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Push-pull strategy: Novel approach of pest management

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Abstract
The production of agriculture is limited by many factors like soil, water, genetic potential of crops and organisms that feed on or compete with food plants. Food crops are damaged by more than thousands of insect pest species. The new alarming facts have prompted efforts on the safer, reduced-risk and environmental compatible method of pest control with the objective to maximize crop productivity. The push-pull strategy, which is novel approach of pest management by combination of behavior-modifying stimuli to manipulate distribution and abundance of insect pests and natural enemies. Insect pests are repelled from the food crop and are simultaneously attracted to a trap crop where they are concentrated, facilitating their elimination. The push and pull components are generally nontoxic. The strategy is a useful tool for integrated pest management programs reducing pesticide input. Therefore, the strategies are usually integrated with methods for population reduction, preferably biological and cultural control.

Keywords: Attractant, behavioral manipulation, push–pull, repellent, semiochemicals, trap crops

Introduction
To ensure the food security for growing population we are much rely upon pesticide to curb the pest of economic crops. However, they cause detrimental effect on environment and biodiversity, also hazardous to the water ecosystem. In India, non-judicious and higher consumption of pesticide leads to residue on/in food and water which indirectly consumed by human. Since, the pesticides are hazardous with high cost and also have problem of resistance development with time [1]. So, we opt new strategy for the conservative and utilization of resources available to modifying the behavior of insect pest affecting the crops for sustainability in agriculture production by reducing the cost of pest management. The effect of push pull strategy adoption is decisive topic because which allow farmers to increase their maize productivity and incomes without increasing their impact on the surrounding environment or their reliance on frequently unreliable agricultural input markets.

Push Pull Strategy
It is innovative approach of pest management, based on the stimulo-deterrent diversionary strategy or push–pull system. A "push–pull" strategy is a cropping system in which specifically chosen companion plants are grown in between and around the main crop. These companion plants release semiochemicals that fend off insect pests from the main crop using an intercrop which is the "push" component and concurrently attract insect pests away from the main crop using a trap crop which is the "pull" component [1]. First time, Australians Pyke and co-workers coined the term push-pull, as a strategy, for insect-pest management. They used repellent and attractive stimuli, arranged in tandem, to maneuver the distribution of *Helicoverpa* species in cotton, there by plummeting reliance on insecticides, to which the insects were becoming resistant to insecticides [2].
The strategy rely upon the principle of main crop is cosseted by negative cues that trim down pest colonization and development, that is, the ''push'' effect. This is achieved either directly, by amending the crop, or by companion crops grown between the main crop rows. Simultaneously, the modified crop, or the companion crop, also creates a means of take advantage of natural populations of beneficial organisms by liberating semiochemicals that attract parasitoids or amplify their foraging. The ''pull'' effect involves trap plants was grown around at perimeter of the main crop and which are attractive to the pest egg laying. The population was reduced by using trap plants, integrating a natural pesticide, or some intrinsic

plant defense. Push–pull may use processes, largely based on semiochemical, each of which, separately, not much effective for pest control. However, the integrated effect must be stout and effective.

Components of Push Pull System:

Push components:

Visual cues: Alteration of shape, size and colour which lead to development of disturbance in pest population which can be utilized in integrated pest management (IPM) [1, 3, 4].

Repellents: Chemical which repel or push the pest from main crop which can be utilized as push component in this strategy. Frontalin acts as repellent i.e. push the coffee berry borer *Hypothenemus hampei* from coffee [5].

Non Host Volatiles: Non host volatiles which disturb the utilization of host plant when intercrop with main crop [1].

Host Volatiles: The herbivore-induced plant volatiles (HIPVs) are produced by plant when herbivores feed on them. The herbivore-induced plant volatiles (HIPVs) can deter plant utilization by subsequent herbivores as indicators of competition or induced defenses [1].

Alarm pheromones

The social insects, including Hymenopterans and gregarious Hemipterans, have developed a diverse blend of chemical compounds that function as releasers of alarm behavior [6, 7]. Alarm pheromone released when attacked by the natural enemies, causing avoidance or dispersal behavior in conspecifics [8]. Many aphid species release (*E*)-β-farnesene (*E*βf) as alarm pheromone [9]. On main crop application of alarm pheromones which ward off aphids in the field and *E*βf also functions as a kairomonal activity to pull natural enemies of aphids [10].

Antifeedants

Several antifeedants, including azadirachtin (the primary active component of neem, derived from *Azadirachta indica*), applied as neem seed kernel extract in cotton against *H. armigera* [11]. However other plants also have antifeedent compounds viz. pongamia, eucalyptus, melia, *Annona*.

Oviposition deterrents and oviposition deterring pheromones

Oviposition deterrents and oviposition-deterring pheromones (ODPs) are compounds that prevent or reduce egg deposition and so it can be corporate in the push-pull strategies to control species that cause damage through this process or whose imagoes are pestiferous [2, 12]. During egg laying both parasitic and phytophagous insects are known to deposit chemical signals that modify the behaviour of conspecifics who consequently stay away from depositing eggs into host that are oviposited by others [13]. The deterrents isolated from nonhosts plants have deterring oviposition of pests, and of these, frequently evaluated formulation was neem-based formulations and some other plants are also used [11, 14, 15].

Pull Components

Visual stimulants

The visual cues related to the plant growth stage can be important sole method used to attract pests to traps or trap crops, but they can enhance the effectiveness of olfactory stimuli [3, 16]. Sexually mature apple maggots, *Rhagoletis pomonella* attracted towards, red spheres (7.5 cm in diameter) mimicking ripe fruit [16]. These traps, coated with either sticky material or contact insecticides and baited with synthetic host odors, have been used successfully for management of pest [17, 18].

Host volatiles

For monitoring, mass-trapping, or in attracticide strategies host volatiles used in host allocation of bait traps. HIPVs are often reliable indicators of the presence of hosts or prey to predators and parasitoids and are therefore attractive (pull) to these beneficials [19, 20]. The conophthorin acting as the 'pull' (attractant) for *Hypothenemus hampei* reported by Njihia *et al*. 2014 [5].

Sex and aggregation pheromones

Sex and aggregation pheromones are released by insects which attract conspecifics for mating and optimizing resource use. Both types of pheromones are increasingly important components of IPM, particularly in pest monitoring in crop developmental stages [21].

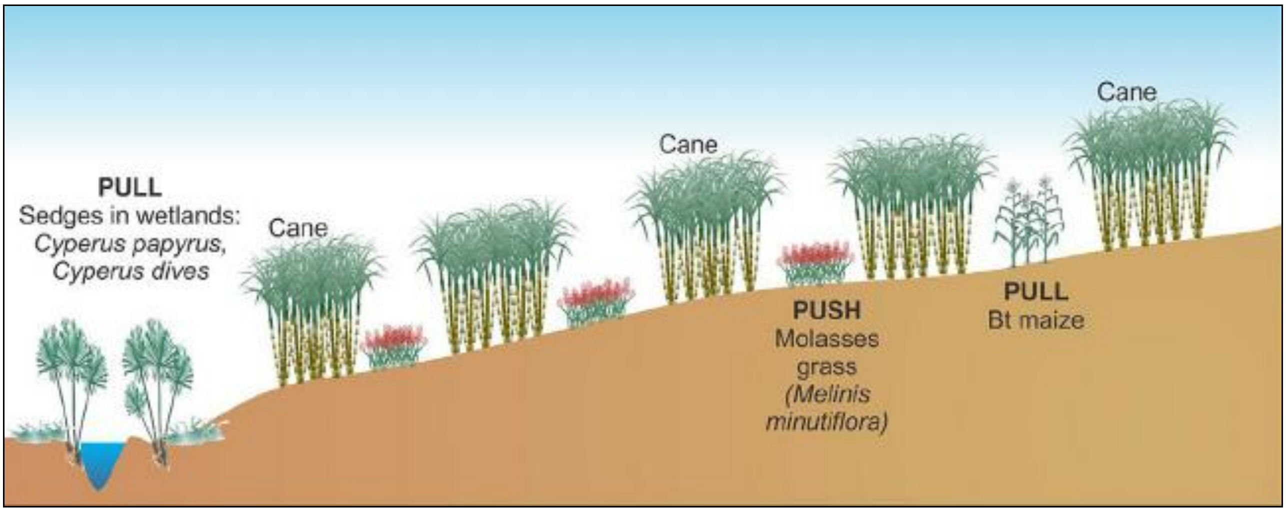
Gustatory and oviposition stimulants

Oviposition or gustatory stimulants produced by the trap crops, which help in pull the pest populations from main crop to trap crop area. The gustatory stimulants, such as sucrose solutions, to increase the ingestion of insecticide bait when applied to traps or trap crops [2, 18]. Some of crops attract and supply the food may also help to establish populations of natural enemies and influence their distribution [22]. The hydrolysed proteinaceous baits as a food odour were lingering to catch a broad series of tephritid fruit fly species and are still in use in lure [23, 24].

Table 1: Push Pull strategy used in crops for management of pest.

Insect Pest	Crop	Components		Reference
		Push	Pull	
Chillo partellus Busseola fusca	Maize and Sorghum	Molasses grass (*Melinis minutiflora*), silverleaf desmodium (*Desmodium uncinatum*)	Napier grass (*Pennisetum purpureum*) or Sudan grass (*Sorghum vulgare sudanense*)	[25]
Meligethis aeneus	Oilseed rape	Perimeter turnip rape trap crop	Cultivars of oilseed rape with low proportions of alkenyt glucosinolates	[26]
Frankliniella occidentalis	Chrysanthemum	Volatiles of the non host plant rosemary	Polygodial (extracted from *Tasmannia stipitata*)	[27]
Helicoverpa armigera	Cotton	Neem seed kernel extracts to the main crop	Trap crop, either okra or pigeon pea (*Cajanus cajan*)	[5]
Chillo partellus	Maize	Silverleaf desmodium (*D. uncinatum*)	Napier grass (*Pennisetum purpureum*)	[28]
Eldana saccharina	Sugarcane	Molasses grass (*M. minutiflora*),	Bt maize and indigenous wetland sedges *Cyperus papyrus*	[29]

Spodoptera frugiperda	Maize	Greenleaf desmodium, *Desmodium intortum*	*Brachiaria* cv Mulato II	[30]



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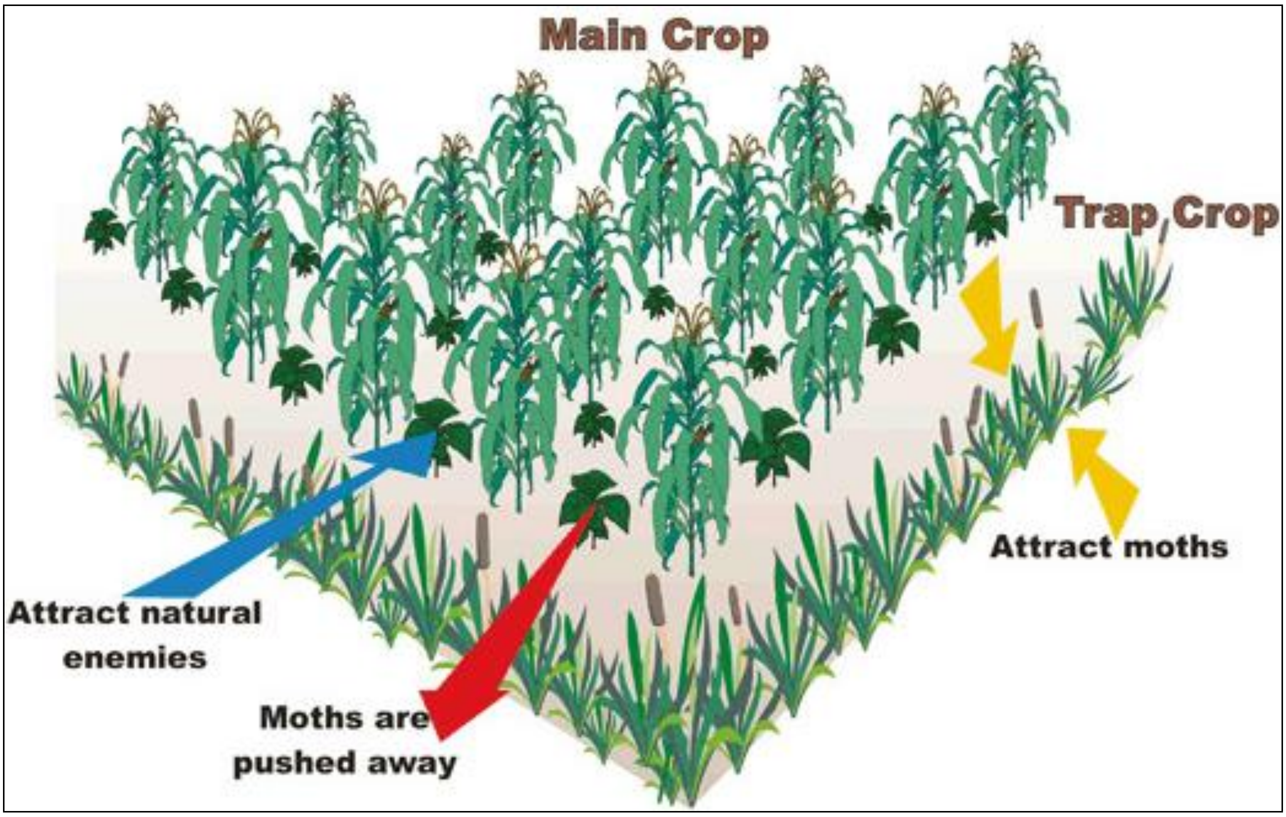

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Fig 1: Pictorial representation of Push Pull Strategy used in a) Sugarcane for management of *E. saccharina,* [28] b) Maize for management of *C. partellus,* [29]. The push-pull strategy it can be become decisive component of IPM. However, its prospective has been underexploited. This strategy helps in sustainability of not only food grains but also indirectly increase the milk production by fodder crops.

Conclusion

The principles of the push-pull strategy are used to minimizing detrimental effect on environment while maximize control efficacy, competency, sustainability and outputs. Although each individual component of the strategy may not be as effective as a broad-spectrum insecticide at reducing pest numbers, the efficacy of push and pull components is increased through tandem deployment. The push and pull components are generally nontoxic and can be useful for the small and marginal farmers by reducing cost of cultivation and indirectly uplift the standard of living. Hence, the strategies are usually integrated with biological control and cultural control for management of pest.

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