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Push-pull strategy: A sustainable approach for integrated pest management

R K Kapadia[1*], H R Desai[2], G B Chopada[1], I M Hirapara[3], S A Rathod[1]
[1] Department of Plant Pathology, N. M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India
[2] Main Cotton Research Station, Navsari Agricultural University, Surat, Gujarat, India
[3] Department of Entomology, N. M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India
Corresponding Author: R K Kapadia
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Abstract
Push–pull strategy is an eco-friendly and sustainable approach in Integrated Pest Management (IPM) that manipulates pest behavior through the use of repellent and attractive stimuli. In this system, companion plants or semiochemicals are used to repel pests away from the main crop ("push") while trap crops or attractants decoy them toward a different location ("pull"). The strategy relies on visual cues, host and non-host volatiles, pheromones, antifeedants and oviposition deterrents to effectively manage insect pests while reducing dependence on chemical pesticides. Push–pull systems not only provide efficient pest suppression but also enhance biodiversity, environmental safety and crop productivity. This review highlights the principles, mechanisms, components, advantages and limitations of push–pull strategies along with examples of their applications in different cropping systems. Despite challenges such as complexity in implementation and the need for detailed ecological knowledge, push–pull technology has emerged as a promising alternative for sustainable agriculture and long-term pest management.

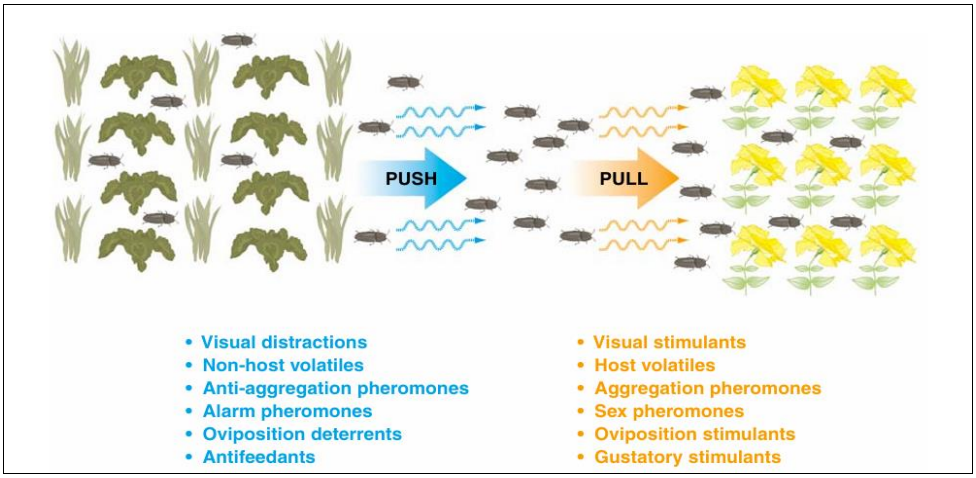
Keywords: Push, pull, repellent, attractants, semiochemicals, eco-friendly

Introduction

Pest management is the science of preventing, reducing or eliminating organisms that cause harm or damage. Integrated Pest Management (IPM) refers to the coordinated use of different pest control methods in a way that considers the ecology of the environment and the interactions between pests, crops and beneficial organisms. IPM focuses on managing pests effectively while minimizing negative effects on the environment, human health and the economy. By using a combination of cultural, biological, mechanical and chemical methods, IPM reduces reliance on chemical pesticides and promotes safer, sustainable pest control practices whenever effective non-chemical alternatives are available (Swami *et al.,* 2022) [12].

The term push-pull was first conceived by Pyke *et al.* (1987) [9] as a strategy for insect pest management. A "push–pull" strategy is an innovative cropping system where carefully selected companion plants are cultivated both among and around the main crop. These companion plants emit specific semio-chemicals that repel insect pests from the main crop (the "push" effect) while simultaneously attracting them toward a more suitable trap crop (the "pull" effect). The core principles of this approach focus on achieving effective, efficient and sustainable pest control with enhanced productivity, while minimizing any negative impact on the environment.

Principle, Mechanism and components of the push-pull strategy



(**Source:** Cook *et al.,* 2007) [6]

Fig 1: Diagrammatic representation of the push–pull strategy showing its major components and their generalized mode of action in pest management

The push–pull strategy is an ecologically based pest management approach that manipulates insect behavior through the strategic use of semiochemicals and companion plants. In this system, repellent stimuli ("push") such as non-host volatiles, alarm and anti-aggregation pheromones, visual distractions and oviposition deterrents are employed within or around the main crop to drive pests away. Simultaneously, attractive stimuli ("pull") including host plant volatiles, aggregation and sex pheromones, visual cues and oviposition or gustatory stimulants are used to lure pests toward trap crops planted at the field margins. This dual mechanism effectively reduces pest colonization and feeding on the primary crop by altering host-selection behavior and concentrating pest populations in manageable areas. The push–pull strategy has gained considerable attention as a sustainable and environmentally friendly alternative to chemical control, contributing to reduced pesticide dependence, enhanced biodiversity and improved crop productivity.

Push and Pull components of push-pull strategy

Push components				
Components	**Crop**	**Target Pests**	**Mechanism**	**Reference**
Visual cues	Cotton	Leafhopper –Trichomes on Leaf midrib/lamina	Manipulation of host color, shape or size to inhibit host orientation and acceptance behaviors of pests	Cooke *et al.* (2007) [6]
Synthetic repellents	Citronella	Cockroaches and invasive lady beetles	MNDA(N-methylneodecanamide) and DEET (N, N-diethyl-3-methyl benzamide) repel hematophagous insects.	Cooke *et al.* (2007) [6]
Non host volatiles	Tomato Cabbage	Spotted spider mite, cabbage looper, cabbage butterfly	Mask host odors or evoke non host avoidance and repellent behavior	Reddy *et al.* (2004) [10] Atshan *et al.* (2017) [3]
Host-derived semiochemicals	Potato, Apple	Potato bee, Codling moth	Insects recognize suitable hosts by using key volatiles that are often present in specific ratio. Directed host orientation ceases if host odor is presented in inappropriate ratio. Repellent behaviors may be elicited if the host odors signal poor-quality hosts.	Cooke *et al*. (2007) [6]
Soybean based semiochemicals	Soybean	Bean bug	Repels bean bug (*Riptortus pedestris*) from soybean plants Induces avoidance behaviour and prevents crop colonization	Song *et al.* (2023) [11]
Anti-aggregation pheromones	Pine tree	Bark beetles	Attractive at low concentrations but repellent at high concentrations (*i.e.,* in crowded conditions)	Cooke *et al.* (2007) [6]
Alarm pheromones	Amaranth	Aphids	Causing avoidance or dispersal behavior in conspecifics	Cooke *et al*. (2007) [6]
Antifeedants	Castor	Caterpillar *Spodoptera litura*	Prevents or interrupts feeding activity by contact chemoreception or by post gustatory effects	Arivoli and Tennyson (2013)
Oviposition deterrents and oviposition deterring pheromones	Cherry trees, Cabbage	Cherry fruit fly, Diamondback moth	Prevent or reduce egg deposition	Cooke *et al*. (2007) [6] Basukriadi and Wilkins (2014) [4]
Pull components				
Components	**Crop**	**Target Pests**	**Mechanism**	**Reference**
Visual stimulants	Apple	Apple maggots	Red spheres (7.5 cm in diameter) mimicking ripe fruit attracted	Cooke *et al.* (2007) [6]
Host volatiles	Paddy	Stem Borer	α-pinene as a key component in inducing repelling activity	Yi *et al.* (2019)
Sex and aggregation pheromones	Little Gourd	Little gourd fruit fly	Male produced pheromones that attract females over a long range are most useful in direct control strategies. Host plant odour can enhance or synergize the attraction of herbivores to sex and aggregation pheromones.	Datkar *et al.* (2018) [7]
Gustatory and oviposition stimulants	Peach fruit	Peach fruit fly	Gustatory stimulants, such as sucrose solutions have also been applied to traps or trap crops to promote ingestion of insecticide bait.	Aleryan *et al.* (2006) [1]

Advantages of Push–Pull Strategies (Chatterjee and Kundu, 2022) [5]

Push–pull strategies offer several advantages compared to conventional pest management approaches, including:

- Effective attraction of both juvenile and adult insect stages
- Use of simple, low-cost, and commercially available components
- Enhanced effectiveness of individual push and pull elements, leading to better pest population reduction
- Greater scope for incorporating antifeedants and oviposition deterrents
- Useful in delaying or managing the development of pest resistance

Disadvantages of Push–Pull Strategies (Chatterjee and Kundu, 2022) [5]

Despite their benefits, push–pull strategies also have certain limitations compared to conventional pest control methods. Some common disadvantages include:

- Limited specificity against certain pests
- Reduced effectiveness when competing with strong surrounding odor sources
- Challenges in development due to:
- Need for detailed understanding of pest behavior and chemical ecology
- Insufficient knowledge that may lead to failure in pest control
- Difficulty in developing suitable semiochemical components
- Challenges in adoption because:

- The approach is more complex and requires integrated pest management practices
- Regular monitoring and decision-making systems are necessary
- Greater dependence on biological control knowledge and reduced reliance on insecticides

Conclusion

The push–pull strategy represents an important advancement in sustainable pest management by integrating ecological principles with crop protection practices. Its ability to modify pest behavior through the strategic use of repellent and attractant stimuli offers a practical alternative to excessive chemical pesticide use. Beyond pest suppression, this approach contributes to ecological balance, conservation of beneficial organisms, and improved resilience of agricultural systems. Successful adoption of push–pull technology depends on proper understanding of pest ecology, selection of suitable companion crops, and effective field management. With continued research, farmer awareness, and technological refinement, push–pull strategies can play a significant role in promoting environmentally responsible and economically viable agriculture in the future.

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