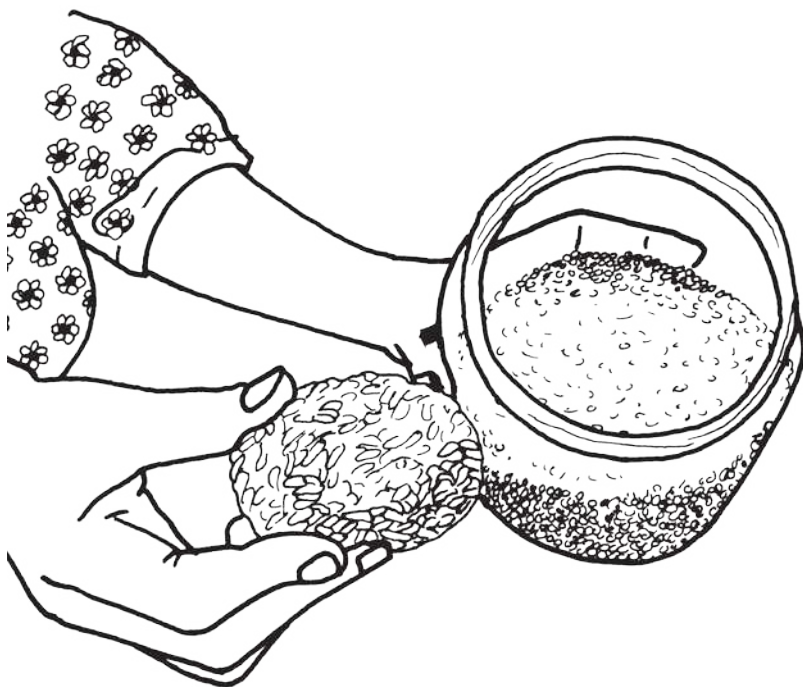


Figure 33. Store desmodium seed in a clean tin or airtight container

- 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 utilizing 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 34). (Minimum or zero tillage options outlined below)



Figure 34. 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 x 30 cm (Figure 35).
- Apply TSP or DAP fertiliser on the maize at the rate of one teaspoonful per hill as top dressing.



Figure 35. 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 cut 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 is 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 which 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 cut 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.

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.

4b. Management of Brachiaria-Mulato2 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-Mulato2 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-Mulato2 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 36).
- 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 37, 38).
- 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 36. Chopping Napier and desmodium forage for feeding cows and goats



Figure 37. Cows feeding on chopped Napier mixed with desmodium forage. Mixing the small-leaved desmodium with Napier reduces wastage of the former



Figure 38. Dairy goats with chopped Napier/Brachiaria 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 not be effective in controlling stemborers, 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 very expensive and is not necessary 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 x 50 m (maximum) or be used on any size farm provided the fields are demarcated into 50 x 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, it is an excellent trap and forage alternative, and another 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 very 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 defense 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 stemborers 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 very recent significant finding is the control for fall armyworm by this technology. Studies and field findings shows that control is effective when maize is inter-cropped with drought-tolerant Greenleaf desmodium and planting *Brachiaria* as a border crop around this intercrop.

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

Answer: Napier grass can be obtained from neighboring farmers or reputable bulking sites (clean Napier stunt resistant cultivars like Ouma2 or South Africa) Desmodium seed is sold by Western Seed Company Ltd., Kitale, Kenya. *Brachiaria* can be

obtained from established root splits during wet season and their 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 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 very 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. The climate smart push pull (desmodium & Brachiaria) has proved very effective in inhibiting fall army worm 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 income generated from sales of fodder and other by products can help in purchasing 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 allows cropping with low risk of 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 Ouma2 and South Africa. Field sanitation and hygiene is essential whereby any traces of the disease should be rouged out totally.

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

Answer: Yes. You can use greenleaf desmodium (*Desmodium intortum*). But the results with silverleaf (*Desmodium uncinatum*) intercropped with maize are the best. Greenleaf desmodium can be used in drier areas and is often used with 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 the 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 (pI. larvae)	newly hatched worm-like forms of insects which 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 (pI. 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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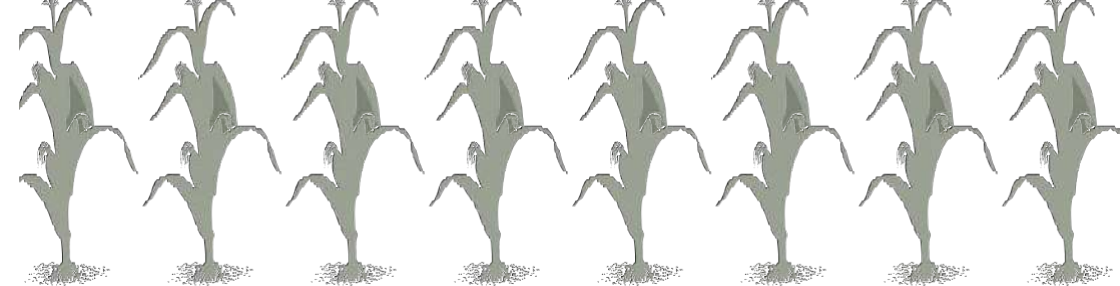
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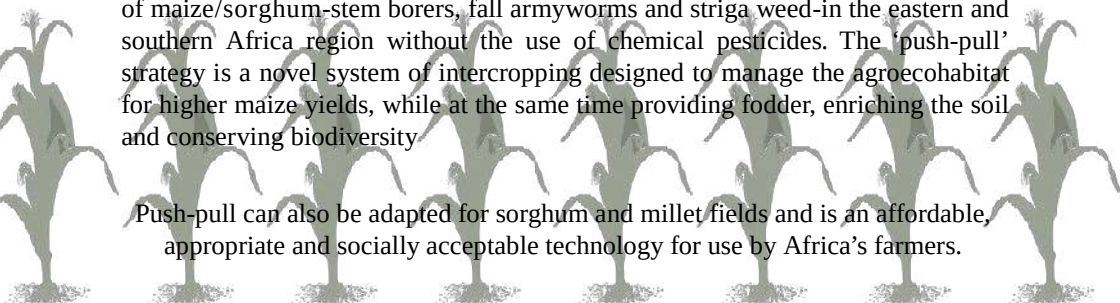
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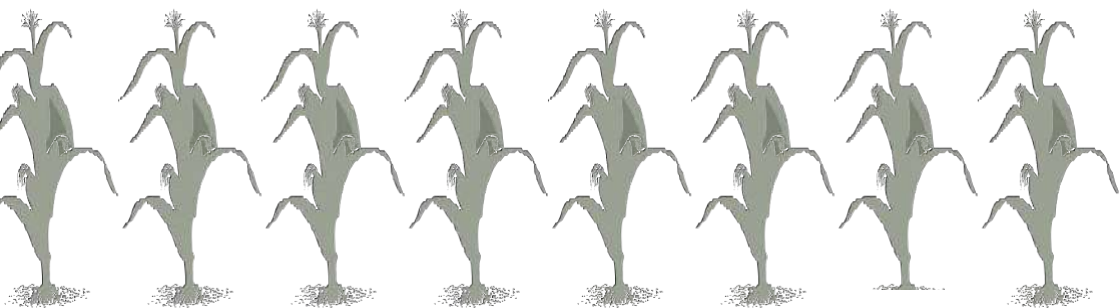
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This easy-to-read primer shows farmers how to manage some of the major pests of maize/sorghum-stem borers, fall armyworms and striga weed-in the eastern and southern Africa region without the use of chemical pesticides. The 'push-pull' strategy is 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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