Script of P.G Seminar

ON

"Exploitation of Push-pull technology in pest management"

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Exploitation of Push-pull technology in pest management

Introduction

Chemical method of control remained the most favourite tool in plant protection for about 4 to 5 decades. But know a days IPM come forward to overcome the insecticidal problem. Many other technology used as a substitute for chemical method of control. For this ,the Push-pull is a new concept which is a behaviour manipulation strategy in which in which behaviour modifying stimuli are integrated with a pest control agent.

Goal= The Push-pull strategy is to concentrate the pest in a limited areas , which would then be targeted with less insecticide or other pest control tools.

The Push-pull strategy, a novel tool for integrated pest management programs, uses a combination of behavior-modifying stimuli to manipulate the distribution and abundance of insect pests and/or natural enemies . In this strategy, the pests are repelled or deterred away from the main crop (push) by using stimuli that mask host apparency or are repellent or deterrent . The pests are simultaneously attracted (pull), using highly apparent and attractive stimuli, to other areas such as traps or trap crops where they are concentrated, facilitating their control**.**

History

1) The term Push-pull was first conceived as a strategy for Integrated Pest Management by Pyke et. al
2) They investigated the use of repellent and attractive stimuli, deployed in tandem to manipulate the distribution of *Helicoverpa* spp. in Cotton tot reduce reliance on insecticides.

3) The concept was later formalized and refined by Miller and Cowles in US (1990) who termed the strategy ñStimulo-deterrent diversion ñwhile developing alternative to insecticides for control of the onion maggot(*Delia antique*)

Principles of the Push-pull strategy

Push-pull strategies use a combination of behavior modifying stimuli to manipulate the distribution and abundance of pest and or beneficial insects for pest management.

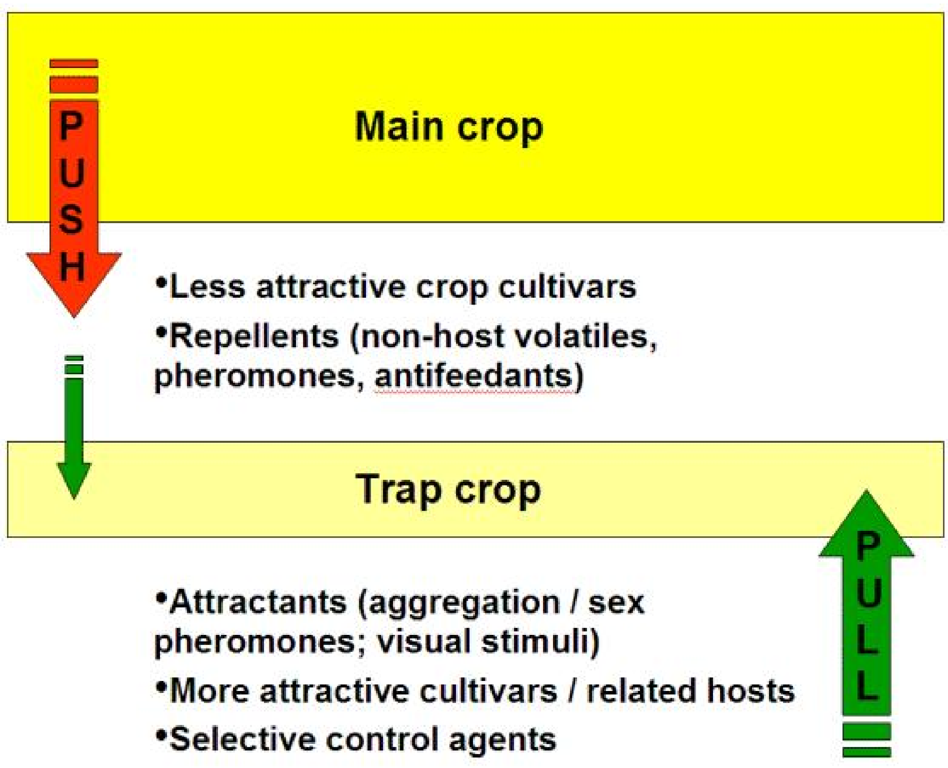
Strategies targeted against pests. Try to reduce their abundance on the protected resource. for example, a crop or farm animal.

What is push?

The pests are repelled or deterred away from resource by using stimuli that mask host apparency or are repellent or deterrent.

What is Pull ?

The pests are simultaneously attracted by using highly apparent and attractive stimuli, to other areas such as traps or trap crops where they are concentrated . Facilitating their elimination.



General information

1) Most of work on Push-pull strategies has targeted pest behavior, so this relates mostly to pests rather than the manipulation of beneficial organisms.
2) However , use of concentrated population on the protected resource to promote biological control, Sometime it can use to push the benificials out of the surrounding area and pull them to where they are required for control.
3) The Push-pull strategies primarily include visual and chemical cues or singnals.
4) Habitat diversification strategies have attracted much interest as pest management strategies. For example, trap crops can be plants of a preferred growth stage , cultivar or species that divert pest pressure from the main crop because they are more attractive.
5) The mechanism underlying differential pest preference usually involve certain visual or seminochemical stimuli.
6) Trap crops can therefore be used to deliver attractive pest-behavior-modifying stimuli.

The Population reducing methods

1) The principles of the Push-pull strategy are to maximize control efficacy, efficiency ,sustainability and out put. While minimizing negative environmental effects.
2) Each individual component of the strategy is usually not effective as a broad spectrum insecticide at reducing pest numbers.
3) In this by concentrating the pests in a predetermined site, the efficiency and efficacy of population reducing methods can also be maximized.
4) The use of renewable sources, particularly plants, for the production of semiochemicals is encouraged and is becoming possible even for insect-product semiochemicals

5) In agricultural system, the goal is to maximize out put from the whole system while minimizing cost and harvestable intercrop or trap crops rather than sacrificial crops, should be use wherever possible.

6) For development of reliable , robust and sustainable Push-pull strategies requires a clear scientific under standing of pests biology and behavioral or chemical ecology of the interaction with hosts.

Components of the Push-pull strategies

1) The function of push components of the Push-pull strategies is to make the protected resource hard to locate, unattractive or unsuitable to the pest. This is achieved through the use of stimuli.
2) This stimuli may act over the long or short range and ultimately lead to the pest being repelled or deterred from the resource or not even approaching it.
3) Long range stimuli represent the first line of defence preventing or reducing infestation in the first place.
4) Stimuli that act over the short range, however , can be powerful tool in preventing specific pestiferous behaviors.
5) The pull components of Push-pull strategies , attractive stimuli are used to divert pest from the protected resource to a trap or trap crop

Stimuli for Push components

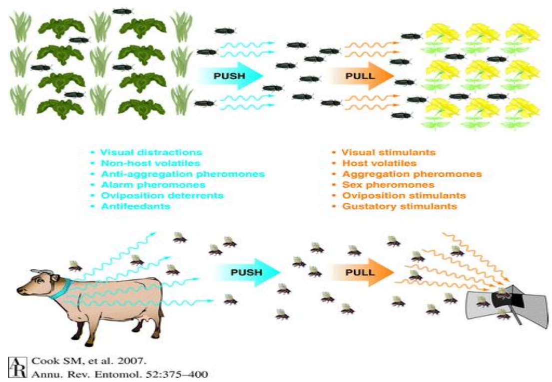
We discuss the stimuli that can be used as push components of the push-pull strategy. The stimuli have been grouped according to following points.

i. Visual cues
ii. Synthetic repellents
iii. Nonhost volatiles
iv. Antiaggregation pheromones
v. Antifeedants

vi. Oviposition deterrents and oviposition deterring pheromones.

Stimuli for Pull components

i. Visual stimulus
ii. Host volatiles
iii. Aggregation pheromones
iv. Sex pheromones
v. Gustatory stimulus



Push Components discus below

1) **Visual cues**

Manipulation of host colour, shape or size to inhibit host orientation and acceptance behaviors of pest. But this is often impractical to change in hosts. However, by understanding how can at least be minimized or even disrupted.

2) **Synthetic repellants**

Repellents such as MNDA (N-methyl-neo-decanomide) and DEET(N,N-diethyl-3-methyl benzamide) are commercially available and may be used in Push-pull strategies against cockroaches and invasive lady beetles. DEET is considered the most effective commercial repellent available and is used primarily to repel hematophagous insect.

3) **Nonhost volatiles**

Volatile derived from nonhosts can be used to mask odours or evoke nonhost avoidance and repellent behaviors. Plant essential oils such as citronella and eucalyptus are commercially produced as repellent against hematophagous insects.

For example: PMD (P-methane-3-8-diol) isolated from Lemon eucalyptus oil of *Eucalyptus citriodora* , has been registered by U.S. Environmental Protection Agency for use against mosquitoes.

4) **Host-derived semiochemicals**

The Codling Moth (*Cydia pomonella*) was repelled by the odors of Apples at inappropriate phonological stages.

Methyl salicylate and Jasmone are HIPVs repellents to Aphids when released in the field.

Herbivore induced plant volatiles(HIPVs) can deter plant utilization by subsequent herbivores as indicators of competition or induced defenses. HIPVs are produced by the plant as indirect defenses that attract natural enemies of herbivore.

Insect recognize suitable hosts by using key volatiles that are often present in specific rations. Directed host orientation ceases if host odors are presented in appropriate rations.

5) **Antiaggregation pheromones**

Antiaggregation pheromones control the spatial distribution of insects and reduce intraspecific competition for limited resources.It is attractive at low concentration are produced by several species of bark beetles to optimize host use.

6) **Alarm pheromones**

The alarm pheromone for many pest, aphids is (E)-ɓ-farnesene (Eɓf). It can be applied to the main crop to repel aphids in field. Eɓf also functions as a kairomone pull for natural enemies of aphids.

7) Antifeedants

Most Antifeedants are plant-derived. Several Antifeedants, including aza-diractin , have toxic effects at normal treatment rates.

The drimone dialdehyde polygodial , first isolated from the water pepper (*Polygonum hydropiper*) and warburganal, isolated from *Warburgia vgandensis* . These show repellent activity aginst several agricultural and some domestic (urban) pests. For less mobile pests , a combination of non-systemic antifeedants and population reducing agents could be effective.

8) Oviposition deterrents and oviposition deterring pheromones.

These are compounds that prevent or reduce egg deposition, so have the potential in Push-pull strategies to control species that cause damage through this process. Numerous botanical deterrents isolated from nonhosts have deterred oviposition by pests. Petroleum oil sprays and some natural enemy food supplements also deter oviposition by some phytophagous insects.

ODPs are another class of spacing pheromones that enable female insects to avoid laying egg on previously exploited hosts, thereby reducing intraspecific competition.

Application of synthetic ODPs of the European cherry fruit fly in field trials showed that it can successfully protect cherry trees (*Prunnus avium*). According to zeya-ur-khan if 1 in every 10 trees were left untrated and baited with visually attractive sticky traps, the strategy would be more effective.

Pull Components discus below

In this section we list and discus the stimuli that can be used as pull components of Push-pull strategies. They are grouped in a manner similar to that used for the push stimuli in previous section.

1) **Visual stimulants**

Visual stimuli are rarely the sole method used to attract pests to traps or trap crops, but they can enhance the effectiveness of olfactory stimuli.

Blule and Black traps, approximating the size of mammalian host , are used to control cattle tsetse fly (*Glossina spp.*). In plant based strategies , the visual cues related to plant grown stage can be important. Red spheres (7.5 cm. in dia.) mimicking ripe fruit attracted sexually mature apple maggots (*Rbagoletis pomonella*) . These traps, coated with either sticky material or contact insecticides and baited with synthetic host odours.

2) **Host volatiles**

Host volatiles used in host location can be used to bait traps for monitoring , mass trapping or in attracticide strategies. Hematophagous dipterans are attracted to mammalian associated volatiles such as CO_2, 1-octen-3-ol and acetone from the breath , and a mix of body odors.

Host plant odors can also be used in traps or to increase the effectiveness of trap crops using knowledge of host specificity and preferences , the attractiveness of synthetic host odor blend can be minimized.

HIPVs are often reliable indicators of the presence of hosts or prey to predatory and parasitoids and are therefore attractive to benificials.

Specific HIPVs such as methyl salicylate and (z)-jasmone are attractive to predators and parasitoid in the field**.**

3) Sex and aggregation pheromones

Insects release sex and aggregation pheromones to attract conspecifics for mating and optimizing resource use.

Trap baited with the pheromones have a lower detection threshold than other methods and can helps in Push-pull strategies to determine the timing of stimuli deployment and population reducing interactions.

Male produced pheromones that attract female over a long range are most useful in direct control strategies. Male produced sex pheromones from the sand fly have been indentified and synthetically produced and may used for control of leishmaniasis in Latin America.

4) Gustatory and oviposition stimulants

Trap crops may naturally contain oviposition or Gustatory stimuli which help to retain the pest population in the trap crop area.

Gustatory stimulants, Such as sucrose solution, have also been applied to traps or trap crops to promote ingestion of insecticide bait. Food supplements may also help to establish population of natural enemies and influence their distribution.

Delivery of Push and Pull stimuli

Various methods are available to deliver the stimuli used for behavioral manipulation of pest within Pull-push strategies.

1) Natural products or nature-identical synthetic analogs
2) Vegetative diversification: Intercropping and trap cropping
3) Antixenotic cultivars
4) Plant induction
5) Traps

1) Natural products or nature-identical synthetic analogs

The seminochemicals used are natural products and can be extracted from plants(e.g. essential oils) or insects. Extraction of pheromones from insects, however,is usually impractical beyond experimental purploses. Most commercially used semiochemicals are synthetic but nature identical. For insect derived pheromones, production from plants or through genetic manipulation is possible and represents a more sustainable route than synthesis.

2) Vegetative diversification

A. Inter-croping

B. Trap cropping

In plant-based system naturally generated plant stimuli can be exploited using intercropping and trap cropping.

Push stimuli can be delivered by intercropping with nonhost plants that have repellent or deterrent attributes appropriate to the targeted pest.

It reduces pest density in crops, principally by disrupting host location through reducing visual appearancy of the host plant by repellants or deterrent semiochemicals in the conhosts or both.

e.g. Molasses grass (*Melinis minutiflora*) and silver leaf desmodium(*Desmodium uncinatum*) which release repellent HIPVs, are used as intercrops in a Push-pull strategies for maize in Africa. It is ecofriendly

As pull component effectiveness of trap crops can be enhanced further by the application of additional attractive semiochemicals .It is a key elements of plant based Push-pull strategies.

3) **Antixenotic cultivars**

It represents plant traits that modify herbivore behavior conferring nonpreference. These plant resistance properties are exploited in nonhost intercrops but could also be used to deliver push stimuli in main crop. Trichomes of wild potato release the aphids alarm pheromones component Eɓf, in which it acts as and allomone and repels aphids at short distances . Trichomes of tomato provide mechanical disturbance to mall herbivores or produce toxic exudates.

4) **Traps**

It is used in mass trapping or attracticide strategies can deliver visual stimuli. Trap design and positioning are importance and can be maximized by adopting a systematic approach in which the behavior of the insect is closely observed.

Push-pull strategies in crops

1) Control of stem borers in Maize
2) Control of *Helicoverpa* in Cotton
3) Control of Urban pest
4) Control of veterinary and medical pests
5) Control of Onion maggots on Onion
6) Control of Thrips on Chrysanthemum

7) Study the Maize stem borer activity under Push-pill system an Bt.-maize. A potential components in managing Bt.resistance

1) Control of Helicoverpa in Cotton

Helicoverpa species are polyphagous lepidopterous pest of wide range of crops.The potential of combining the application of neem seed extracts to the main crop (push) with and attractive trap crop, either pigeon pea (*Cajanus cajan*) or maize (*Z. mays*)(pull) to protect cotton (*G. hirsutum*)

Trap crop efficiency was increased by application of a sugar insecticide mixture. Trap crops, particularly Pigeon pea , reduced the number of eggs on cotton plants in target areas. In this we found that , the push-pull strategy was significantly more effective than individual components alone. In India neem, combined with a pigeon pea or okra (*Abelmosebus esculentus*) trap crop , was on effective strategy against *Helicoverpa armigera* In India such push-pull technology was studied in Dr.P.D.K.V.Akola. by S.B.Jadhav and Dr. A.K. Sadawarte.

According to his experiment on Push-pull technology on cotton for *Helicoverpa* spp.

Material for experiment

1. Cotton variety = PKV-Rajat
2. Pigeon pea variety = TAT-10
3. Sunflower variety = Mordern

Treatment details

Treatment	Details of experiment
T1	Cotton (NSE treated) Pigeon pea(NPV treated)
T2	Cotton (NSE treated) Pigeon pea(untreated)
T3	Cotton (untreated) Pigeon pea (NPV treated)
T4	Cotton (untreated) Pigeon pea(untreated)
T5	Cotton (NSE treated) Sunflower (NPV treated)

T6	Cotton (NSE treated) Sunflower(untreated)
T7	Cotton (untreated) Sunflower (NPV treated)
T8	Cotton (untreated) Sunflower(untreated)
T9	Cotton (NSE and NPV Cotton (NSE
T10	Cotton (NSE treated)
T11	Cotton (NOV treated)
T12	Cotton (untreated)

Observation

All observation were recorded 3rd , 7th and 14th DAS . Egg, larval population and damage in fruiting bodies on main crop and intercrop.

Result

Treatment	Eggs/plant	Larvae/plant	%age fruiting damage
T1	5.52 (2.28)	0.86 (0.92)	0.90 (0.95)
T2	5.56 (2.36)	1.47 (1.21)	1.36 (1.17)
T3	11.72 (3.42)	2.81 (1.67)	2.48 (1.57)
T4	13.13 (3.62)	3.33 (1.82)	2.45 (1.72)
T5	5.79 (2.41)	1.10 (1.05)	1.09 (1.04)
T6	6.17 (2.48)	1.74(1.32)	1.49 (1.22)
T7	12.11 (3.48)	2.95 (1.72)	2.76 (1.66)
T8	13.59 (3.69)	3.44 (1.85)	3.19 (1.78)
T9	8.73 (2.95)	2.19 (1.48)	1.73 (1.31)
T10	9.40 (3.06)	2.51(1.58)	2.08(1.44)

T11	14.74 (3.84)	4.09(2.09)	2.59(1.61)
T12	15.79 (3.97)	4.89 (2.21)	6.10 (2.47)
F test	Sig.	Sig.	Sig.
SE(m)±	0.02	0.04	0.03
CD @ 5%	0.06	0.12	0.09

Effect of ñPush-pull techniqueò on egg laying, Larval and percentage damage on of *H.armigera* on main crop, Cotton.

Effect of Push-pull technology on Egg laying of *H.armigera* on trap crop, Pigeon pea.

Tr no.	Treatment details	Average egg production of *H.armigera* per plant			Average
		3 DAS	7DAS	14DAS	
T1	Cotton (NSE treated) Pigeon pea(NPV treated)	7.75	8.76	9.85	8.79
T2	Cotton (NSE treated) Pigeon pea(untreated)	9.58	10.80	12.15	10.84
T3	Cotton (untreated) Pigeon pea (NPV treated)	13.82	14.97	16.05	14.95

T4	Cotton (untreated) Pigeon pea(untreated)	13.28	14.67	16.22	14.72

Best treatment was T1 and T2 Application of NSE on cotton reduces egg laying on trap crop also. This is due to repellent action on cotton as well as pigeon pea, due to less distance between the cotton and pigeon pea

Effect push-pull technology on egg laying of *H.armigera* on trap crop sunflower

Tr. no	Treatment details	Average egg production of *H.armigera* per plant			Average
		3DAS	7DAS	14DAS	
T5	Cotton (NSE treated) Sunflower (NPV treated)	2.54	3.12	4.11	3.26
T6	Cotton (NSE treated) Sunflower(untreated)	3.51	4.10	4.94	4.18
T7	Cotton (untreated) Sunflower (NPV treated)	4.31	5.44	6.26	5.34
T8	Cotton (untreated) Sunflower(untreated)	4.98	5.55	6.58	5.70

Minimum egg laying was observed in T5 and T6

Effect push-pull technology on Larval population of *H.armigera* on trap crop Pigeon pea

Tr no.	Treatment details	Average egg production of *H.armigera* per plant			Average
		3 DAS	7DAS	14DAS	
T1	Cotton (NSE treated) Pigeon pea(NPV treated)	1.65	1.55	2.01	1.64
T2	Cotton (NSE treated) Pigeon pea(untreated)	2.26	2.68	3.03	2.66
T3	Cotton (untreated) Pigeon pea (NPV treated)	2.17	2.45	2.92	2.51
T4	Cotton (untreated) Pigeon pea(untreated)	3.23	3.60	4.04	3.64

Best effective treatment was T1 followed by T3

Both contain NPV .This indicate that NPV on trap crop reduced the larval population of *H.armigera.*

Effect push-pull technology on Larval population of *H.armigera* on trap crop Sunflower

Tr. no	Treatment details	Average egg production of *H.armigera* per plant			Average
		3DAS	7DAS	14DAS	
T5	Cotton (NSE treated) Sunflower (NPV treated)	0.38	0.42	0.70	0.50
T6	Cotton (NSE treated) Sunflower(untreated)	1.02	1.28	1.71	1.37
T7	Cotton (untreated) Sunflower (NPV treated)	0.84	0.80	1.33	1.01

T8	Cotton (untreated) Sunflower(untreated)	1.126	1.55	1.85	1.55

Minimum larval population found inT5 thenT7, NPV plays important role for larval control.

Effect push-pull technology on percent pod damage by *H.armigera* on trap crop Pigeon pea.

Tr no.	Treatment details	Average egg production of *H.armigera* per plant			Average
		3 DAS	7DAS	14DAS	
T1	Cotton (NSE treated) Pigeon pea(NPV treated)	5.60	9.60	11.20	8.80
T2	Cotton (NSE treated) Pigeon pea(untreated)	13.60	10.40	19.20	14.40
T3	Cotton (untreated) Pigeon pea (NPV treated)	9.60	13.60	12.80	12.00
T4	Cotton (untreated) Pigeon pea(untreated)	12.80	14.40	23.20	16.80

Minimum damage T1 and T3

Due to treatment of NPV on trap crop, the pod damage was reduced.

HaNPV found effective in minimizing pod damage.

Economics of Push-pull technology

Treatment	Yield kg/ha		Cost of yield Rs/ha		Gross monitory Rs/ha	Cost of plant protection	Net return Rs/ha
	Cotton	Trap	Cotton	traps			
T1	862	786	17067.60	6149	23216.60	1689	21527.60
T2	580	180	11484.00	3870	15354	858	14496
T3	520	220	10296	4730	15026	831	14195
T4	485	160	9603	3440	13043	0	13043
T5	690	150	13662	2700	16362	1689	14673
T6	519	120	10692	2160	12852	858	11994
T7	489	130	9682	2340	12022	831	11191
T8	475	95	9405	1710	11115.5	0	11115
T9	553	-	10969.20	-	10969.20	1689	9280.20
T10	541	-	10711.80	-	10711.80	858	9853.80
T11	497	-	9860.40	-	9860.40	831	9029.40
T12	450	-	8910.00	-	8910.00	0	8910.00

Maximum yield was found T1 followed by T5

Push-pull for management of cereal stem borers in eastern Africa

Maize and Sorghum are the principal food and cash crops for millions of the poor people in the predominantly mixed crop.and livestock farming. System of eastern Africa.

Stem borers are one of the major constraints to increased maize production.At least four species of stem borer (*Chilo partelus, Eldana saccharina, Busseola fusca and Sesamia calamiatis*) infest maize and sorghum crop in the region. Reported yield losses of 30 to 40% of potential output. Stem borers are difficult to control, largely because of the cryptic and nocturnal habits of Adult moths and the protection provided by the stem of the host crop for immature stages.

The main method of pest control is use of pesticides. It is uneconomical for small scale farmers. A Push-pull strategies for managing cereal stem borers in Africa was developed by scientists of ICIPE (International Centre of Insect Physiology and Ecology) in Kenya and Rothamsted Research in U.K., in collaboration with other research organization in eastern Africa.

This strategy involved the combined use of intercrops and trap crops, using plants that are appropriate to the farmers.

This Push-Pull technology does not use any chemical deterrents or toxins, but uses repellent plants to deter the pest from the main crop.

The Push-pull strategies for cereal stem borers involves trapping stem borers on highly attractant trap plants (pull) while driving them away from the main crop using repellent intercrops(push).

Plants that have been indentified as effective in the push-pull tactics include Napier grass (*Pennisetum purpureum*) , Sudan grass (*Sorghum vulgare sudanense*), Molasses grass (*Melinis minutiflora*) and Desmodium (*Desmodium uncinatum and D.intortum*)

Napier and sudan grass are used as trap plants, where as molasses grass and desmodium repel ovipositing stem borers . Molasses gras, when intercropped with maize, not only reduce the infestation of the maize by stem borers , but also increased stem borer parasitism by natural enemies

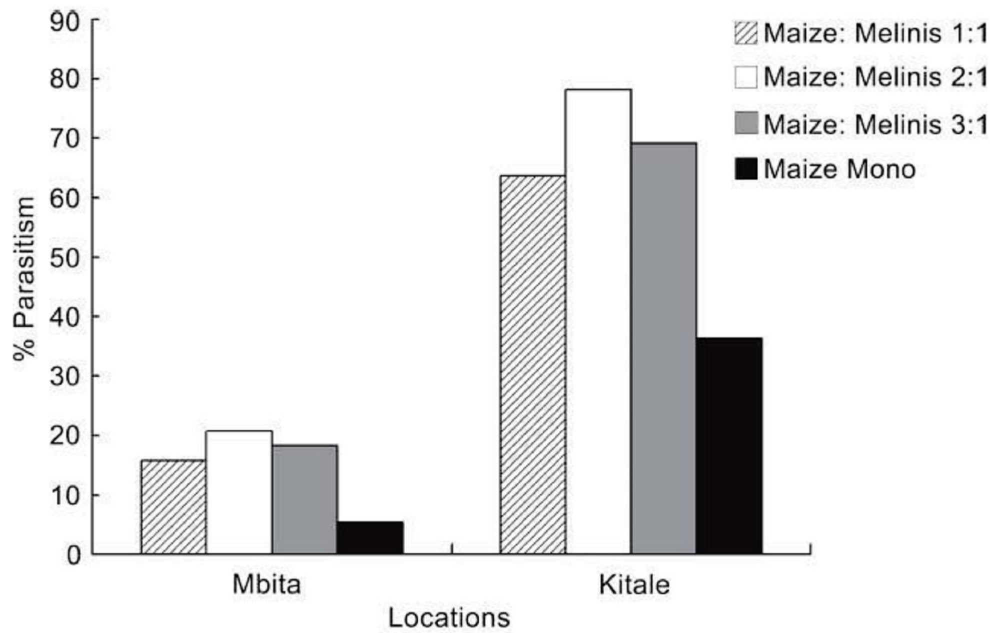


Figure 2. Parasitism of stemborer larvae by *Cotesia sesameae* in maize-*M. minutiflora* intercrops planted in various ratios.

This Push-pull strategies also used for control of striga weeds in maize.

How Push-pull strategies works

1. The plant chemistry responsible for stem borer control involves release of attractive volatile from trap plants and repellant volatiles from the intercrops.
2. To understand the chemical ecology of the push-pull strategies , volatile chemicals from trap and repellent plants have been investigated using gas chromatography (GC) coupled ï electro antennagraphy on the antennae of stem borers and their natural enemies.
3. GC peaks consistently associated with EAG activity were tentatively identified by GC coupled mass spectrometry(GC-MS) and identity was confirmed using authentic samples
4. A general hypothesis developed during this work on insect pests is that non host plants are recognized by colonizing insects through the release of repellent or masking semiochemicals

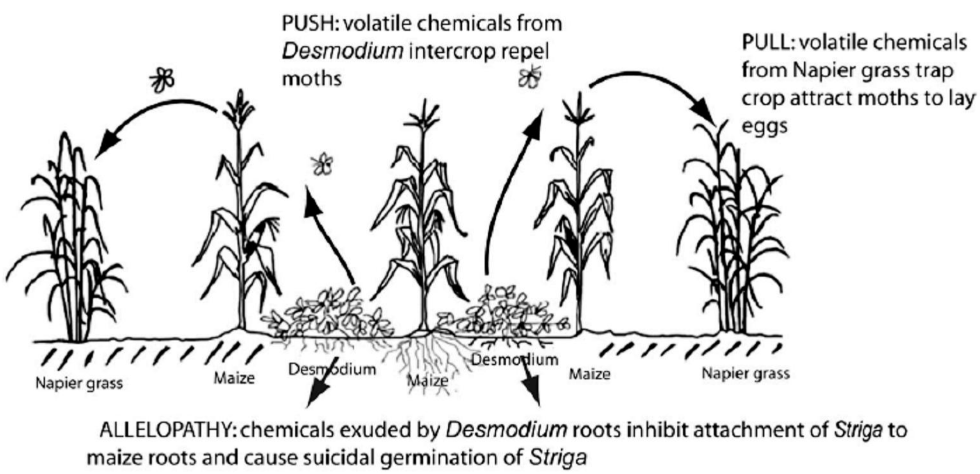
5. Compounds produced by *Poaceae* family are (E)- ɓ-ocimene, ɓ-caryophyllene, humulene and (E)-4,8-diamethyl-3,7-nanatriene
6. Ocimene and nonatriene had already been encounted as semiochemics produced during damage to plants by hervivorous insects
7. It is likely that these compounds being also with a high level of stemborer colonization and in some circumstances , acting as foraging cues for parasitoids, would be repellent to ovipositing stemborers
8. This was subsequently demonstrated in behavioral tests
9. Investigating the legume volatiles, it was shown that D. uncinatum also produced the ocimene and nonatriene. The smell pushes away the moths from the maize crop.
10. When Napier gras use as trap crop, stemborer oviposit heavily on it. It produces a gummy substance which restricts larval development and only few survive to adulthood.
11. A trap crop of sudan grass also increased efficiency of stem borer natural enemies when it is surrounded by field
12. Napier grass is also planted around the maize crop as a trap plant and it attract female moth
13. When egg hatch and the small larvae bore into napier grass stem, the plant produces a sticky substance like glue,which traps them and they die.
14. In addition , desmodium , interplanted among the maize , reduces striga weed.
15. It has been shown that nitrogen fixed by desmodium and chemicals produced by roots of desmodium are responsible for suppressing the striga weed. Therefore, striga does not grow in the maize-desmodium intercrop

16. Attraction of insects to plants and other host organisms involves detection of specific semiochemicals (natural chemicals signal mediating changes in behaviour or development)

17. avoidance of unsuitable hosts can involve the detection of specific semiochemicals, or mixtures of semiochemicals, associated with non-host taxa

18. The underlying semiochemistry of the push and pull companion plants was investigated. This was considered essential for maintaining sustainability in the event that new planting material releases different volatiles from the plants originally investigated.

19. Volatile compounds released by the trap plants, Sudan grass, Napier grass, and other highly attractive hosts were captured by absorption onto a porous polymer.



1. How the pushï pull system works: stemborer moths are repelled by intercrop volatiles while attracted to trap crop volatiles.

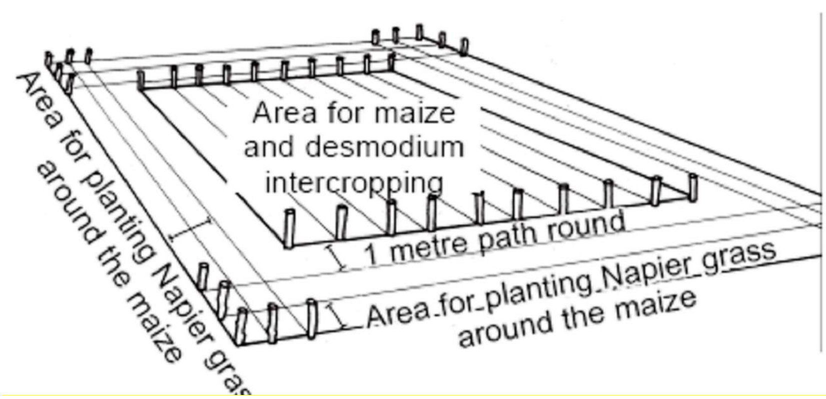
2. Root exudates from the Desmodium uncinatum intercrop cause suicidal germination of Striga and inhibit attachment to maize roots

Preparing and laying out the push-pull plot.

1. Two things are necessary when establishing a good and easy manage push pull plot i.e.

- **i.** Proper land preparation
- **ii.** Careful layout of field

2.If we follow good management practices the napier grass and desmodium we will establish this year will benefit your push pull plot for 5 or more years.



Lay-out of push-pull plot

3. Mark out a plot measuring 21mX21m by using tape

4. Put a peg at each corner of measured area, put more pegs all around the plot at interval of 75 cm.

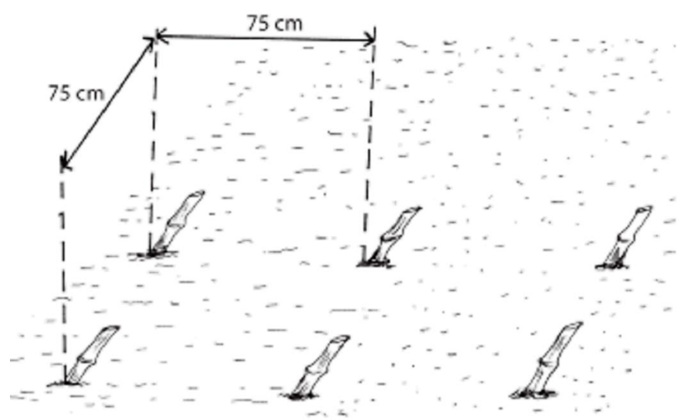
What not to do?

Do not plant push-pull in less than 21mX21m plots. Because N.garss tends to grow tall and therefore creating shading effect on maize crop.

Planting order.

1.Planting of Napier grass

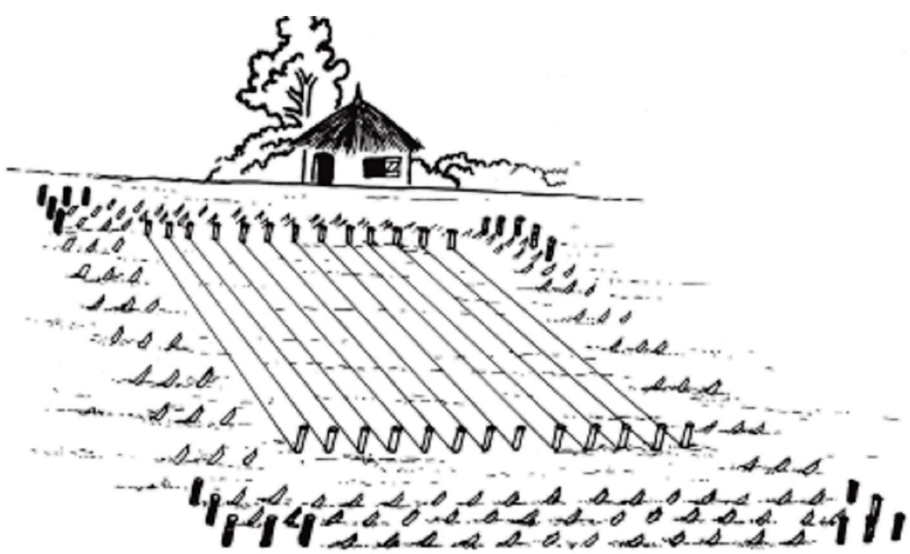
Bana is the best variety of Napier grass for use in push pull in Africa. At corner it is plant as 75cmX75cm, 3 rows around corner



Rows and plants at 75 cm apart

2. Planting desmodium

For 21cmX21cm ,250 gm to 300 gm seed required



Strings running across the plot

3.Planting of Maize

It is planted in straight line between the rows of desmodium. It is ensure that the first row of maize is at least 1m away from the inner row of Napier grass 75cmX30 cm distance

How to prepare the second season push-pull plot

Cut back the desmodium leaving a stubble of 6 cm above the ground encourage regrowth and applied between desmodium row.

Another Experiment on bt-maize

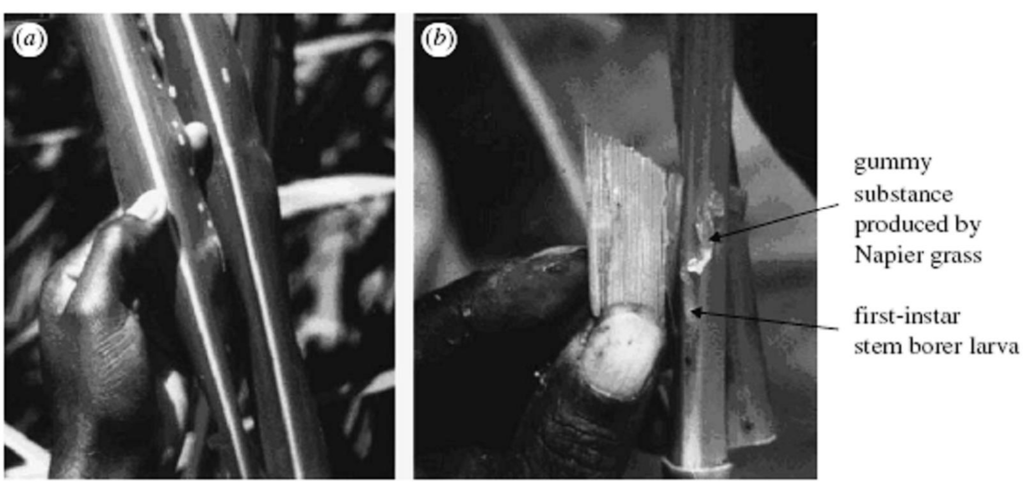
Studies have indicated that push-pull strategies significantly reduces stem borer population . Thus integration of Bt-maze and Push-pull strategy could further play an important role in the resistance management.

Plots are

1. **Bt-maize under push-pull**
2. **Bt-maize monocrop**
3. **Non-Bt-under push-pull**
4. **Non-Bt-maize monocrop**

1) Oviposition preference and egg predation studies

1.Weekly inspection in each plot carried out , because *B.fusca* prefers to oviposit under the plants leaf sheath

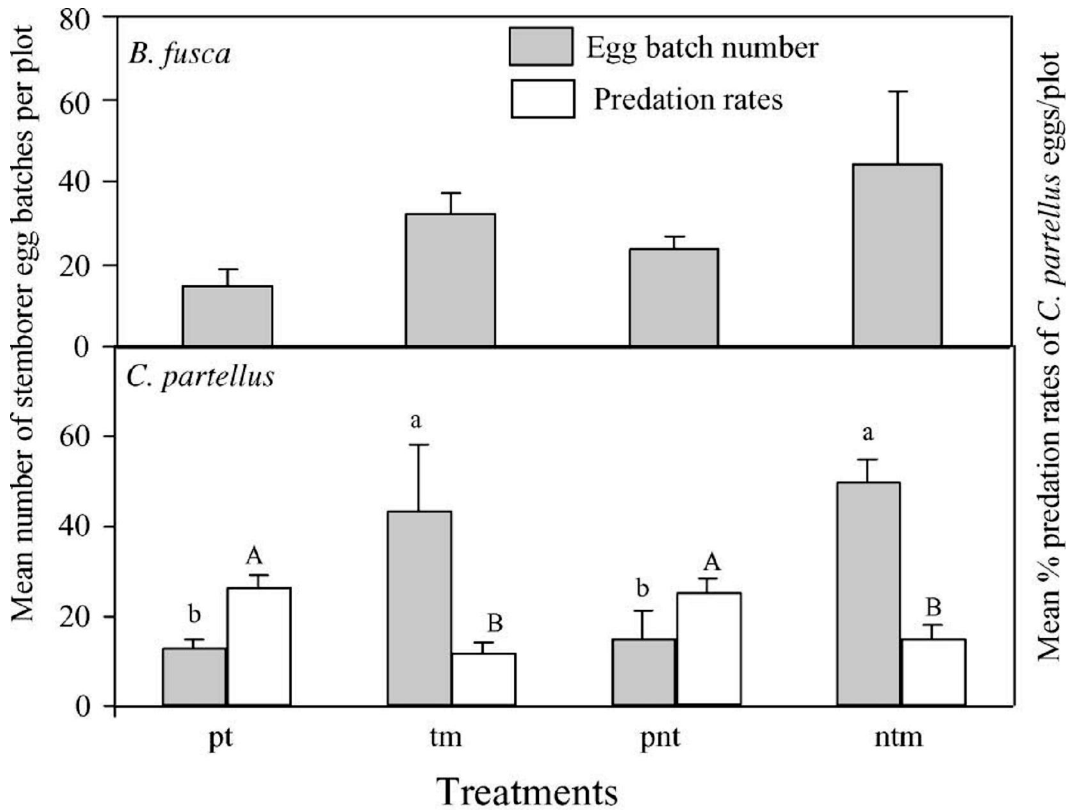


(a) Feeding marks of stem borer larvae on Napier leaves and (b) production of sticky exudate by Napier grass tissue in

response to penetration by first- and second-instar stem borer larvae. Adapted from Khan & Pickett (2004).

2.The presence of its egg batches was felt by running finger tips over the leaf sheath.

3.Newly eggs batches were counted and recorded to provide data on oviposition presence.Data were expressed as percentage eggs sprayed upon per plot and collect eggs to study the parasitoids.



Key:

pt	Bt-maize under 'push–pull'
tm	Bt-maize monocrop
pnt	non-Bt under 'push–pull'
ntm	non-Bt-maize monocrop

Figure 1. Mean number of stemborer egg batches and predation rates per plot in Potchefstroom. Means represent data averages of two cropping seasons. Bars marked with different letters (lower case for egg batch numbers and upper case for predation rates) are significantly different (P50.05). The unmarked bars are not different.

4. There were , however no significant difference in no. of egg batches between non-Bt-maize and Bt-maize monocrop

5. Highest no. of C.partellus egg batches were recorded in maize monocrop

6. There were no significant difference in Bt-maize under push pull and non-Bt-maize under push pull for egg batches.

7. B.fusca predation rates were always less than 1% so no recorded here.

8.Predation rates of C.partellus eggs was significantly higher in the push-pull than maize monocrop treatment.

2. Predators

- **i.** Ants(formacidae), earwing (forficulidae), and spider (lycosidae) were the main stem borer predator recorded
- **ii.** Earwing and Spiders seemed to be most important group. They were significantly more abundant in the push pull than maize monocrop plots
- **iii.** both the predators generally more abundant in push pull than in maize abundant monocrops plots and their population seemed unaffected by the Bt-maize

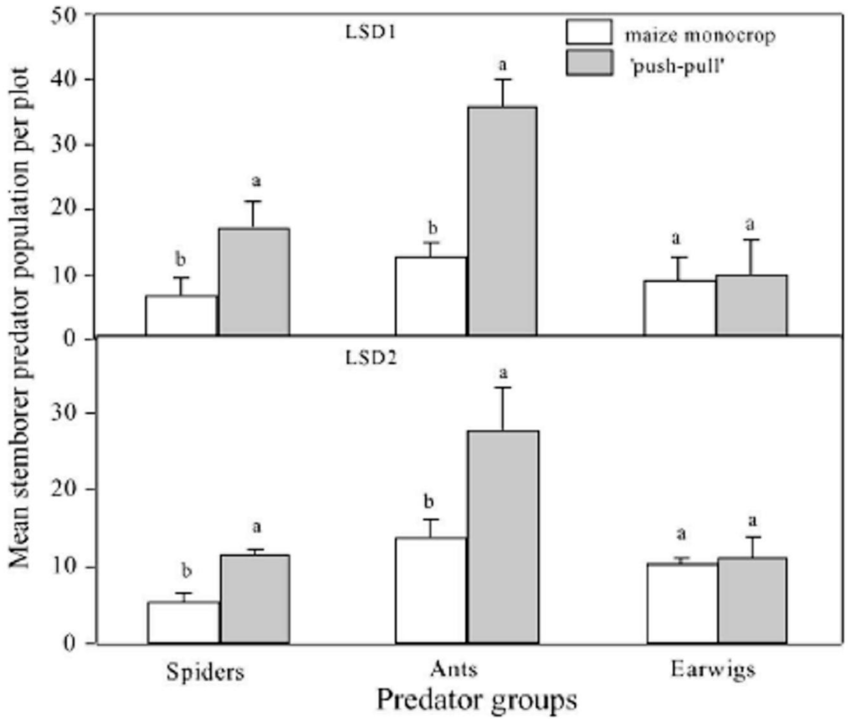


Figure 2. Mean (+SE) stemborer predators recovered at LSD1 and LSD2. Means represent data averages of four plots during two cropping seasons. Within a predator group, bars marked with different letters are significantly different ($P<0.05$).

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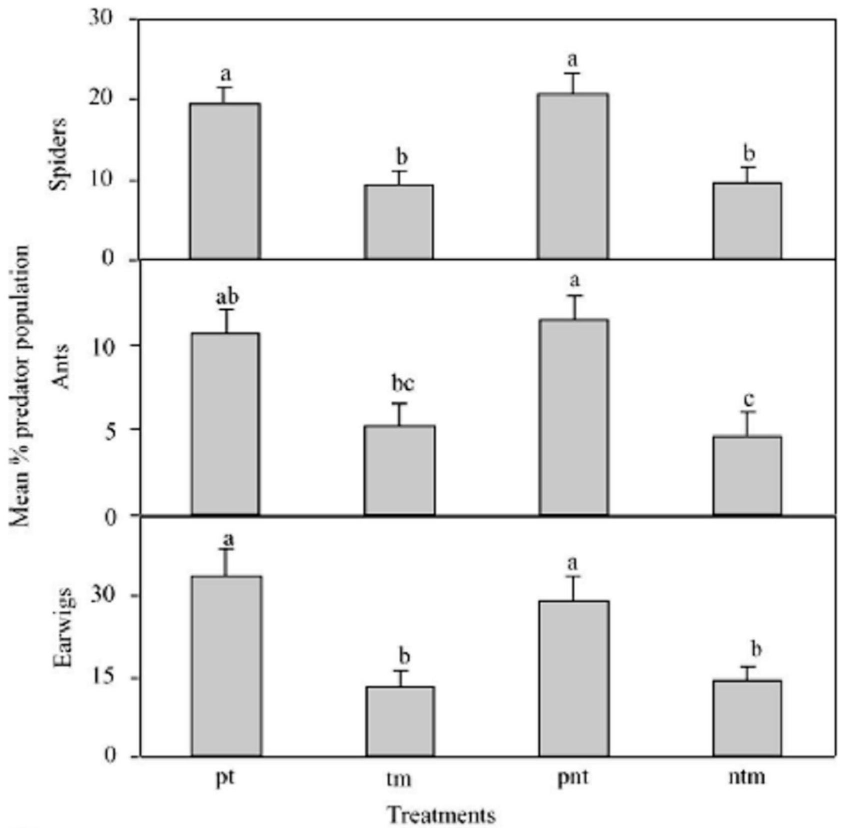


Key:

pt	Bt-maize under 'push–pull'
tm	Bt-maize monocrop
pnt	non-Bt under 'push–pull'
ntm	non-Bt-maize monocrop

Figure 3. Mean (+SE) stemborer predators recovered in Potchefstroom. Means represent data averages of two cropping easons. Within a predator group, bars marked with different letters are significantly different (P<0.05).

3.Small larvae

a. Significantly higher no. of small larvae of C. partellus were recovered from control plants in maize monocrop than push-pull plot.

b. In table no.iv showed that recovery rates of small larvae of B.fusca and C.partellus from control were significantly higher in the maize monocrop plots than those under push pull technology.

c. But were not different between Bt-maize and non-Bt maize monocrop

d. Bt- maize has no impact on larval recovery rates were not significantly different between control and exclusion plants.

Table III. Mean (± SE) recovery rates (percentage) of *C. partellus* larval and pupal stages from control and exclusion plants in both maize monocrop and 'push–pull' plots at LSD.

			Maize monocrop				Push–pull			
Larval recovery	Year	Site	Control	Exclusion	*t* value	*P* value	Control	Exclusion	*t* value	*P* value
Small larvae	2002	LSD1	52.1(9.5)a	71.0(9.4)	−1.42	0.206	24.8(4.3)b	38.8(5.9)	−1.9	0.105
		LSD2	56.6(9.9)a	23.5(10.3)	2.32	0.059	44.6(8.9)a	56.6(11.0)	−0.85	0.429
	2003	LSD1	61.3(5.1)a	64.8(3.2)	−0.58	0.584	38.5(2.1)b	50.3(6.4)	−1.75	0.132
		LSD2	67.8(10.1)a	65.8(3.8)	0.19	0.859	51.0(4.4)a	59.3(10.9)	−0.7	0.509
Large larvae	2002	LSD1	68.6(9.9)a	72.7(6.4)	−0.35	0.739	70.0(9.3)a	67.3(10.4)	0.19	0.854
		LSD2	52.9(13.8)a	58.2(12.5)	−0.29	0.783	63.6(12.5)a	56.6(13.0)	0.39	0.713
	2003	LSD1	80.3(2.5)a	80.5(4.6)	−0.05	0.963	50.3(6.5)b	75.5(8.2)	−2.41	0.053
		LSD2	74.5(7.8)a	59.5(11.9)	1.05	0.332	60.8(13.5)a	65.0(6.3)	−0.29	0.785
Pupae	2002	LSD1	62.4(12.9)a	65.1(12.6)	−0.15	0.886	65.0(14.0)a	60.5(14.9)	0.22	0.832
		LSD2	60.3(15.7)a	60.0(14.0)	0.02	0.988	55.3(9.4)a	59.2(14.8)	−0.22	0.831
	2003	LSD1	77.8(4.6)a	86.5(3.9)	−1.45	0.197	73.3(9.5)a	79.5(8.1)	−0.5	0.633
		LSD2	78.0(7.6)a	86.8(4.2)	−1.01	0.353	64.3(11.9)a	72.5(9.3)	−0.55	0.605

Means of stemborer larval and pupal recovery rates from control plants in maize monocrop and ôpush ï pullôplots in a site and stemborer life stage within a year (rows)

Table IV. Mean (±SE) recovery rates (percentage) of *C. partellus* and *B. fusca* larval and pupal stages from control and exclusion plants in the treatments plots in Potchefstroom.

Life stage	Treatment	Control	Exclusion	*t* value	*P* value
B. fusca					
Small larvae	Bt-maize/push–pull	40.0(3.7)b	53.3(8.2)	−0.31	0.7601
	Bt-maize monocrop	65.8(5.8)a	60.0(7.7)	0.6	0.561
	Non-Bt-maize/push–pull	34.2(5.1)b	53.3(6.8)	−2.26	0.05
	Non-Bt-maize monocrop	59.2(7.5)a	66.7(4.8)	−0.85	0.417
Large larvae	Bt-maize/push–pull	54.2(9.2)a	53.3(3.3)	0.09	0.934
	Bt-maize monocrop	53.3(8.8)a	63.3(6.7)	−0.9	0.387
	Non-Bt-maize/push–pull	40.0(5.8)a	50.0(6.3)	−1.17	0.27
	Non-Bt-maize monocrop	56.7(7.6)a	71.7(6.0)	−1.55	0.153
Pupae	Bt-maize/push–pull	60.0(8.5)a	71.7(5.4)	−1.16	0.272
	Bt-maize monocrop	53.3(10.5)a	72.5(4.8)	−1.67	0.127
	Non-Bt-maize/push–pull	77.5(4.4)a	79.2(3.0)	−0.31	0.762
	Non-Bt-maize monocrop	77.5(4.8)a	81.7(2.5)	−0.77	0.457
C. partellus					
Small larvae	Bt-maize/push–pull	26.7(4.4)b	26.7(4.2)	0.00	1.00
	Bt-maize monocrop	55.0(4.1)a	60.0(5.3)	−0.75	0.473
	Non-Bt-maize/push–pull	29.2(4.7)b	32.5(4.2)	−0.53	0.611
	Non-Bt-maize monocrop	52.5(4.9)a	58.3(3.8)	−0.93	0.372
Large larvae	Bt-maize/push–pull	50.8(6.5)a	51.7(6.4)	−0.09	0.929
	Bt-maize monocrop	54.2(4.7)a	50.8(10.8)	0.28	0.7837
	Non-Bt-maize/push–pull	55.8(8.5)a	55.0(7.3)	0.07	0.9422
	Non-Bt-maize monocrop	56.7(8.1)a	53.3(7.5)	0.3	0.769
Pupae	Bt-maize/push–pull	37.5(7.4)a	40.8(11.4)	−0.24	0.8120
	Bt-maize monocrop	44.5(8.2)a	66.4(5.5)	−2.21	0.0512
	Non-Bt-maize/push–pull	47.2(6.7)a	54.4(11.2)	−0.55	0.5965
	Non-Bt-maize monocrop	57.5(4.8)a	61.7(2.5)	−0.77	0.457

4.Large pupae

a. Both larvae was not significantly different between control and exclusion plants in all field under study
b. More larvae were recovered from control plants in maize monocrop than push pull in 2003

5. pupae

There is no significant difference on recovery rate of pupae

Benefits of adopting the Push-pull strategies

1.Increase maize yield by 25 % to 30% in the areas where only stem borers are a problem but more than 100% where both stem borers and striga problem.

2.Increase supply of cattle feed from Napier grass and desmodium

3.Fix nitrogen into your farm by desmodium legume, so we save on fertilizer costs

4.Protect soil from erosion as desmodium acts as a cover crop

5.Retain soil moisture in plot because desmodium acts as a mulch

6. Get money from sale of desmodium seed at an attractive price

7.Save on farm labour as you do not have to manually remove striga weed from the farm.

8.Protect maize from strong winds when surrounded by napier grass

9.The push pull components are generally nontoxic and therefore , the strategies are usually integrated with biological control

10.The push pull technology has the potential to improve the livelihood of small holder farmers and rural families, increase agril. productivity and improve environmental sustainability

11.Striga weed control (witch weed or striga(scrophulariaceae) are obligate (partial) root parasite of cereal crops

Economics of push-pull

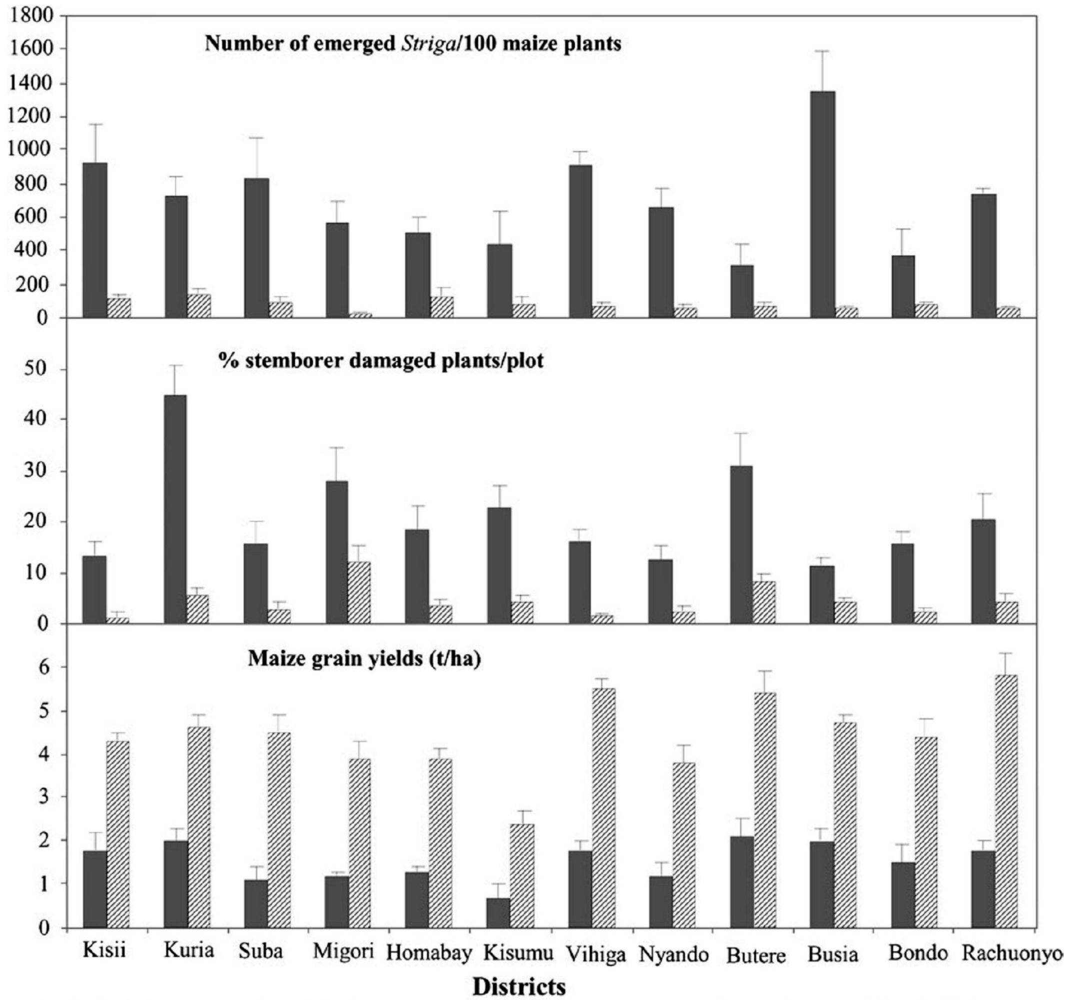
1. In push pull , intercropping or mixed cropping of maize, grasses and fodder legumes has enabled farmers to increase crop yield and thus improve their food security and gross benefit

2.Although total labor cost and total variable cost were lower in farmers practice as compaired to push pull field

3. Total gross benefit of push pull were significantly higher

Economics of push-pull strategy as compared to farmerӧs practice in six districts in Kenya (from Khan et al., unpublished)

Districts	Total Labor Cost ($)/ha		Total Variable Cost ($)/ha		Total Gross Revenue ($)/ha		Gross Benefit ($)/ ha	
	Push-pull	Farmers' Practice	Push-pull	Farmers' Practice	Push-pull	Farmers' Practice	Push-pull	Farmers' Practice
Trans/ Nzoia[a]	223 ± 1.2	128 ± 1.5	493 ± 1.6	374 ± 2.0	1290 ± 27.7	628 ± 32.4	797 ± 28.0	254 ± 31.0
Suba[a]	167 ± 1.6	134 ± 0.4	278 ± 1.1	250 ± 0.7	679 ± 10.2	329 ± 5.9	401 ± 9.9	79 ± 5.7
Bungoma[b]	247 ± 3.8	222 ± 2.3	331 ± 3.9	300 ± 2.8	867 ± 22.6	415 ± 8.6	536 ± 21.3	115 ± 9.9
Busia[b]	222 ± 1.7	118 ± 0.3	321 ± 1.9	243 ± 0.6	862 ± 11.9	418 ± 2.9	541 ± 12.7	175 ± 2.9
Kisii[b]	184 ± 1.8	140 ± 1.1	246 ± 2.1	210 ± 1.0	733 ± 6.4	334 ± 15.7	487 ± 5.3	134 ± 15.9
Vihiga[c]	227 ± 1.9	128 ± 1.0	359 ± 2.3	331 ± 1.5	785 ± 12	423.1 ± 7.1	426 ± 13.4	92 ± 7.0



In all districts, mean number of *Striga* emerged and % stemborer damaged plants where significantly higher in the maize monocrop while grain yields were significantly higher in the push-pull plots (p<0.0001)

Mean number of emerged Striga hermonthica per plot, proportion of stemborer-damaged plants per plot, and average maize grain yields (t ha¯1) from maize monocrop (shaded bars) and pushï pull plots (striped bars) in different districts in western Kenya. Means represent data averages from 30 farmersôfields per district over three cropping seasons (long and short rains 2007, and long rains 2008).

Future direction

Cereal production biotic constraints addressed by the pushï pull system: (a) Striga hermonthica weed; (b) maize grown alone damaged by Striga; (c) stemborer larva inside a stem; (d) maize intercropped with Desmodium uncinatum and not damaged by Striga.

i. The push pull strategy is a powerful and effective IPM tool
ii. Several new technologies may help develop and improve future push pull technology

iii. On station and on farm trials have also demonstrated that push pull strategies could also be used for control of stem borer in sorghum and millets

iv. Although the experience to date has been restricted to cereal based farming system, we belive that the general approach is applicable to a much wider range of pest problem in variety of crop and thus can serve as a model for other researcher in their efforts to minimize pest induced yield losses in an economically and environmentally sustainable manner.

v. Changing attitude towards replacing broad spectrum insecticides with new technologies, particularly seminochemical tools, to manipulate the behavior of natural enemies for improved biological control will enable push pull strategy to be developed and used more widely in the future

Disadvantages

i. The major constraint to widespread technology transfer of push pull has been availability of desmodium seed.

ii. Diffusion and adaptation of technology

When discus a push pull strategy with farmer some question asked by farmer

Q. 1 What is the maximum and minimum size of the Push-pull plot?

Ans= A Push-pull plot can range from 50 m X 50 m to any size of the farm provided the fields are demarcated into 50m by50m using border rows of Napier grass

Q2. How long can the Push-pull plot be kept?

A. You could benefit from your Push-pull plot for 5 or more years if well managed

Q3. Can I graze my cattle directly on the Push-pull plot?

A. No. Grazing destroys desmodium and Napier grass

Q.4 Are there alternatives to Napier grass and desmodium?

A. Yes. Forage sorghums like Sudan grass can be used to trap stemborers instead of Napier grass and molasses grass can be used to repel stemborers instead of desmodium. However, molasses grass does not control Striga weed.

Q5.` Can I plant maize first, then Napier grass after a few weeks?

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

Q6. Can I use Push-pull on sorghum?

A. You can intercrop Greenleaf desmodium with sorghum to repel stemborers and control Striga weed.

Q7. How effective is Push-pull against stemborer and striga weed?

A. Push-pull is very effective. It is even better than insecticides for the control of stemborer and better than manual removal of striga weed, both in terms of cost and effective control.

Q8. If I don't have desmodium seed, can I plant only Napier grass in my Push-pull plot?

A. Yes. If you plant only Napier you will be able to reduce stemborers on maize but you will not be able to control striga weed

Q9. Can I use other species of desmodium other than silverleaf?

A. Yes. You can use Greenleaf desmodium, but the results of silverleaf with maize are the best. Greenleaf desmodium do best in

in dryer areas.

Push-pull in control of urban pest

Control of domestic (urban) pests that infest our homes, workplaces and other public building relies heavily on use of chemical insecticides. The use of toxic chemicals in these places , particularly schools and hospitals, is often impractical or undesirable. Push-pull may offer effective, non-toxic solution to control some of these pests.

Control of Cockroaches

1) Aggregation in the German Cokroaches (*Blattella germanica*) is induced by pheromones contained in their frass. The pheromones comprise volatile attractant (several alkylomines and(R,S) -1-dimethylamino-2-methyl-propanol) and contact chemoreceptive arrestants (blattellastanoside-A and ï B derived from ɓ-sitosterol)

2) Attractant and pheromones are ued commercially in attracticide traps forcockroaches

3) A push pull strategies comprising the insect repellent N-methylneodecanamide and a feses (i.e. pheromone-containing)-contaminated surface as attractant with insecticide based food bait has been evaluated.

4) The push pull treatment effective than individual components and the control in influencing cockroach distribution , bait intake percentage and speed of mortality

5) This strategy is improved by using Biopesticides based on the entomopathogen *M. anisopliae* are registered for cockroach control in some countries

6) Also chemical derived from the Catnip plant (*Nepeta caturia*) are being developed as botanical repellents and could replace synthetic repellents as push component in this strategy.

7) In laboratory test, catnip essential oil performed better than DEET in repelling cockroaches

Push-pull strategies for control of veterinary and medical pests

A. Control of mosquito

Push-pull strategies may control disease transmitting flies of medical importance, such as mosquitoes and biting midges by exploiting natural differential attractiveness within a host species or using botanical repellents as push stimuli and attracticides based on host odors or attractive pheromones as pull stimuli.

However this strategies have yet to be tested.

Push-pull technology in Horticulture

A) Control of Onion maggots on onion

1) *Delia antique* is an important pest of onion (*Alium cepa*) in northern temperate regions (Canada,Europe,and US)
2) Onion culls (small or sprouting unmarketable bulbs) Have been used as a trap crop. It used to divert oviposition from seedling onions
3) Unless fly densities are unusually low this strategy alone is unlikely to provide adequate control and a push pull strategies has been suggested
4) Cinnamaldehyde was selected as a promising oviposition deterrent
5) And push pull strategy comprising potted cull onions as trap plants and seedling treated with cinnamaldehyde (50% formulated in activated charcoal)
6) Each component reduced oviposition significantly after 2 days, but they had the greatest effects when combined together as a push pull treatment

Although this strategy still remains to be tested in the field

B) Control of Thrips pm Chrysanthemum

i. Western flower thrips (*Frankliniella occidentalis*) are a serious pest of greenhouse ï grown Chrysanthemum

ii. They cause feeding damage and transmit viruses and their presence is unacceptable in flowers for market

iii. The predatory mite *Amblyseius cucumeris* is used in IPM strategies but prey on first instar larvae and control is not always maintained

iv. The predatory bug *Orius laevigatus* has potential for controlling thrips on flower and predatory mites *Stratiolaelaps* mites and *Gaeolaeps aculifer* showed potential for controlling ground dwelling thrips stages.

v. To make such a combination of predators economical, a push pull strategies being developed to push thrips from targeted plants and concentrated them onto trap plants where predators are released or maintained.

vi. Volatiles of the non-host plant rosemary (*Rosmarinus officinalis*) showed potential to be used in this strategy as thrips repellents but they were also repellent the predatory bugs O.*laevigatus*

Negative effect of push pull components on beneficial should be minimized, so the antifeedant polygodial (Extracted from *Tasmannia stipitata*) was selected for use as a push in this system

Vii For practical reasons , a pull based on preferred cultivars of Chrysanthemum was sought by growers and a bronze coloured cultivar Springtime was found to be most attractive and provided pollen for the maintenance of predators in the absence of thrips

Viii Trap plants were effective when baited with the attractive host plant volatile Eɓf, reducing infestation on the antifeedant treated main crop

Ix The thrips alarm pheromone decyl and dodecyl acetateand the recently indentified aggregation pheromone (R)-Lavandutyl acephate and neryl(S)-2-methyl butanoate may be suitable as additional push-pull components respectively.

X The alarm pheromone increased take off and decreased landing rates in Adults .

Push pull for livestock pest and disease vector

I. Combination of repellent and attractant semiochemistry may also find use in push pull tactics for control of livestock pest and disease control.

II. The adult of the brown ear tick, *Rhipicephalus appendiculatus* , the vector of the cattle disease East Coast Fever (*theileria*), have been shown to be push pull semiochemistry to locate bovid ears

III. Thus , odour collected from the anal region repels the tick and that from ears will attract it.

IV. Interestingly in related species ,*Rhipicephalus eversti* ,which prefers to feed around anal region, the two semiochmicals perform the opposite function.

V. Characterization of the attractant semiochemical may allow the development of push pull tactic that combine the use of a source of a synthetic or botanical tick repellent at the with fungal pathogen or acariside on the back of the animal.

VI. A preliminary experiment undertaken on the Kenyan coast, comparing the effect of protecting cattle with a synthetic repellent (push), baited trap (pull) and a combination of theretwo (push-pull) suggests better performance of push pull approach for control tsetse fly.

Advantages of Push-pull strategy

I. Increased efficiency of individual push and pull component

Individual elements may fail because their effect are not strong enough to effect control on their own

For exam. Trapping strategies using attractive baits may have a significant impact on species with low reproductive rate But fail for species with high repreocutive rate

By adding on other component with negative effect on host selection, the preference differential is increased and additive effects may reduce pest to below economic threshold

Further more the efficiency of push and pull behavior controlling elements is often not only additive but synergetic

II Improved potential for antifeedants and ovipostion deterrents

The use of these tactics in IPM is often limited or ineffective because of habituation or host deprivation, in the absence of more suitable hosts.

By adding pull stimuli, a choice situation is created and alternative feeding or oviposition outlets are provided, which can mitigate there effects

III Increase efficiency of population reducing components

As the pest population are concentrated in predetermined areas (either trap or trap crops). Less chemical or biological control material is required to treat the pest population thereby reducing cost.

Leaving areas untreated also provide on enhanced opportunity for the conservation of natural enemies and other non targeted organism

IV Resistance management

Because the behavior modifying stimuli used in push pull technology are used in combination and are not highly effective when used alone, the components does not select strongly for resistance.

The strategy is generally compatible with the use of conventional insecticide and the reduction in the amounts required for control reduces the opportunity for pest to develop insect resistance.

In some cases, non insecticidal component can replace the need for insecticides, push pull strategies could also contribute to resistance management of Bt crops

Disadvantages of push pull

i. **Limitation to development**

A good understanding of behavioral and chemical ecology of the host pest infestation and effect of the strategies on beneficial is essential but requires considerable research efforts.

If knowledge is insufficient , control may break down. Development of semiochemical component is often limited by formulation and delivery technology.

ii. **Limitation to adoption**

An integrated approach to pest control is more complex, requiring monitoring and decision system

More belief on insecticide and low knowledge of biological control agent

Future for push pull technology

- The continued spread of insecticide resistance and the withdrawal of insecticides due of legislation leave few other alternatives. Adoption would increase
- Push pull targeted at predator and parasitoid, while enable to manipulation of their distribution for improved biological control, are just around the corner. This prospect will allow these strategies to applied in novel ways and increase their use in IPM in future
- Changing attitudes towards replacing broad spectrum insecticide with new technologies, particularly semiochmical tools, to manipulate the behavior of natural enemies for improved biological control will enable improved push pull strategies to be developed and used more widely in the future

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