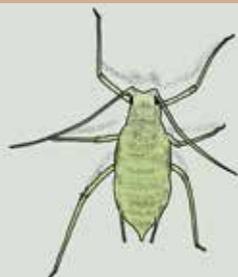
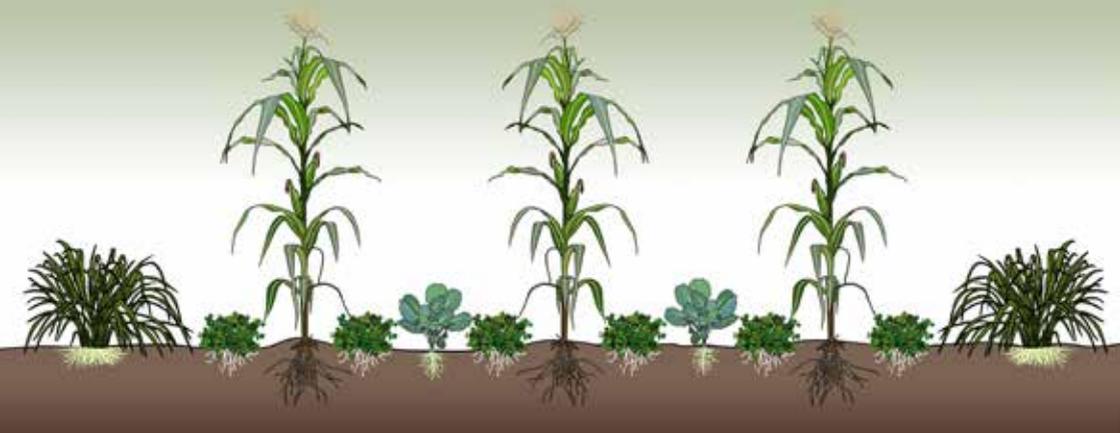


# A Primer on Planting and Managing Vegetable-Integrated Push–Pull Fields for Control of Stemborers, Fall Armyworm, Vegetable Pests and *Striga* Weed

## A Step-by-Step Guide for Farmers and Extension Staff



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





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**Donor:** Biovision Foundation, Switzerland.

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## List of acronyms

<b>cm</b>	centimetre
<b>DAP</b>	diammonium phosphate (fertiliser)
<b>ft</b>	feet
<b>ha</b>	hectare
<b>kg</b>	kilogram
<b>km</b>	kilometre
<b>m</b>	metres
<b>NPK</b>	nitrogen phosphorus and potassium (fertiliser)
<b>spp.</b>	species (plural)
<b>SSP</b>	single superphosphate (fertiliser)
<b>TSP</b>	triple superphosphate (fertiliser)
<b>VI-PPT</b>	Vegetable-Integrated Push-Pull Technology



# Foreword

This handbook by International Centre of Insect Physiology and Ecology (*icipe*), with support from Biovision Foundation, 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 vegetable-integrated 'push-pull' field.

Staple food production in sub-Saharan Africa (SSA) has not kept pace with the rate of its population growth, increasing at 2.6% per year. Since most parts of SSA have a tropical, equatorial or sub-tropical climate, they provide an ideal environment for pests, weeds and crop diseases. The production of staple crop yields is limited by a myriad of problems such as stemborers, fall armyworm (FAW), *Striga* weed and poor soil fertility, causing high levels of food insecurity, undernutrition and poverty. Similarly, vegetables, which are a vitally important source of micronutrients, vitamins and minerals, and essential components of balanced and healthy diets, are also attacked by various insect pests, mainly aphids, cabbage looper, diamondback (DBM) moth, tomato leafminer and others. This results in heavy use of pesticides. Food production in SSA must increase by either increasing individual crop yields or intensifying land use to produce more food from the same land. The staple-based diets in SSA based on maize need to be diversified with vegetables to increase nutrition and income generation.

Push-pull technology, developed by *icipe* and partners, provides an effective management of stemborers, FAW, *Striga* weeds and soil fertility, while sustainably providing high quality animal fodder, thus allowing intensification of smallholder cereal-livestock systems. The technology has been adapted to dry areas by incorporation of drought-tolerant companion forage plants, with reports indicating improved crop yields, incomes and gender equity.

The push-pull system involves planting two types of companion plants. Between the rows of cereal crops, farmers plant a legume (*Desmodium*), which continuously emits defence 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'). In the adapted climate-resilient push-pull version, *Brachiaria* functions as a 'push' plant that also repels the FAW pests. *Desmodium* and *Brachiaria* emit chemicals that attract (pull) natural enemies of the FAW. The companion plants also increase soil fertility by fixing nitrogen, improving carbon sequestration, soil organic matter and soil microbiota, preventing soil erosion and enhancing the abundance and diversity of below- and above-ground beneficial insects, such as bees. The ecological basis of push-pull, i.e., repellence and attractance works well in vegetable-maize systems, providing a formidable tool for combatting pests in vegetables, without negative competition.

## Why vegetable push-pull?

- Push-pull provides integrated management of insect pests (stemborers and FAW), parasitic *Striga* weeds and soil fertility.
- The technology fits well with traditional mixed cropping systems in Africa; farmers can integrate legumes and vegetables into the system.
- The technology is economical and appropriate for resource-poor African farmers as it is based on locally available plants and does not require expensive external inputs.
- Increased cereal yields: maize, sorghum and millet production is at least doubled.
- Effective control of stemborers and FAW by trap and repellent plants, which also increases natural enemies of the pests.
- *Striga* control by *Desmodium*, which progressively depletes *Striga* seed bank in the soil.
- Restores degraded farmlands by controlling soil erosion and improving soil organic matter and physical properties. Moisture conservation by intercrop plants improves soil water holding capacity.

- Improved soil fertility through increased biological nitrogen fixation by the *Desmodium* intercrop.
- 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).
- Restores biodiversity through increased abundance and diversity of beneficial organisms.
- Provides year-round quality fodder from the trap and intercrop plants leading to improved milk production.
- The integration of vegetables ensures sustainable land use and returns, especially between the cereal cropping seasons (fallow period).
- Availability of clean, healthy, surplus vegetables for the household, providing both nutritional and income support.
- Push-pull has been adapted to climate change by incorporating more drought-resilient companion crops.
- Push-pull has been intensified to include high value seasonal legumes and vegetables, providing better nutrition and improved incomes. Some significant vegetable pests and diseases can be effectively managed with push-pull in a way that is both economical and environmentally acceptable.

This easy-to-read Primer has useful illustrations and contains frequently asked questions. It is a useful tool for farmers and extension personnel on this cutting-edge technology to boost vegetable production, enhance environmental sustainability and resilience, and improve smallholder farmers' and rural families' quality of life while mitigating the effects of climate change.

The ability of push-pull to manage such a devastating and difficult pest as the FAW clearly demonstrates the utility of the technology as a platform in addressing the multitude of challenges that affect cereal-livestock farming systems in Africa. Thus, *icipe* intends to continue disseminating the technology as widely as possible to farmers across Africa.

**Segenet Kelemu**, PhD, FEAS, FAAS, FTWAS, Director General & CEO, *icipe*, Nairobi, Kenya (2023)

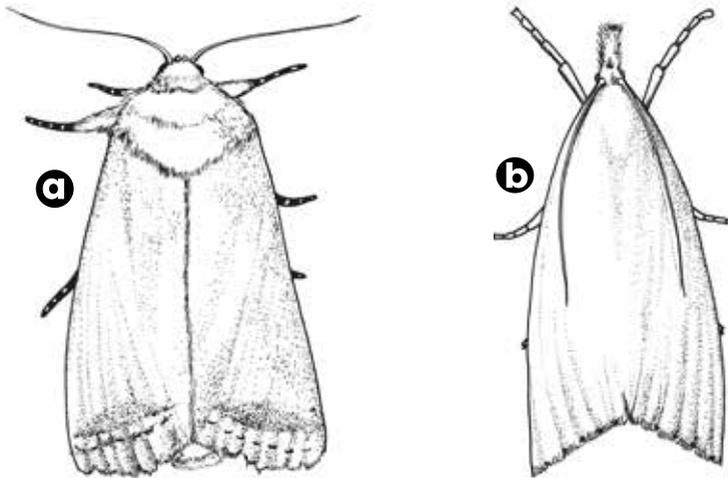


# Stemborers, Fall Armyworm and *Striga* Weed

Stemborers, fall armyworm (FAW) 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 FAW by insecticides and *Striga* weeds by herbicides is expensive for resource-poor farmers and is also harmful to the environment.

## Stemborers

Stemborers are the most significant 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 see Figure 1 that cause heavy damage to cereal crops.



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

*Busseola fusca* is indigenous to Africa and is present in high- and mid-altitude areas (3,500 ft [1,077 m] above sea level and higher). *Chilo partellus* accidentally came to Africa from Asia in the 1930s and is present in low- and mid-altitude areas (zero to 4,000 ft [1,230 m] above sea level).

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



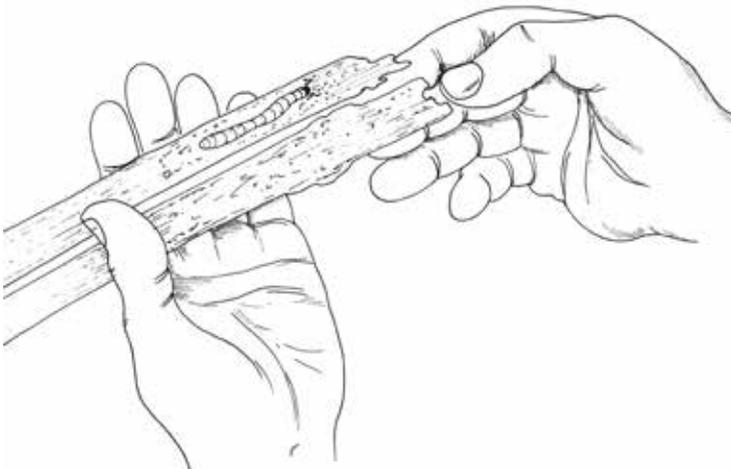
*Figure 2. Maize plant damaged by stemborer larvae*

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

At a later stage of growth, the larvae make extensive tunnels inside the stem (see 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 out of every 10 bags that could be harvested are lost.



*Figure 3. Deadheart caused by stemborer larvae feeding inside a maize plant*

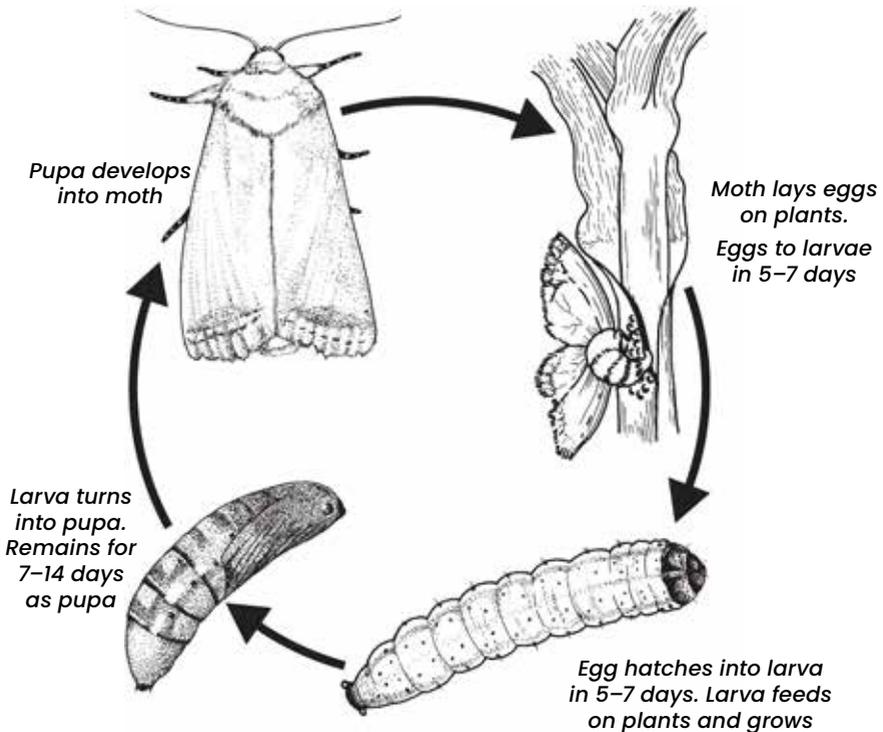


*Figure 4. A stemborer larva feeding inside a maize stem*

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

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



**Figure 5. Life cycle of the *Busseola fusca* stemborer**

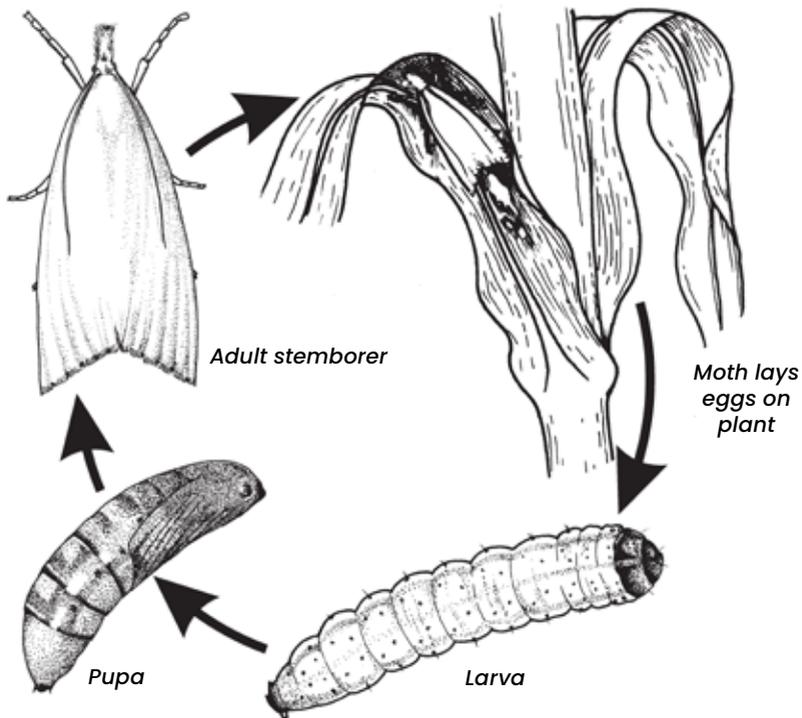


Figure 6. Life cycle of the *Chilo partellus* stemborer (the spotted stemborer)

## Fall armyworm (*Spodoptera frugiperda*)

The Fall armyworm (*Spodoptera frugiperda*) is a major invasive pest which can spread and reproduce quickly. Moths lay eggs on the underside of cereal crop leaves, which hatch to caterpillars. These cause damage during their growing stages. The young caterpillars can spin and use silken threads which catch the wind and transport them to new plants. The leaves around the cob silks are preferred in older plants whereas the leaf whorl is preferred in young plants. In a plant that has already developed cobs, the caterpillar will eat its way through the protective leaf bracts into the side of the cob where it begins to feed on the developing kernels.

## How to identify

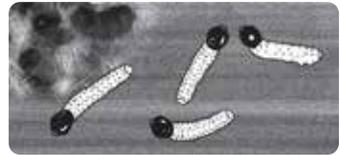
The FAW (see Figures 7–10) has a feature that distinguishes it from other armyworm species.

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



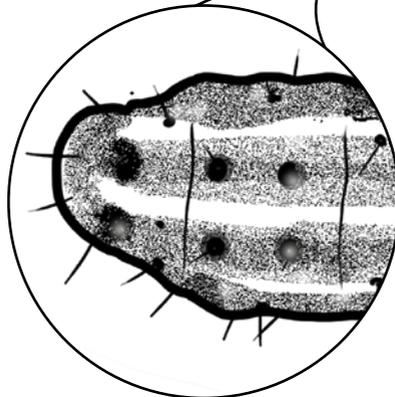
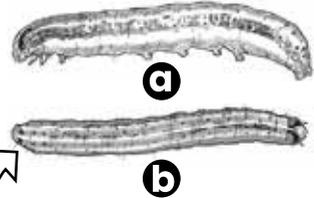
*Figure 7. The inverted Y-shaped suture on a FAW head*

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

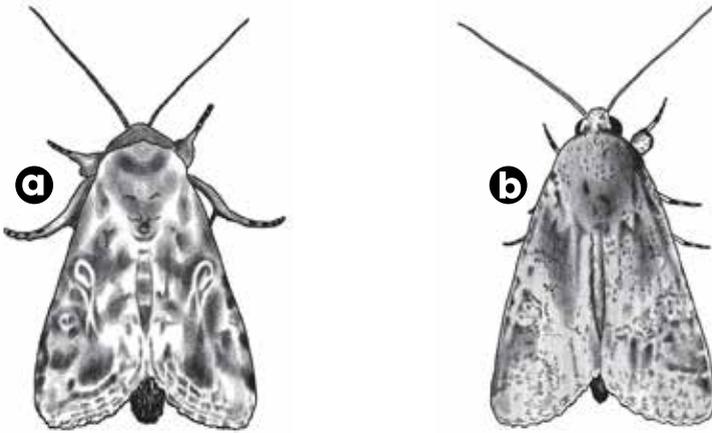


*Figure 8. Newly hatched FAW larvae*

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



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



*Figure 10. Adult FAW male (a) and female (b)*

## **Feeding habits**

The FAW has a voracious appetite and is a heavy feeder. It feeds on more than 80 varieties of crops. It feeds any time of the day or night. However, it is most active early in the morning or late in the evening.

Small FAW 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 they attain full growth. 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.

The moths are nocturnal and most active during warm humid evenings. They can fly over 100 km a day assisted by the wind; thus, they can spread fast.

## Life cycle

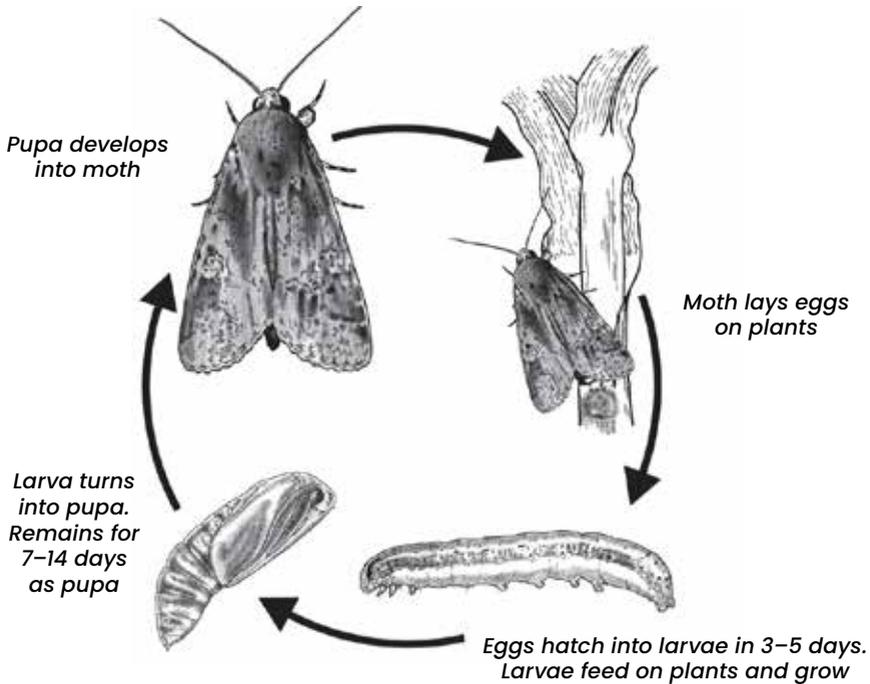


Figure 11. Life cycle of the fall armyworm

The FAW is an insect labelled as an incredibly successful invasive species. Its life cycle (see Figure 11) and 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 FAW is a fertile insect, laying up to 2,000 eggs in a lifetime. The adult female lays 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.

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 FAW emerges from the pupa and begins the egg-laying cycle after 3 to 4 days.

## Striga weed

*Striga* or 'witchweed' is a parasitic weed that affects cereal crops in many parts of Africa, reducing production by 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* (see 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 to and penetrating the roots of the host (e.g., maize) plant (see Figures 13 and 14).

Each *Striga* plant can produce as many 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* seed germinates, its roots grow towards and penetrate the host crop's roots, and start to draw nutrients from it. 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

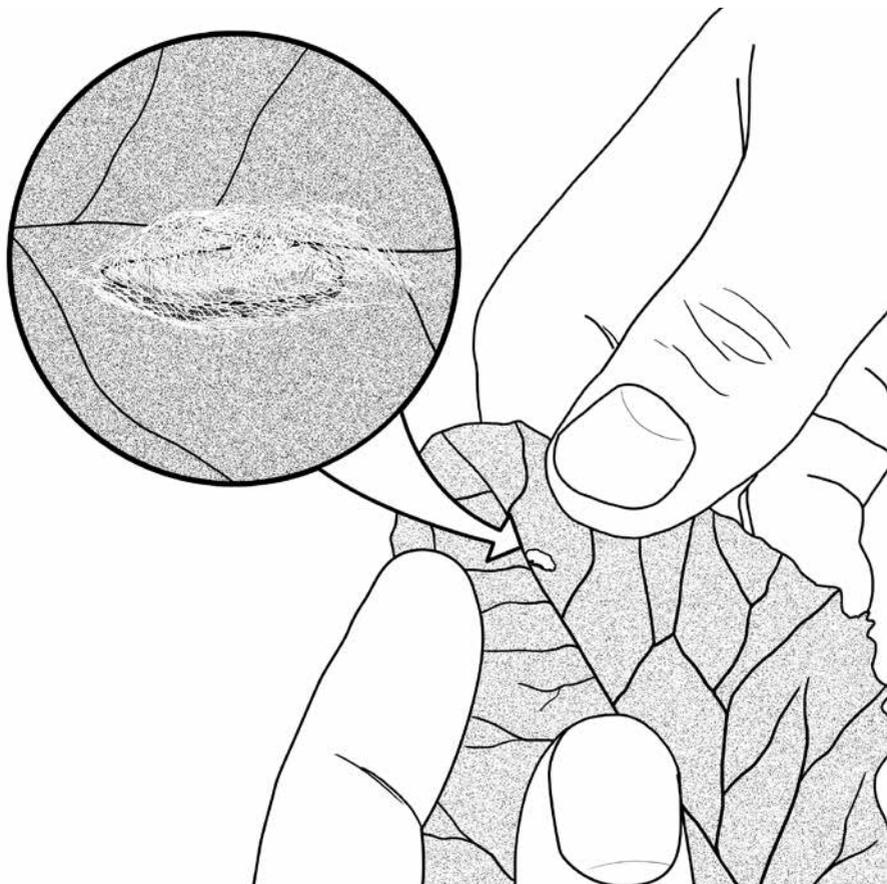


Figure 14. *Striga* flower

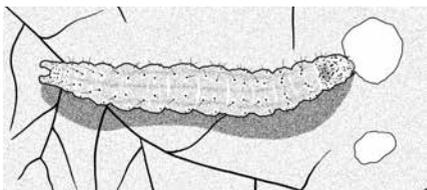
## Vegetable pests and diseases addressed by the Push–Pull Intensification with Vegetables

### Pests' broad descriptions

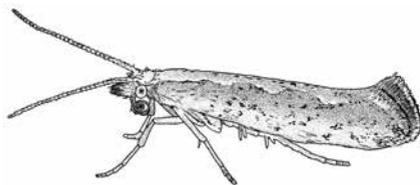
**Diamondback moth (DBM)**—damage is by the larva, a green caterpillar which feeds on the leaf tissue except the veins. Infestation causes significant losses if the pest is not controlled.



*Figure 15. Diamondback pupa on a plant leaf*

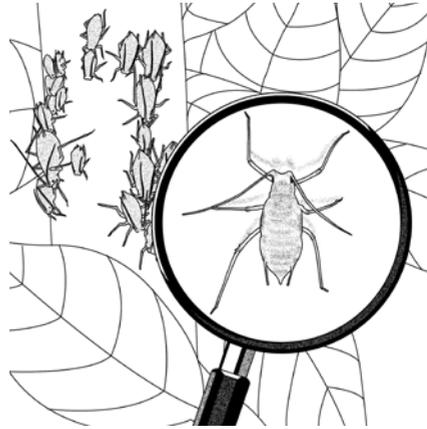


*Figure 16. Diamondback larva feeding on a plant leaf*



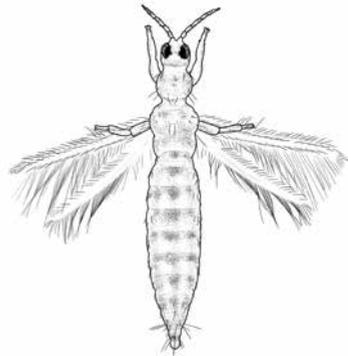
*Figure 17. Diamondback moth*

**Aphids**—tiny black and green soft-bodied sap-sucking insects usually found on the undersides of the leaves or on the stems. They suck sap from leaves, stems, petioles, flowers and pods. Heavy infestation causes death of young seedlings, stunted growth and delayed flowering, especially on older plants. They secrete honeydew as they feed which encourages the formation of sooty molds. They are vectors of viral diseases.



*Figure 18. Aphids on a plant*

**Thrips**—they cause major damages on flowers and flower buds. The attacked flower buds turn brown and die eventually while the flowers become distorted, discoloured and malformed, eventually falling off. Infected pods are also malformed.



*Figure 19. Thrips*

**Whiteflies**—these are small white insects which suck plant sap and excrete honeydew where molds grow, affecting a plant's growth and vigour. Their feeding causes crop damages and reduces the crop's vigour.



*Figure 20. Whiteflies*

***Tuta absoluta* (Tomato leafminer)**

– this is a devastating leafminer of the tomato crops. Leaf miners can cause yield reduction of up to 50%–100% on tomato crops. It reproduces rapidly with a life cycle of 24–38 days. Eggs are normally deposited on the underside of leaves. Caterpillar larvae are yellowish when newly hatched, but later turn yellow green with a black band behind the head, and the fully grown ones have a pinkish colour on their back. Larvae mine inside the leaf, stem or fruit, but exit to pupate. They prefer leaves and stems, but may occur on fruit crowns or inside the fruit itself. They attack only green fruit

Serious infection leads to the leaves dying off completely.

Mining to the plant causes malformation and damage to fruit paves way for fungal infections, leading to fruit rot before or after harvesting.

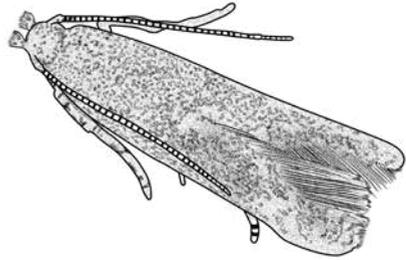


Figure 21. *Tuta absoluta* moth

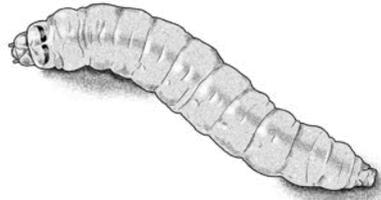


Figure 22. *Tuta absoluta* larva



Figure 23. *Tuta absoluta* larva

## Diseases' broad descriptions

**Black rot**—this is a bacterial disease whose symptoms are seen as V-shaped yellow to brown lesions which start forming from the leaf margin. In severe cases of infection, leaves drop and subsequently the crop dies.

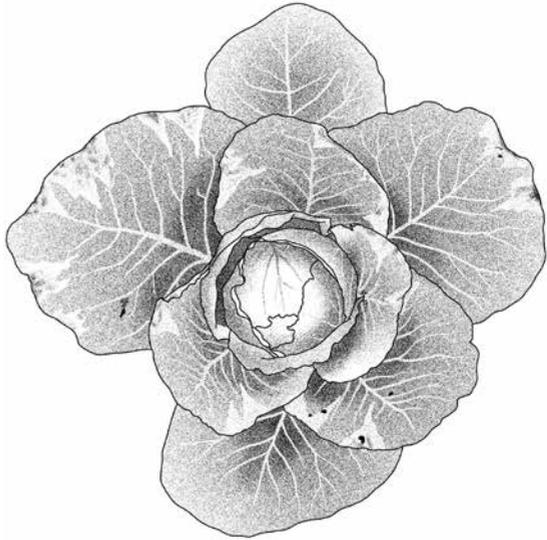


Figure 24. Black rot on a cabbage plant

**Late blight and early blight**—These are two diseases that affect tomato plants of the Solanaceae family. While the early blight is caused by the fungus *Alternaria* in relatively warmer temperatures resulting in decaying stems which emit a distinct foul rotting odour, whereas late blight is caused by the oomycete *Phytophthora* in cooler temperatures (wet conditions) resulting in a slimy, wet rot of the entire fruit.

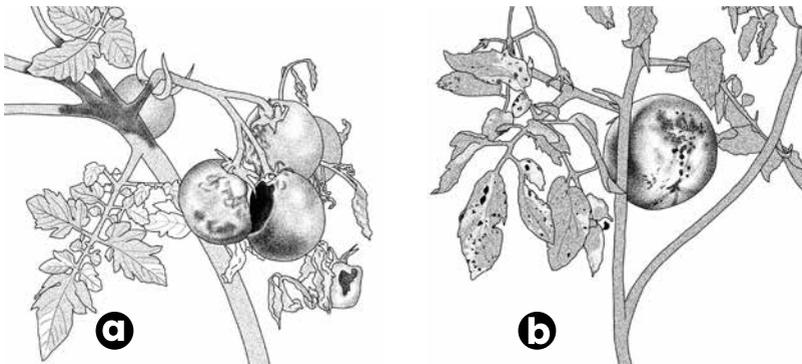


Figure 25. Late blight (a) and early blight (b)

# Control of Stemborers, Fall Armyworm, Vegetable pests and diseases, and *Striga* Weed using a Push–Pull Strategy

## What is push–pull?

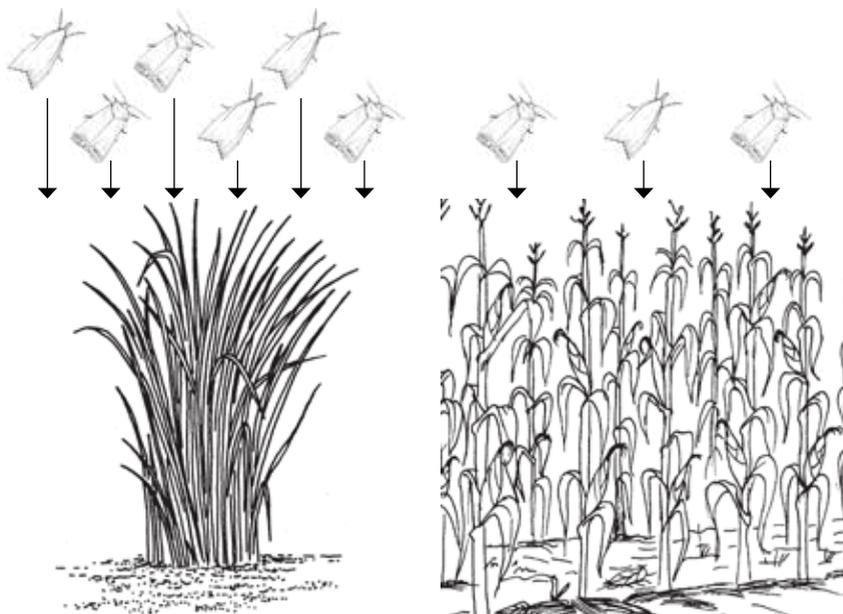
Together with her partners, *icip*e developed an effective, low-cost and environmentally friendly technology known as ‘push–pull’ to control stemborers and FAW and to suppress *Striga* weeds in maize and sorghum.

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 *Desmodium* (*Desmodium uncinatum*) and greenleaf *Desmodium* (*Desmodium intortum*)) 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.

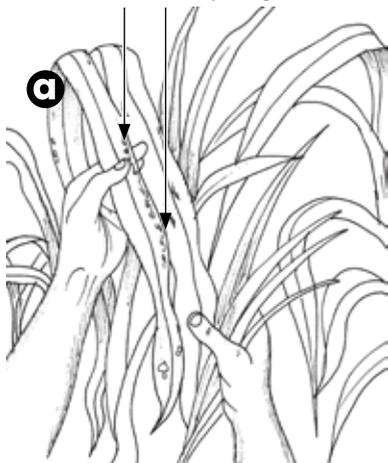
Maize and/or vegetables are planted between the rows of *Desmodium*, which produces a smell or odour that stemborer moths, FAW moths/larvae and some vegetable pests dislike. The smell ‘pushes’ away these moths and pests from the intercrops.

**Conventional push–pull:** This involves the use of clean Napier stunt disease-resistant Napier grass cultivars (Ouma II and South Africa cultivars are recommended). The Napier grass, planted around the maize crop as a trap plant, is more attractive to stemborer moths than maize and it ‘pulls’ the moths to lay their eggs on it (see Figure 26). However, Napier grass does not allow stemborer larvae to develop on it. When the eggs hatch and the small larvae bore into its stems, the plant produces a sticky glue-like substance which traps them, and most die (see Figure 27). Few stemborer larvae survive and the maize is saved because of the ‘push–pull’ strategy.

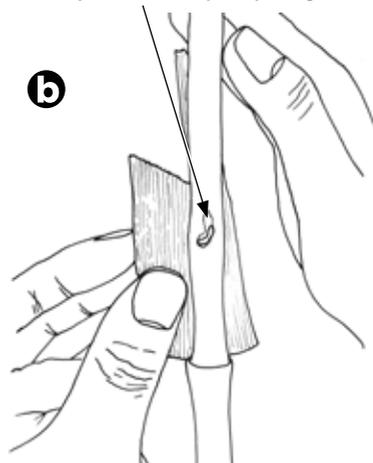


**Figure 26.** More stemborer moths are attracted to Napier grass than to maize. Napier, therefore, acts as the 'pull' in push-pull

*Feeding marks of stemborer larvae on Napier grass*



*Stemborer larvae killed by glue-like substance produced by Napier grass stem*



**Figure 27.** Napier leaves attacked by stemborer larvae (a). The larvae are killed by the sticky glue-like substance produced by Napier grass (b).

**Climate-smart push-pull:** Maize or sorghum, are planted between the rows of *Desmodium* legume; it makes the cereal crops unattractive to stemborers due to the chemicals *Desmodium* emits (which provides the 'push'). A drought-tolerant grass, *Brachiaria* spp., 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 (which provides the 'pull'), but allows only minimal larval survival.

**Push-pull vegetable intensification system:** This an improvisation for the sustainable technology. The vegetables are incorporated into either of the above mentioned push-pull strategies. The vegetable intercrop replaces some select cereal rows in the chosen arrangement (see Figure 28). The vegetable integration arrangements can vary but must be guarded by *Desmodium* rows on both sides. For example, the vegetable crop rows can alternate every 1 to 3 rows of maize all intercropped between *Desmodium* rows. The reverse arrangement of rows of the maize crop row can also alternate between 1 upto 3 rows of vegetables intercropped between *Desmodium* rows. The integration is ideal with vegetables whose physiological and agronomic requirements can be compatible with the push-pull technology. Farmers, therefore, need to consider factors such as light and water requirements. The plot still gets the standard benefits of the technology, whereby the chemical smell *Desmodium* emits (which provides the 'push') also serves to repel vegetable pests and protect the crop from some diseases as the repelled pests include vectors of diseases.

In addition, a ground cover of *Desmodium* (*Desmodium* spp., greenleaf or silverleaf), intercropped among the maize or sorghum, reduces *Striga* weed. Chemicals produced by the roots of *Desmodium* are responsible for suppressing the *Striga* weed. Therefore, *Striga* weed does not grow where *Desmodium* is growing. Being a legume, *Desmodium* also fixes nitrogen in the soil and thus enriches the soil.

The smell of *Desmodium* (which provides the 'push') also serves to repel both the FAW moths and larvae from the *Desmodium*-cereal intercrop.

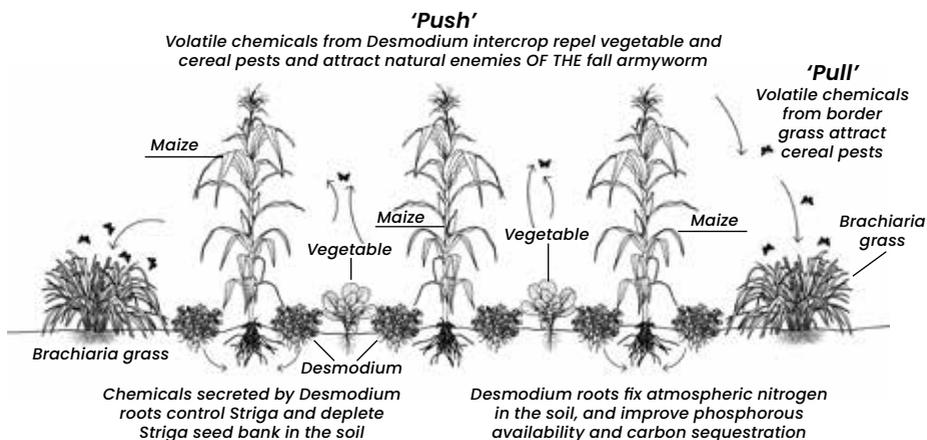


Figure 28. Profile of the Push–pull technology vegetable intensification



**Note:** If the prevailing cropping conditions are favourable, either of the cereals (maize or sorghum), and preferred vegetable integration arrangements can be planted in any of the push–pull options.

## Benefits of adopting a push–pull strategy

When you adopt the push–pull strategy, you will:

- Increase maize/sorghum yields by 25% to 30% in areas where there is an infestation of only stemborers. The yields can double where there is an infestation of both stemborers and *Striga* weed.
- Protect your crop from FAW invasion and damage.
- Increase the supply of livestock feed from harvesting Napier grass/*Brachiaria* and *Desmodium*.
- Increase the quality of animal feed by increasing protein from *Desmodium*.
- Enable nitrogen fixation into your farm's soil by *Desmodium* legume, saving on fertiliser costs.
- Protect soil from erosion, as *Desmodium* acts as a cover crop.

- Retain soil moisture, as *Desmodium* acts as mulch.
- Earn income from the sale of *Desmodium* seeds at an attractive price of USD 50 to USD 60 (KES 5,000 to KES 6,000) per kilogram.
- Earn income from the sale of fresh *Brachiaria*/Napier grass forage and *Desmodium*, and also from the sale of hay from these plants.
- Make more income from the sale of surplus milk from increased milk production due to the quality feeds of *Brachiaria*/Napier grass 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 Napier grass.

When you adopt the farmer Push–Pull Intensification with Vegetables, you will have:

- Healthier vegetables, which are free from crop pest and disease damage.
- Improved nutrition and food security, providing vegetable assurance in the family diet.
- Improved household income from the sale of surplus vegetables.
- Organic vegetable farming benefits from reduced toxic chemical use.
- Other push–pull benefits such as cover cropping, mulching and availability of fodder for livestock.
- Increased land and moisture use efficiency.



**Note:** 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.

# Push–Pull Intensification with Vegetables

Scientists at *icipe* have improved on the push–pull to enable the inclusion of vegetables in the technology arrangement commonly referred as Push–Pull Intensification with Vegetables. It involves the planting of maize and vegetable crops in alternate rows intercropped between *Desmodium* rows and surrounded by a border trap plant of *Brachiaria* or Napier grass (*the arrangement of the Desmodium intercrop rows can be varied*). Under this push–pull vegetable intensification system, the chosen vegetables depend on the farmer’s preference.

The chosen agronomic arrangement must be compatible with the push–pull system. For example, the vegetable crop can alternate every one to three rows of maize/sorghum, intercropped between *Desmodium* rows. The push–pull vegetable intensification has been successfully used on kales, cowpeas, African black nightshade, tomatoes and spring onions (green and bunching onions).

**Kale** (*Brassica oleracea* variant *acephala*): Locally known as *sukuma wiki* in Kenya, this a leafy herbaceous biennial or perennial plant in the family Brassicaceae grown as a leafy green vegetable. The kale plant is a non-headed, cabbage-like plant with curly or straight, loose blue-green or purple leaves. It is usually grown as an annual plant, harvested after one growing season and can reach a height of 1 m (3.3 ft). It is used as a green vegetable and is usually cooked before consumption.

The technology addresses the **pests**: diamondback moth (DBM), aphids, leafminer (*Tuta absoluta*) and cabbage looper, and **diseases**: early and late blight, and black rot Leafminers.

**The African black nightshade (*Solanum nigrum*):** This leafy indigenous vegetable is an erect, multi-branched herb growing 0.5 to 1.0 m high. It bears thin, oval, slightly purplish leaves growing up to 15 cm in length. The plant has numerous white flowers and usually bears purple to black round berries of about 0.75 cm in diameter containing many small, flattened, yellow seeds.

The technology addresses the **pests:** aphids and whiteflies, and **disease:** early blight. It also significantly reduces incidences of bacterial blight.



*Figure 29. The African black nightshade (*Solanum nigrum*)*

**Cowpea (*Vigna unguiculata*):** This is an annual leguminous crop which is grown for its seeds and leaves. The crop residues are used as livestock fodder. This is the easiest crop in the bean family to grow and is quite drought-tolerant. It is popular with farmers residing in low-rainfall areas



*Figure 30. Cowpea (*Vigna unguiculata*)*

The technology addresses the **pests**: thrips, flea beetle and *Maruca vitrata* (*legume pod borer*), and **disease**: leaf rust (a disease which causes small reddish brown pustules to develop on both sides of the leaf surfaces).

**Spring onions** (*Allium cepa*): Also known as green bunching and onions, they are very easy to grow both for subsistence and commercial purposes. Consumers like them because they can be used in a variety of recipes and in a variety of ways such as cooking and, seasoning in soups and in salads hence their other name, salad onions. The technology addresses the **pest**: thrips.

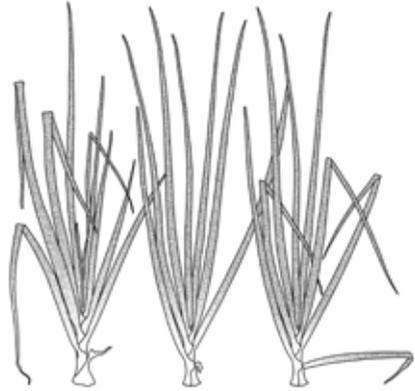


Figure 31. Spring onions (*Allium cepa*)

**Tomato** (*Lycopersicon esculentum*): This is one of the essential vegetables grown. Its fruits are used fresh, cooked or processed. Tomato does well in low–medium rainfall, and may need irrigation during long periods of dry spells. Disease incidences increase under wet conditions and affect profitable production.

The technology addresses the **pests**: Leafminer (*Tuta absoluta*), aphids, mites, early and late blight.



Figure 32. Tomato (*Lycopersicon esculentum*)

# How to Establish a Vegetable Integrated 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 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.
- Separately, a vegetable nursery should be established (if it is a requirement for the variety of vegetable chosen) and managed well a month before transplanting to the Vegetable Integrated Push–Pull Technology (VI-PPT) site. This will ensure the vegetable is available during planting time, especially if the seeds need nursery establishment.
- Measure out your Vegetable Integrated push–pull plot to a maximum size of 50 m by 50 m (see Figure 33).
- If you wish to layout a Vegetable Integrated push–pull plot on land that is larger than 50 m by 50 m, then divide it into plots measuring a maximum size of 50 m by 50 m.
- If your land is less than 50 m by 50 m, the VI-PPT will still work; however, do not plant push–pull in plots less than 15 m by 15 m, as the Napier grass will have a shading effect on the maize/sorghum crop.

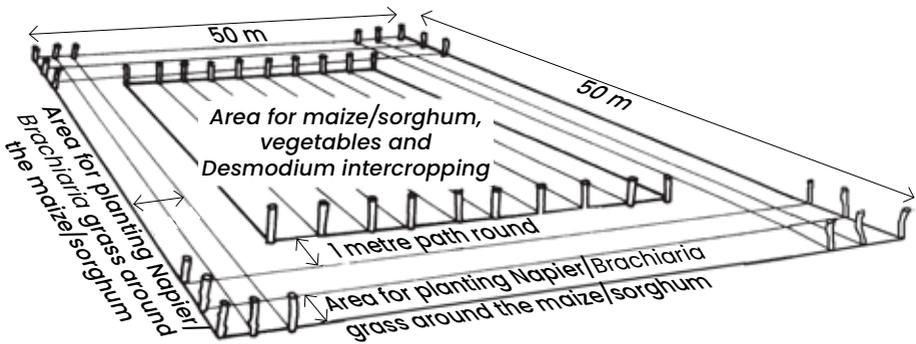


Figure 33. Layout of a push-pull plot

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

## Step 2. Planting material

Ensure that you have all the needed viable planting material:

- Maize/Sorghum seeds
- *Desmodium* seeds
- Certified vegetable seeds or seedlings (for the chosen vegetable for integration), for example, kales, cowpeas, African black nightshade, tomatoes, and green and bunching onions. Use clean, disease-free, healthy seedlings if not using vegetable seeds. Certified viable vegetable seeds or seedlings from own nursery are recommended.
- Napier grass root splits or cane cuttings with at least three nodes (see Figure 34). Use of clean Napier stunt disease-resistant cultivars (like Ouma II and South Africa cultivars) is recommended (see Figures 35 and 36 for identification of healthy and diseased Napier grass plants).
- *Brachiaria* (Mulato) seeds or splits if using the climate-smart option
- Triple superphosphate (TSP) or single superphosphate (SSP) fertiliser and/or farmyard manure (some farmers use both).

## Sources of planting material

- **Napier grass:** Agricultural Research Centres, Ministry of Agriculture, Animal Industry and Fisheries or other farmers.
- ***Brachiaria* (Mulato):** Stockists, via *icipe* directions
- ***Desmodium*:** Western Seed Company Ltd, Kitale, Kenya
- **Cereal:** Seed companies, and appointed stockists
- **Vegetable:** Seed companies, and vegetable nursery farmers, (ensure clean and healthy seedlings (see Figures 37 and 38 for identification of clean and healthy kale and tomato seedlings, respectively) if buying seedlings from other vegetable nursery farmers)

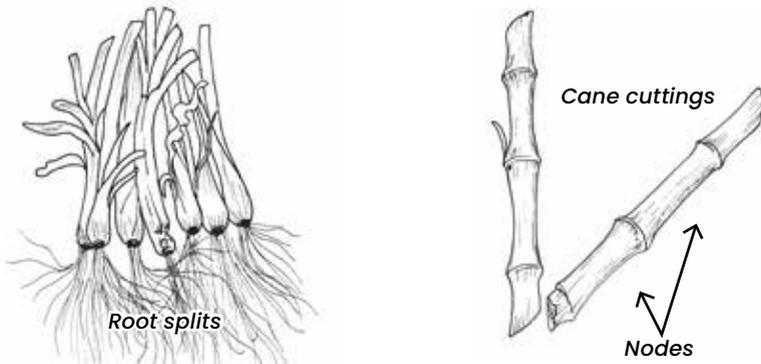


Figure 34. Clean Napier grass root splits and cane cuttings for planting



Figure 35. Healthy Napier grass



Figure 36. Diseased Napier grass



Figure 37. Clean kale seedling



Figure 38. Clean tomato seedling

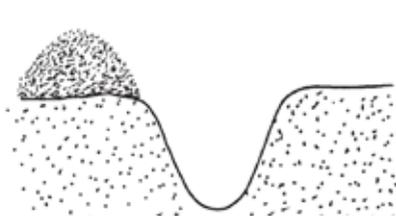


**Note:** Diseased Napier grass plants are yellowish, stunted plants with short internodes. The leaves are narrow (see Figure 36). The disease is carried by a microorganism (phytoplasma) and is transmitted by an insect vector known as *Maestas banda* (Kramer) on field sites.

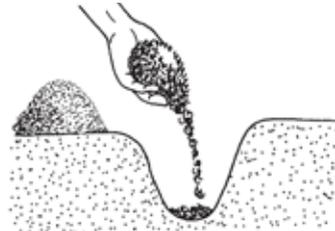
## Step 3. Planting the Vegetable Integrated push–pull crops

### Planting Napier grass

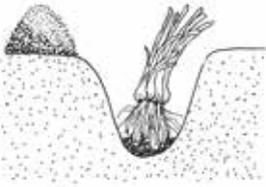
- Plant clean and healthy Napier grass cultivars (preferably Napier stunt disease-resistant cultivars, like Ouma II or South Africa varieties) in a border around the maize/sorghum plot as shown in Figures 33 and 40.
- Plant at least three rows of Napier/*Brachiaria* grass all around the maize/sorghum field. The spacing should be 75 cm between rows and 50 cm between Napier grass plants within a row (see Figure 39).



Hole ready for planting



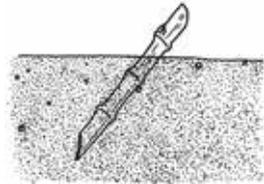
Put in one teaspoonful of TSP fertiliser or two handfuls of farmyard manure



Planting splits



Place cane in the hole



Cover cane with soil after planting

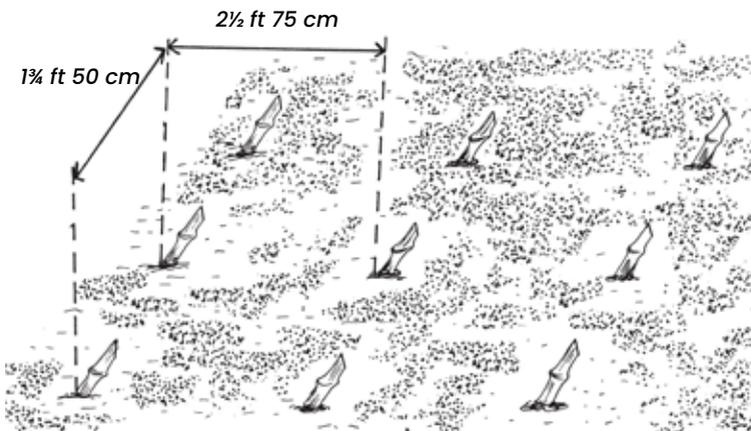


Figure 39. Newly planted Napier grass field

- Apply one teaspoonful of TSP fertiliser or two handfuls of well decomposed farmyard manure in each hole before planting the Napier grass root splits or cane cuttings (see Figure 39).
- Place a three-node cane cutting into the ground, ensuring that two of the nodes are covered, or place the Napier grass root splits into the planting holes and cover with soil (see Figure 39).

- Plant Napier grass before the rains so that it has a start on the maize/sorghum. The stemborer moths will like the larger Napier grass for laying their eggs even more than the maize.

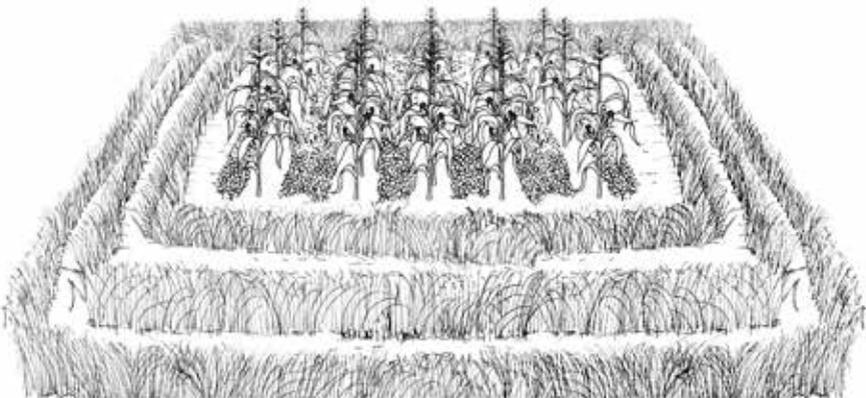
## Planting maize

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

- Ensure that the 1<sup>st</sup> 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 TSP or two teaspoonfuls of SSP per hole.
- Plant two maize seeds per hole and then thin to one plant per hill after the first weeding.



**Note:** *Napier grass rows should be planted so that they alternate with maize rows (Napier grass should not be planted in the same row with maize), so that ploughing of the field in the next season will be easy (see Figure 40).*



*Figure 40. Diagram of maize and Napier grass in different rows*

## Planting vegetable intercrop

Plant your vegetable in the established push–pull technology field, ideally during the planting of the other companion crops or almost immediately after maize emergence. Some seasoned farmers plant all the crops at the same time during first establishment.

- Ensure that the vegetable row(s) are separated from maize row(s) by a *Desmodium* intercrop.
- The vegetable crop should alternate every one to three rows of maize, intercropped between *Desmodium* rows or the reverse arrangement of the maize crop row can alternate between one to three rows of vegetables intercropped between *Desmodium*. This is according to individual farmer's preferred arrangement. Viable arrangements are many and optional, for example, two rows of maize and two rows vegetables intercropped with *Desmodium*, etc.
- The spacing for vegetables is 75 cm between rows and the spacing between hills in a row is determined by the specific vegetable recommendations. Some of the farmers really intensify by planting beans or cowpeas between the maize crop in the same row. Kales are included but in a separate row.
- Apply a handful of well-made farmyard manure or one teaspoonful of diammonium phosphate (DAP) fertiliser per vegetable planting hole.

## Planting *Brachiaria* grass

*Brachiaria* cv. Mulato II or Xaraés are the best varieties 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 hole, about 1 cm, at each peg on the border of the marked plot (see Figure 33).
- Step 2:** Apply one teaspoonful of DAP or NPK (contains nitrogen, phosphorus and potassium) fertiliser or a handful of well-decomposed farmyard manure in each hole and mix it well with the soil.

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

**Step 4:** Cover lightly with soil ensuring that the planted seeds are sparsely, but well-covered.

**Step 5:** Repeat steps 1 to 4 for the rest of the rows, ensuring spacing of 75 cm between rows 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 around the maize/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/maize intercrop are established in the subsequent season. This helps to control stemborers and FAW 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 layout field.*

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

## **How to intercrop *Desmodium***

*Desmodium should be the last crop to be planted if establishing everything at the same time in a new field/plot.*

- You will need 1 kg of *Desmodium* seeds for 1 acre (0.4 ha) of land.

- Maize / sorghum / vegetable is planted first, followed by *Desmodium*. *Desmodium* is drilled in between the maize / sorghum / vegetable rows so that the distance between the maize / sorghum / vegetable rows and *Desmodium* rows is 75 cm.
- Using a strong pointed stick, make a furrow 1–2 cm deep in the middle of the space between the rows of maize / sorghum / vegetable (see Figure 41).

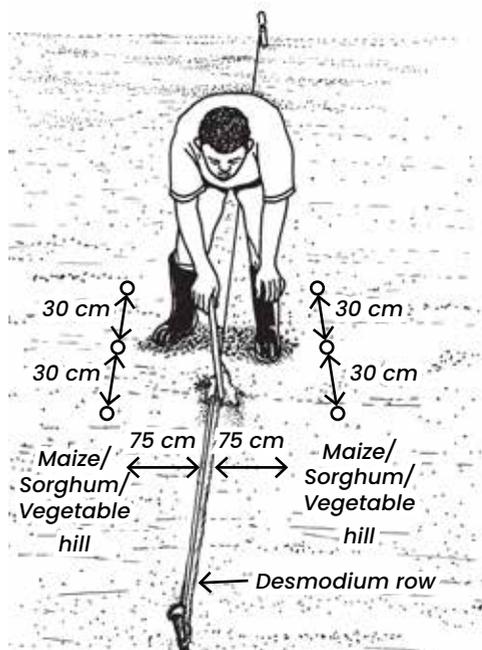
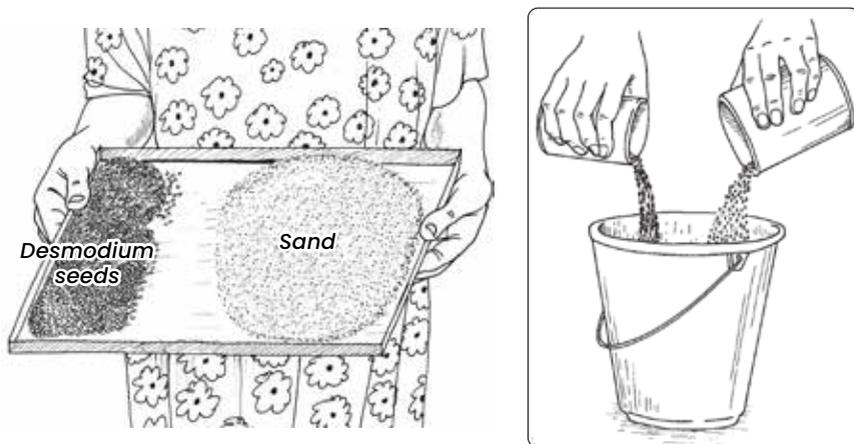
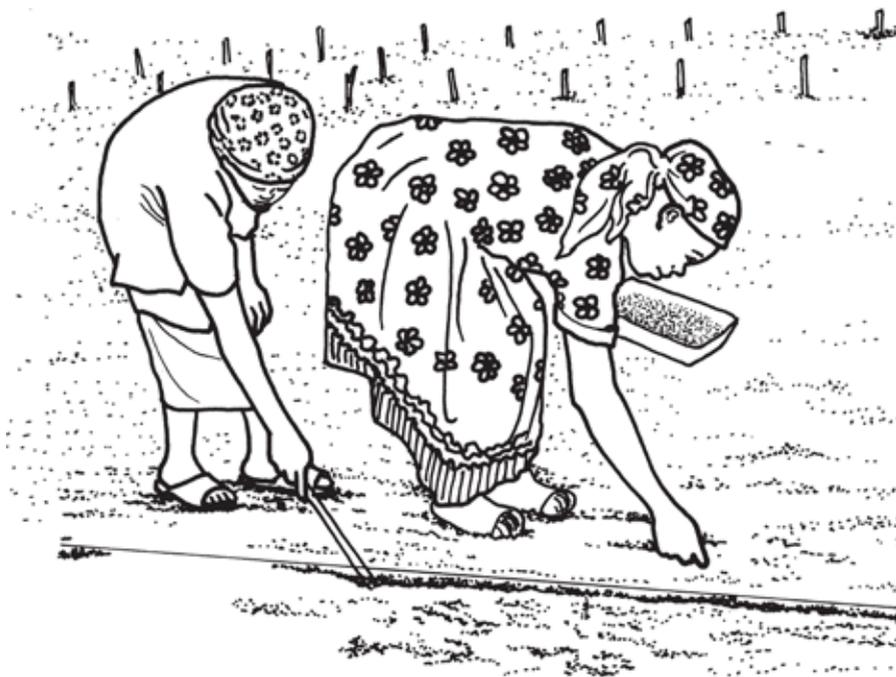


Figure 41. A farmer making rows for drilling *Desmodium* seeds

- Mix the *Desmodium* with superphosphate fertiliser (about one handful of seeds and two handfuls of fertiliser). If you cannot afford fertiliser, then mix the seeds with dry soil or fine sand (see Figure 42).
- Sow the seed–sand or seed–fertiliser mixture into the furrows you have made and cover lightly with a small amount of soil (see Figure 43).
- A single row of *Desmodium* should also be drilled on the outer rows of maize/sorghum at an interrow spacing of 37.5 cm between the outermost maize/sorghum row and the outer *Desmodium* row, hence the very 1<sup>st</sup> row and the last row should be of *Desmodium* crop.



*Figure 42. A farmer mixing Desmodium seeds with dry soil or sand for drilling. Use the ratio of 1 part seeds to 3 parts sand*



*Figure 43. Farmers drilling and covering the Desmodium seeds*

- Plant *Desmodium* with the rains for maximum germination.
- In areas where *Striga* weed is NOT a problem, you can plant *Desmodium* after every three or five rows of maize/sorghum and use the other rows to plant beans. Stemborers will still keep away from the maize/sorghum.
- In case *Desmodium* seeds are unavailable, 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 of Vegetable Integrated Push-Pull plot

### 1<sup>st</sup> weeding and crop management

- Early weeding is important for the successful establishment of a Vegetable Integrated push-pull plot.
- The first weeding should be carried out when the maize/sorghum plants are 3 weeks old.
- The vegetable rows should be weeded and kept clean. *Desmodium* vines besides the vegetables should be trimmed to allow the crop vigour.
- Do not allow the *Desmodium* vines to canopy the young vegetable bases/stems as they will pose competition and can also smother the plants.
- It is important to know the difference between *Desmodium* and weeds. If in doubt, consult the nearest extension staff. Figures 44 and 45 show young *Desmodium* plants.
- Take care when weeding the drilled *Desmodium* line. Handpicking of weeds in the line is recommended at this stage (see Figure 46).
- Thin maize/sorghum to one plant per hill.

- In *Striga*-infested areas, apply nitrogen fertiliser (calcium ammonium nitrate–CAN) to the maize/sorghum at the rate of one teaspoonful per plant after the first weeding.
- Napier grass/*Brachiaria* rows should also be weeded. Figure 47 shows a push–pull plot after the first weeding.



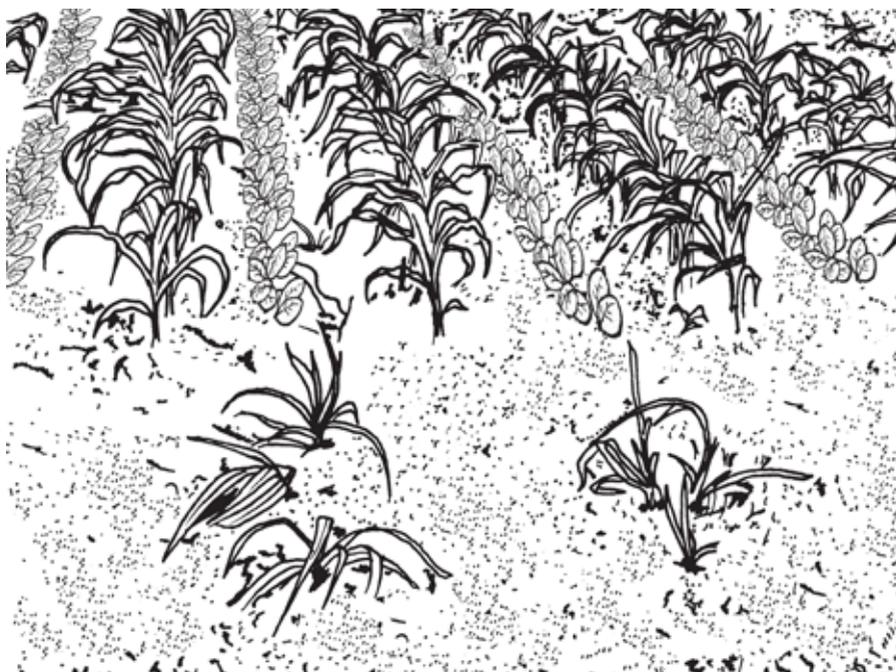
*Figure 44. One-week-old silverleaf Desmodium (left) and greenleaf Desmodium (right) plants*



*Figure 45. Three-weeks-old silverleaf Desmodium (left) and greenleaf Desmodium (right) plants*



*Figure 46. Hand weeding Desmodium rows and weeding the space between maize/sorghum/vegetables and Desmodium rows with a hoe*



*Figure 47. A push-pull plot after the first weeding*

## 2<sup>nd</sup> weeding

- The second weeding should be done when the maize/sorghum plants are 5 weeks old (Figure 48 shows a push-pull plot after the second weeding). The *Desmodium* vines growth can be allowed to canopy only at the bases of the maize/sorghum rows, NOT the vegetable rows, after this necessary weeding.
- Take care to distinguish between *Desmodium* and weeds (see Figure 49 for identification of *Desmodium* plants).
- Napier/*Brachiaria* grass rows should also be weeded again.
- The vegetables should be weeded again, and weeds kept at the very minimal (*Desmodium* should not be allowed to smother the vegetables). Do not allow the *Desmodium* vines to canopy the vegetable bases/stems; maintain a clear base for vegetable rows. The chopped vines can be used as fodder.
- Top-dress the maize/sorghum, vegetable and Napier/*Brachiaria* grass with CAN fertiliser at the rate of one teaspoonful per plant.



Figure 48. Push-pull plot after the second weeding



*Figure 49. Five-weeks-old silverleaf Desmodium (left) and greenleaf Desmodium (right) plants*

## Step 5. Harvesting of vegetables

The harvesting of vegetables should begin upon the crops achieving physiological maturity. The continuous harvesting process is guided by the specific vegetable recommendations. Most vegetable transplants are ready for harvest after one month.

- **Kale:** The vegetable is ready for harvest when the leaves are at least the size of your open hand. Pick no more than one-third of the plant leaves at a time. Maintain the terminal bud (at the top centre of the plant), it will help to maintain the plant's productivity. Procedurally, all varieties of kale are harvested in the same way. To harvest mature leaves, hold the stem of a mature outer leaf at mid base from the main stalk and break downwards and out. Repeat this process with each mature leaf. Avoid breaking from the central main stalk. (This will shorten the productivity of the plant.)
- **Black nightshade:** Harvesting should be done weekly or fortnightly. The cutting of stems at 10–15 cm above the ground will allow ratooning/new shoots to develop hence boosting production. Harvesting leaves is best done in the morning after the dew has evaporated from the leaves and before the sun becomes too hot, or late in the cool evening.

- **Tomato:** Harvesting should be done about 50 days onwards after transplanting as determined by the planted variety. The stage of harvesting is determined by the market and intended use. It is best to harvest early in the morning, while temperatures are cool. The actual harvesting process is picking by hand, by twisting and turning until the fruits snap off the vine, Harvesting the fruit with fruit stem pedicel keeps it fresh for a longer period.
- **Cowpea harvesting:** The leaves are more popular as a vegetable than the grain. Leaves can be harvested from three to four weeks after planting. Harvests should be young and soft as these are the ones preferred in the market. Cowpeas can be uprooted as whole plants and sold in the market as such. The end consumer will remove the leaves from the plants before cooking. Another option is harvesting a few leaves from the plant. This results in the cowpea plant developing more leaves. Cowpeas will yield a lot of leaves with shorter harvesting frequency of the leaves. This means more leaves, but the plant will not develop less grain yields.
- **Spring onion harvesting:** The onions are harvested when the leaves are succulent and when the stems reach a diameter of 0.25 inches to 0.5 inches. Harvesting is done by uprooting the entire plant, cleaning, and tying them in bunches, ready to go to the market. To continue the propagation, the farmers select, separate and replant one split immediately in uprooted hole when harvesting.

## **Step 6. Management and harvesting of the grasses**

### **Step 6a. Management of Napier grass**

- You can start harvesting Napier grass when it is 3 months old or 1–1.5 m high after planting (see Figure 50).
- Start with the inner row nearest to the maize/sorghum row and harvest this row all around the field. Leave a stem height of 4 inches (10 cm) from the ground at harvesting to encourage it to regrow quickly (see Figures 50 and 51).
- 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 to reduce wastage while feeding it to the livestock.



*Figure 50. Farmers start harvesting Napier grass when it is 3 months old or 1–1.5 m high after planting*



*Figure 51. 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 1–1.5 m high again. 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 6b. Management of *Brachiaria* grass**

- You can start harvesting *Brachiaria* grass when it is 5 months old after planting and just before flowering. When harvesting, cut at 2–3 cm above the ground. Harvest the next crop after every 3–12 weeks, good conditions prevailing.
- Start with the inner row nearest to the maize/sorghum row and harvest this row all around the field. Leave a stem height of 1.5 inches (2–3 cm) from the ground at harvesting to encourage it to regrow quickly. The third row should be harvested only when the inner row is between 0.5–1.5 m high again. 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 the grass 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 grass.

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. It can persist up to 20 years with good management.

## Step 7. Harvesting the cereal crop in a Vegetable Integrated

### Step 7a. 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.
- Remove the cereal stovers, dig and plant more viable vegetables if conditions allow or dry season-tolerant vegetables like cowpeas in the rows from which maize/sorghum crops have been harvested.

### Step 7b. Harvesting of sorghum

- Harvest the sorghum once it attains maturity; once kernel moisture reaches 25%. 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 harvesting.
- Remove the cereal stovers, dig and plant more viable vegetables if conditions allow or dry season-tolerant vegetables like cowpeas in the rows from which harvested maize/sorghum rows
- Sorghum stover (stalks) left over after crop harvest can be removed, stored well and used as livestock feed, particularly during the dry season. Always store the sorghum stover in a dry place to minimise spoilage.

## Step 8. Management and harvesting of *Desmodium*

### Step 8a. Management of *Desmodium* in a Vegetable Integrated Push-Pull plot

After harvesting your maize/sorghum crop and removing the cereal stover, the vegetable crop will still be standing and will need to be managed for continued production. Thus, management of *Desmodium* is required. *Desmodium* can either be harvested as

forage for livestock (see Figure 52) or left to produce seed before it is harvested for forage (see Figure 53). When intensifying land use, additional viable vegetables can be established in the rows from which the maize/sorghum crops have been harvested. The proper preparations need to be done.



*Figure 52. Harvesting Desmodium forage after harvesting maize/sorghum from the field*



*Figure 53. Flowering/podding Desmodium after harvesting maize/sorghum*

## Step 8b. 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 regrowth.
- Chop the harvested *Desmodium* and mix it with Napier grass/*Brachiaria* to reduce wastage when feeding it to livestock.
- When forage is in short supply, particularly during the dry season, chop and mix the *Desmodium*, Napier grass/*Brachiaria* and maize/sorghum stover before feeding them to your livestock.



**Caution:** *Never, never bring your livestock to graze in a push-pull field as they will destroy the *Desmodium*.*

## Step 8c. 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 and 800 kg of green forage from a one-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 8d. Harvesting and processing *Desmodium* seed

### When and how to harvest the seed:

- Harvest the seed weekly once the pods have turned brown. Hand-strip (see Figure 54) the ripe pods and place them in a tin.
- Sun-dry (see Figure 55) and then thresh the dried *Desmodium* pods on a stone using an old slipper or the sole of a rubber shoe (see Figure 56).

- Winnow to get clean seed (see Figure 57).
- Store the seeds in a dry, clean tin or airtight container (see Figure 58).

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



Figure 54. Harvesting of ripe *Desmodium* pods

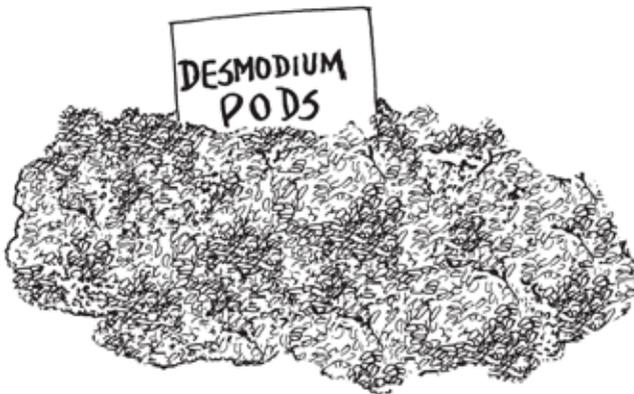


Figure 55. Sun drying of *Desmodium* seeds



*Figure 56. Threshing of Desmodium seeds on a stone using an old slipper*



*Figure 57. Winnowing Desmodium seeds*



Figure 58. Store Desmodium seeds in a clean tin or airtight container



**Note:** In areas where moles and rats (rodents) are a problem, after the first season's harvesting, cut all the Desmodium and Napier grass/Brachiaria after harvesting the maize and feed them to your livestock.

# Planting Vegetable Integrated Push–Pull during the Second and Subsequent Seasons

## Step 1. Land preparation

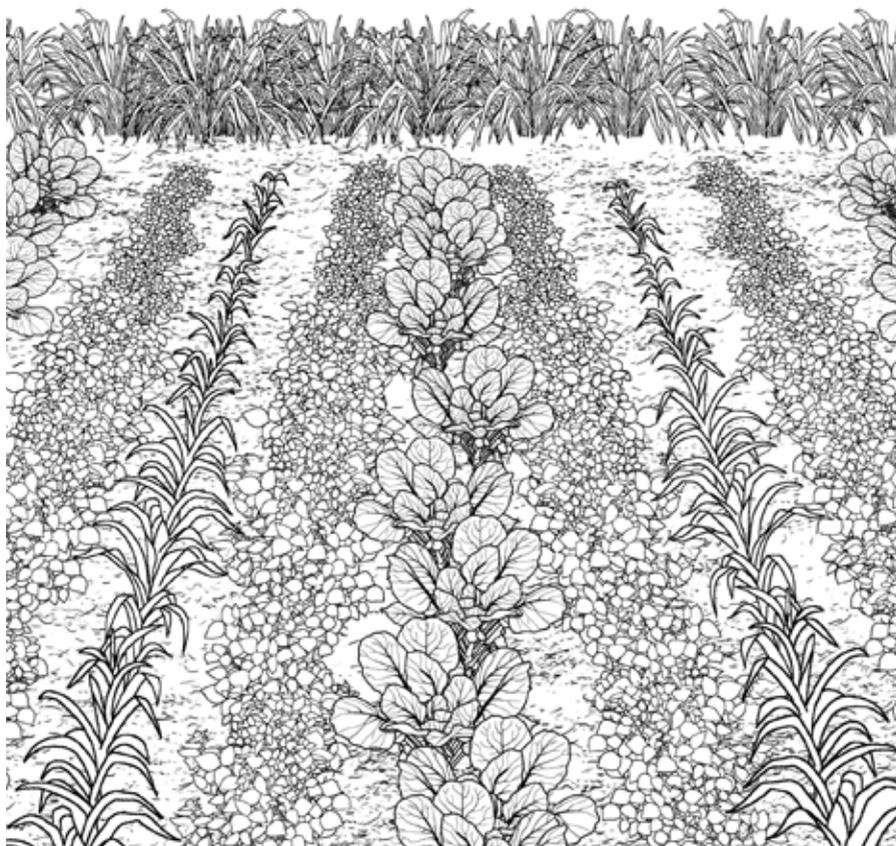
- Continue cutting and utilising Napier grass, starting with the inner row as before and weeding the cut Napier lines.
- If climate-smart option: continue cutting and utilising *Brachiaria*/Mulato grass, starting with the inner row as before and weeding the cut *Brachiaria*/Mulato lines.
- Ensure the existing vegetable rows are kept well weeded and *Desmodium* vines are kept from the base of the vegetable crop.
- Apply farmyard manure or CAN fertiliser after cutting and weeding.
- Cut back the *Desmodium* and feed to the livestock. Clear the land of maize/sorghum stover and feed to the livestock.
- Before planting maize/sorghum/vegetables, dig or plough between the rows of *Desmodium* (see Figure 59) Minimum or zero tillage option is outlined on Page Page 51 to Page 53. Care should be taken not to disturb/uproot the *Desmodium* lines as *Desmodium* is a perennial crop.



*Figure 59. Push-pull plot ready for planting maize/  
sorghum/vegetable during the second season*

## **Step 2. Planting the second crop of Vegetable Integrated push-pull**

- Plant maize between *Desmodium* rows as per the preferred vegetable/cereal arrangements at a spacing of 75 cm by 30 cm (see Figure 60).
- Plant vegetable seeds/seedlings in chosen rows between the *Desmodium* as per the preferred arrangement.
- Apply TSP or DAP fertiliser as top dressing on the maize/vegetables at the rate of one teaspoonful per hill.



*Figure 60. Newly planted Vegetable Integrated push-pull plot during the second season*

## **Planting the 2<sup>nd</sup> season Vegetable Integrated push-pull**

- Step 1:** Cut back the greenleaf *Desmodium* leaving a six-centimetre stubble above the ground to encourage regrowth. Keep and feed the *Desmodium* to the livestock.
- Step 2:** Hand-weed the *Desmodium*.
- Step 3:** Dig or plough well between the rows of greenleaf *Desmodium*. (Optional choice: one can practise zero or minimal tillage—see Page 51 to Page 53.)

**Step 4:** Weed the *Brachiaria* grass.

**Step 5:** Plant sorghum/Maize/vegetable between greenleaf *Desmodium* rows at a spacing of 30 cm. Apply one teaspoonful or soda bottle top of TSP or DAP fertiliser per hole. 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.)

**Step 6:** Plant vegetables between greenleaf *Desmodium* rows at recommended spacing. Apply one teaspoonful or soda bottle top of TSP or DAP fertiliser per hole. You may also use a handful of well-decomposed manure per hole. Plant your cereal in rows between the *Desmodium* lines, within the same vegetable/*Desmodium* intercrop field surrounded by *Brachiaria*. Weeding should be done earlier and when necessary, particularly along the vegetable rows. Weed the field at least 3 and 6 weeks after planting the cereals.

**Step 7:** After harvesting cereals, fast-maturing vegetables like cowpeas, which require little rainfall, can be intercropped in the cereal rows between the *Desmodium* during the dry season if viable.

# Planting the 2<sup>nd</sup> season (zero or minimum tillage)

If one opts to practise 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 two seasons.

**Step 1:** Cutback the greenleaf *Desmodium* leaving a six-centimetre stubble above the ground to encourage regrowth. Keep and feed the *Desmodium* to the livestock.

**Step 2a: If practising zero tillage,** plant the cereal seeds along the initial lines of the previous season's cereal crops 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 2b: If practising minimum tillage,** plant the cereal seeds and/or vegetables only along the initial cereal lines of the previous season. Dig or plough well between the rows of greenleaf *Desmodium*, along the initial lines of the previous season's cereal crops. Plant the cereal seeds within this dug area.



**Note:** For both options, in the subsequent seasons, the *Desmodium* should be allowed to overgrow only in between the maize or sorghum crops after the second weeding. It should be trimmed between the rows of vegetables.

## Step 3. Weeding of vegetable integrated push-pull technology crops

### 1<sup>st</sup> weeding

- Weed the maize/sorghum/vegetable crop when it is 3 weeks old. Napier/*Brachiaria* grass and *Desmodium* should also be weeded at this time. Note that weeding

timeliness can be varied and it can be done earlier if the plot has a lot of weeds before 1<sup>st</sup>, 2<sup>nd</sup> or after the specified periods of weeding.

- *Desmodium* at this stage can smother maize/sorghum /vegetables if not trimmed. It is recommended that you trim it when the maize/sorghum is 3 weeks old.
- Thin maize/sorghum to one plant per hill.
- In *Striga*-infested areas, top-dress the maize/sorghum/vegetables with CAN fertiliser at the rate of one teaspoonful per hill.

## 2<sup>nd</sup> weeding

- The second weeding should be done when the maize/sorghum/vegetable crop is 5–6 weeks old.
- *Desmodium* should be trimmed again at this stage. Always trim the *Desmodium* vines along the vegetable rows and use as fodder for livestock.
- Top-dress the maize/sorghum 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 one-metre high row of Napier grass surrounding the tender maize/sorghum and be sure to give time for the previously cut row to grow before cutting the next.



**Caution:** *Leaving maize/sorghum without a Napier grass border or row of one-metre high will encourage stemborers to attack your maize/sorghum.*

## 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 5 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 one-metre high row of *Brachiaria*/Mulato II grass surrounding the tender maize/sorghum 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 one-metre high will encourage stemborers to attack your maize/sorghum.*

## Step 5. Management of *Desmodium*

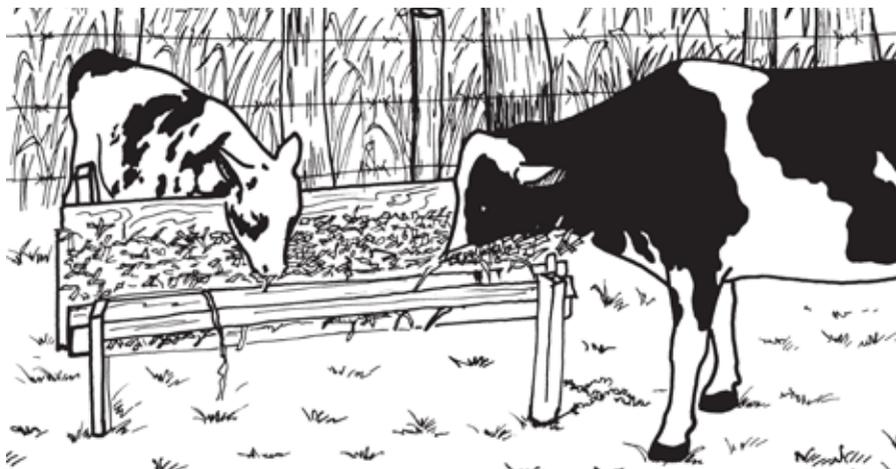
- After the second trimming (5–6 weeks after planting maize/sorghum), leave the *Desmodium* to grow until the maize/sorghum is harvested.
- After the second trimming (5–6 weeks after planting maize/sorghum), keep on trimming the *Desmodium* vines growing towards the bases of the vegetable rows.
- After the cereal harvest, the stovers can be removed and vegetables planted in the same rows. During management, make sure the *Desmodium* does not smother the vegetables.
- The rest of the management practices are similar to those for the first season.
- If you follow a good management regime for Napier/*Brachiaria* grass and *Desmodium*, you could benefit from your push–pull plot intercrops for five or more years.

# Feeding Your Livestock

- Chop the harvested Napier/*Brachiaria* grass and *Desmodium* to reduce wastage while feeding it to your livestock (see Figure 61).
- During the dry season, chop the maize/sorghum 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 a higher milk production of your cows and goats (see Figures 61, 62 and 63).
- Two acres (0.8 ha) of a well-managed push-pull plot can give enough Napier grass and *Desmodium* to feed one dairy cow for a year, if supplemented with maize/sorghum stover or other feeds during the dry season.
- Always remember to give your livestock the recommended mineral supplements.



**Figure 61. Chopping Napier grass and *Desmodium* forage for feeding livestock**



*Figure 62. Cows feeding on chopped Napier grass mixed with Desmodium forage. Mixing the small-leaved Desmodium with Napier grass reduces wastage of the former*



*Figure 63. Dairy goats eating chopped Napier grass mixed with Desmodium in a trough*

# Things Not To Do

1. Do not trim *Desmodium* during the first season (unless it is swamping or canopying the vegetables).
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. Do not allow the *Desmodium* to spread into the vegetable rows, if vegetables are cropped in between maize hills, only allow after the vegetables have all been removed. This reduces the competition between the two crops.
7. Do not allow the *Desmodium* to spread into the vegetable rows throughout the season. Ensure that the rows are continuous and parallel to the vegetable rows.
8. Only intercrop vegetables whose growth behaviour is compatible with the push-pull strategy arrangement. To date, the following are viable vegetables which have been successfully integrated: cabbages – “Kabeji”, kales/collard greens – “sukuma wiki”, black nightshade – “osuga/suchaa”, spring onions or green bunching onions – “kitungu majani”, cowpeas – “kunde” and tomato – “nyanya”.
9. Do not cut the *Desmodium* rows during the fallow period (in between the cereal crop, maize/sorghum, growing) by cropping vegetables to maximize on the push-pull field. This will ensure pests control. Manage by trimming the *Desmodium* rows to avoid them covering the base of the vegetables.
10. Never cut all the three rows of Napier/*Brachiaria* at once. This is to avoid ‘windowing’. Always cut one row all around your maize/sorghum at a time.
11. Do not let Napier/*Brachiaria* grass overgrow because it will seed and be ineffective in controlling stemborers and FAW, and will become hard and coarse for cattle to feed on.
12. Do not plough under the *Desmodium* rows. Replanting the *Desmodium* is expensive and is unnecessary, as it can grow for up to five years or more.

# Frequently Asked Questions

The following questions are sampled from the most commonly asked by interested farmers.

Additional queries can be addressed to the contact information listed within the Primer.

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

*Answer.* A vegetable integrated push-pull plot should measure 50 m by 50 m (maximum) or can be used on a farm of any size provided the fields are demarcated into 50 m by 50 m sections using border row pull crops of either Napier or Brachiaria grass. However, a push-pull plot should not be less than 15 m by 15 m.

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

*Answer.* Not less than 15 m (50 ft).

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

*Answer.* If well managed, you can benefit from your push-pull plot intercrops for five or more years. The oldest continuous push-pull plot was first established in 1997.

**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 seeds 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/cowpeas into your push-pull plot; these can be interplanted in between

*maize/sorghum crop in the same line or either of the crops can be interplanted in between maize/sorghum crop in the same line, with the other crop intercropped on alternate rows with maize/sorghum crop and Desmodium. 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. How long does it take for *Desmodium* to effectively push away all the vegetable pests from the push-pull field?**

*Answer. The full repellent benefits of Desmodium has been acknowledged by the second season. Farmers have reported the push effect in some well-covered, fully established push-pull fields by the first season.*

**Q8. Are there specific pests/insects and diseases which *Desmodium* repels in the push-pull-vegetable plot?**

*Answer. The push-pull system intensification with vegetables addresses: pests (diamondback moths (DBM), aphids, thrips, leafminer-*Tuta absoluta* and whiteflies) and diseases (black rot, and both late and early blight).*

**Q9. Does Napier/*Brachiaria* also repel or kill vegetable pests as in cereal (maize/sorghum)?**

*Answer. Certain pests are being repelled in a manner similar to control in cereals.*

**Q10. Do the maize pollen grains interfere with the growth or quality of vegetables in a push-pull field?**

*Answer. The spacing of the crops in the push-pull strategy is very specific with *Desmodium* intercrop ensuring spacing which limits the pollen amounts falling on and affecting the quality of vegetable leaves.*

**Q11. Are there alternatives to Napier grass and *Desmodium*?**

*Answer. Yes. A drought-tolerant grass *Brachiaria* spp. can be planted around the maize or sorghum plot as a trap*

*crop, as it is an excellent trap crop 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, or fix nitrogen hence can be used in *Striga*-free areas.*

**Q12. 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.*

**Q13. 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.*

**Q14. 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 FAW, the benefits are immediate upon proper establishment and management of the technology. Vegetable harvests can also be obtained one month after transplanting in the intensification plot translating to nutritional provision and additional income.*

**Q15. Can I use vegetable integrated push-pull technology on sorghum?**

*Answer. Yes. Intercrop greenleaf *Desmodium* (*Desmodium intortum*) with sorghum to repel stemborers and control *Striga* weed. This is often encouraged under the climate-smart push-pull, whereby the greenleaf *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.

**Q16. Can I use push–pull technology on all types of vegetables?**

**Answer.** No. Only intercrop vegetables whose growth behaviour is compatible with the push–pull strategy arrangement. The following are viable vegetables which have been successfully integrated to date: cabbages – “Kabeji”, kales/collard greens – “sukuma wiki”, black nightshade – “osuga/suchaa”, spring onions or green bunching onions – “kitungu majani”, cowpeas – “kunde” and tomato – “nyanya”.

**Q17. 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. However, 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 FAW by this technology. Studies and field findings show that control is effective when maize/sorghum is intercropped with drought-tolerant greenleaf *Desmodium* and *Brachiaria* is planted as a border crop around this intercrop.

**Q18. Where can I obtain Napier grass, *Brachiaria* and *Desmodium* seeds?**

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

**Q19. What can I do if I don't get *Desmodium* or *Brachiaria* seeds?**

**Answer.** Use *Desmodium* root splits or cuttings from your neighbours. Additionally, *Brachiaria* can be obtained from

root splits established 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, FAW 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, in terms of both cost and labour. Push-pull is the most effective control method. The climate-smart push-pull (*Desmodium* and *Brachiaria*) has proven effective in inhibiting FAW access and damage to the crops.*

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

**Answer.** *No. However, you can apply to various projects on dairy animals to find out if you qualify. Also, the income generated from the sale of fodder and other by-products can enable you to purchase your own dairy 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 vegetable integrated push-pull technology work in all parts of Kenya or Africa?**

**Answer.** *Yes, but only in areas recommended for growing *Desmodium* and can support the choice vegetable for integration, where rainfall and climate allow cropping with low risk of the crop failure. 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. Cultivars approved by icipe 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 silverleaf?**

**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 is ongoing on African Desmodium varieties for possible integration.*

# Glossary

- deadheart** destruction of the growing bud in the plant whorl can result in a 'deadheart' (drying, stunting and complete loss of yield in a plant such as maize plant)
- drilling in** to sow seeds in a furrow or trench in rows
- emergence** the appearance of a seedling through the soil
- greenleaf** greenleaf *Desmodium* (*Desmodium intortum*)
- host** an animal or a plant that maintains a parasite
- indigenous** a plant or animal originating (native to) in an area
- infestation** penetration of germinating seeds (**of *Striga***) into the host root
- internodes** part of stem between two nodes (**for Napier or *Desmodium***)
- 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
- manual** by hand
- molasses grass** *Melinis minutiflora*, a long-lived grass, usually growing 0.6-1 m tall, with upright, straggling or trailing, slender hairy stems, sticky hairy leaves narrow leaves and pale pink, reddish or purplish branched seed-heads, and with a strong molasses odour
- node** an enlarged point on a stem where a leaf, bud, or other organ is attached

- NPK fertiliser** Fertiliser that contain a mixture of nitrogen, phosphorus and potassium
- 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* (*Desmodium uncinatum*)
- 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 *Striga hermonthica*



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 and herbicides. 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. Moreover, adopting the Push-Pull System Intensification with Vegetables affords the farmers' households improved nutrition and food security, providing vegetable assurance in the family diet.

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

**For more information, contact:**

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