

A Review of Intercropping's Function in Sustainable Insect-Pest Management

Arshdeep Singh¹, Shimpy Sarkar²

Department of Entomology, School of Agriculture, Lovely Professional University, Phagwara 144 411, Punjab, India

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ABSTRACT

The review's findings showed that: (1) DDTs and HCHs are more prevalent pesticides in rice grain and agricultural soil than other OCP isomers; (2) the OCPs forbid DDTs and HCHs; (3) recent and past pesticide applications are the main causes of pesticide contamination in agricultural soil; and (4) children are more susceptible to pesticides than adults. In order to limit public access to pesticides, regulatory bodies have been advised to step up surveillance of banned pesticides and swiftly phase out particularly hazardous chemicals through national policy and implementation. The list of approved/permitted pesticides must be routinely reviewed in order to correctly distinguish between restricted, prohibited, and general-use pesticides. The use of less pesticide-dependent alternative farming techniques, the creation of new pesticides with unique modes of action and enhanced safety profiles, and the improvement of currently used pesticide formulations toward safer formulations are all ways to mitigate the negative effects of pesticides. The top three policy objectives are to reduce pesticide use (promoting IPM), enhance pesticide controls (quick policy action to phase out OCPs), and fund research toward safer alternatives (creating biopesticides).

Keywords: Environmental impacts; intercropping; pesticide; sustainable pest management; insect ecology; environmental safety; pest infestation.

INTRODUCTION

To feed the 9.6–12.3% rise in the world's population by 2100, agricultural production must double (100–110%) from its 2005 level [1,2]. Pest-related crop production losses of 10–16% [3,4] constitute a serious danger to entire global regions and drastically lower agricultural yield [5,6,7,8]. Additionally, there is rising fear that in the upcoming decades, pest damage to plants will rise due to climate change [9,10,11]. For every degree of global mean surface warming, yield losses of wheat, rice, and maize are expected to rise by 10 to 25%. In a forecasted scenario of a 2°C warmer climate, the average increases in yield losses caused only by pest pressure are 59, 92, and 62 metric megatons annually for wheat, rice, and maize, respectively [12]. The detrimental effects of synthetic pesticides [13] on the environment and human health [14], as well as their decreased effectiveness due to insect population resistance [15], have led to an increase in the use of alternative control techniques within the context of integrated pest management (IPM). Two popular IPM techniques that are frequently employed to attain long-term control are the "push-pull" approach and the addition of biological control agents [16,17]. Using volatile plant chemicals to affect insect behaviour is a key component of push-pull tactics [18,19,20]. Insects employ volatile substances that plants produce to detect and identify possible food and breeding plants [21,22]. Because they release volatiles with repellent or deterrent qualities in response to an attack, non-host plants (such as aromatic plants) can be used to make insecticides, anti-feedants, or insect repellents [23,24]. However, the "appropriate/inappropriate landings theory" contends that by providing insects with a choice of green surfaces to land on (both host and non-host plant leaves), the presence of non-host plants may impede host-plant seeking and host-plant acceptance behaviour [25, 26]. The effectiveness of biological control can be increased by attracting natural enemies to the region through intercropping, especially with aromatic plants [27,28], supplying food resources [29,30,31], or offering refuge and oviposition locations. To maximise pest management in intercropping systems, it is critical to assess how intercropped plants affect both pests and natural enemies [32]. In this context, an effort was made to examine the

existing literature, gather data on intercropping research conducted globally over time, and search for potential insights for further studies in this field. Intercropping is a long-standing agronomic technique that increases crop productivity and income [33, 34, 35, 36, 37, 38]. It is a very helpful tactic to lower the incidence of diseases and pests and to promote the development of natural predators [39]. The strategic use of intercropping and the planting of crops that can kill or repel pests [40,41], attract natural enemies [42,43,44], or have antibacterial effects in between the rows of economic crops [45,46,47,48] can reduce the damage caused by diseases and pests and lower the need for pesticides. Additionally beneficial to the economy, intercropping, which encourages plant diversity, can increase agricultural productivity and guarantee higher and more reliable returns [49]. It is therefore better suited to small farms that need a lot of human labour because it offers greater financial assurance than monoculture. Additionally, intercropping lessens the negative effects of agriculture on the environment by reducing the requirement for fertiliser and pesticides [50]. environment and making it possible to manage biological insect pests more successfully.

1. OBJECTIVES OF INTERCROPPING

The major objectives of intercropping include

1. It can serve as an alternate for generation of additional income through crop diversification.
2. .
3. It can serve as a potential alternative for enhancing land use efficiency by occupation of limited arable land under diverse crops.
4. It can serve as a soil fertility booster by improving the soil microflora and ecological diversification in soil It can help in minimizing the dependency on chemical fertilizers especially under legume intercropping system through improvement in soil fertility status and nutrient utilization capacity.
5. Intercropping is aimed at production maximization under limited land availability

2. PROBLEMS ASSOCIATED WITH MONOCROPPING

The practice of using the same land for a single crop year after year is known as monocropping. Although it requires favourable conditions and may result in increased production costs, the concept is perfect for crop production. Nevertheless, the constraints still exist because it offers no insurance in the event of a total crop loss due to weather-related difficulties or the prevalence of pests and illnesses. Among the issues with monocropping are:

2.1 Higher Pest Infestation

The practice of using the same land for a single crop year after year is known as monocropping.

2.2 Higher Pesticide Use

Monoculture crops are more susceptible to diseases and pests due to reduced biodiversity, which increases the need for pesticides to preserve the crop and raises the possibility of pest resistance [52,53].

2.3 Soil Degradation and Fertility Loss

Monoculture farming upsets the delicate balance of soils. The diversity of bacteria and microorganisms decreases and soil nutrients are depleted when the same crop is grown year after year [54].

2.4 Higher Use of Fertilizers

When a single crop is grown on a piece of land, the soil eventually becomes exhausted and depleted since there are no living things to restore its natural diversity. To artificially boost the productivity of their deteriorated fields, farmers frequently employ chemical fertilisers, which upset the delicate ecosystem's equilibrium by changing the natural composition of the soil [55].

2.5 Higher Water Use

If only one type of crop is grown on a piece of farmland, the soil will deteriorate and water will be wasted because the root systems aren't strong enough to hold the soil together. This is why such farmlands have an uneven distribution of water after rainfall. It is necessary for farmers to increase their water consumption to compensate for this loss.

2.6 Decrease in Biodiversity

As a result of the overuse of chemical pesticides in monoculture, biodiversity declines, and the ecosystem as a whole suffers.

2.7 Negative Impact on Pollinators

As pesticide use increases in monoculture, pollinating insects become sicker and eventually die off, and their absence from the ecosystem is a direct result. The use of chemicals has a serious impact on pollinizers and therefore it is often recommended to avoid chemical sprays during bloom.

2.8 Economic Risks

3. A monoculture farm would lose its whole yield all at once in the case of a catastrophic failure in crop development, such as an exceptionally protracted drought, unusually heavy rainfall, or an infestation of a particularly virulent strain of a pest [56].

3.1 Environmental Degradation

Chemicals are overused in monoculture, leading to environmental degradation. These chemicals not only deteriorate the soil health but also lead to deterioration of soil micro beneficial microbes [57].

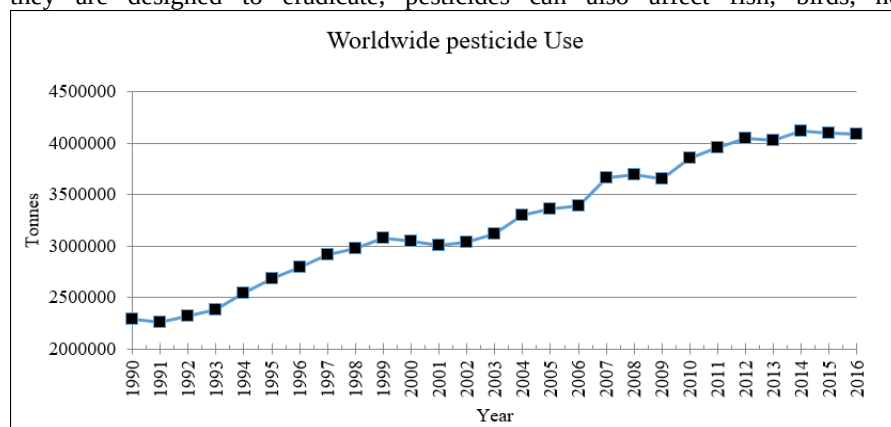
4. PESTICIDE CONSUMPTION IN WORLD AND INDIA

Pesticides are chemicals or mixtures of chemicals designed to mitigate the target pest in order to minimise or eliminate losses caused by biotic species, such as weeds, illnesses, insects, etc. A chemical or biological substance, such as a virus, bacteria, antibiotic, or disinfectant, that deters, incapacitates, or eliminates pests is commonly referred to as a pesticide. It is commonly used to control or eradicate a variety of agricultural pests that can damage crops and livestock and reduce farm productivity. Pesticide use and production are increasing globally (Fig. 1). India started producing BHC in 1952 at a factory in Calcutta, and according to the Food and Agriculture Organization, it is currently the largest pesticide producer in Asia, second only to China, and the twelfth worldwide. India produced 5,000 metric tonnes of technical grade pesticides in 1958; by 1998, that number had risen to 102,240 metric tonnes. The global demand for pesticides was predicted to reach Rs. 22 billion (USD 0.5 billion) in 1996–1997, or around 2% of the market [58]. According to the graph, India's use of pesticides has increased hundreds of times over the past seven decades, from 154 MT in 1953–1954 to 57,000 MT in 2016–17. Between 1994 and 1995, India utilised 80,000 MT of pesticides in a single year [59]. In 2016–17, Maharashtra had the greatest pesticide usage, followed by Uttar Pradesh, Punjab, and Haryana. Punjab used the most pesticides per acre (0.74 kg), followed by Haryana (0.62 kg) and Maharashtra (0.40 kg) (0.57 kg). The two states of Maharashtra and Uttar Pradesh account for 41% of India's overall pesticide consumption, as seen in Fig. 2. Over 70% of India's crop protection pesticides are used by the six most populous states combined. Many consumers now choose all-natural, non-chemical products over conventional, synthetic ones due to growing health and environmental consciousness. Because of its many beneficial characteristics, including minimal toxicity to non-target organisms, high effectiveness, quick biodegradation, and suitability for use in integrated pest management (IPM) projects, biopesticide is growing in popularity. The possibility of using biopesticides without having a detrimental effect on the ecosystem is well known [60].

4.1 Adverse Effects of Pesticides

Production workers, formulators, sprayers, mixers, loaders, agricultural farm workers, and anybody else who is directly or indirectly exposed can all be significantly impacted by pesticides. This may harm natural diversity in addition to posing major health risks to humans. The majority of these pesticides cause chronic toxicities such as reproductive toxicity, genotoxicity, endocrine disruption, kidney damage, metabolic alterations, liver and bladder toxicity, gastrointestinal issues, etc., in addition to being potential human carcinogens, mutagens, and acetylcholinesterase inhibitors [61,62,63]. • The effects of pesticides on food commodities, such as poisoning and increased crop residue retention, are a major issue, particularly for final consumers. The presence of residues in food products renders the produce unacceptable in international markets in accordance with the stringent guidelines set forth by international food standard committees, such as the FSSAI and CODEX Alimentarius Commission [64,65]. • Two examples of the consequences on the environment

include pollution of water supplies and different types of plant life. In addition to being detrimental to the insects and weeds they are designed to eradicate, pesticides can also affect fish, birds, helpful insects, and non-target plant



s. • In addition to harmful impacts on soil health, such those brought on by persistent pesticides, untreated plant and soil runoff can contaminate surface and subsurface water. • A decrease in pollinator and beneficial soil microbe populations may lead to a loss of biodiversity, which affects soil fertility. • Pesticide sprays can contaminate surrounding soil, air, and non-target plants in a number of ways, including by evaporating into the atmosphere, drifting from the treated area, or falling directly on the plants.

Fig. 1. Pesticide usage and consumption in World

Source: [56]

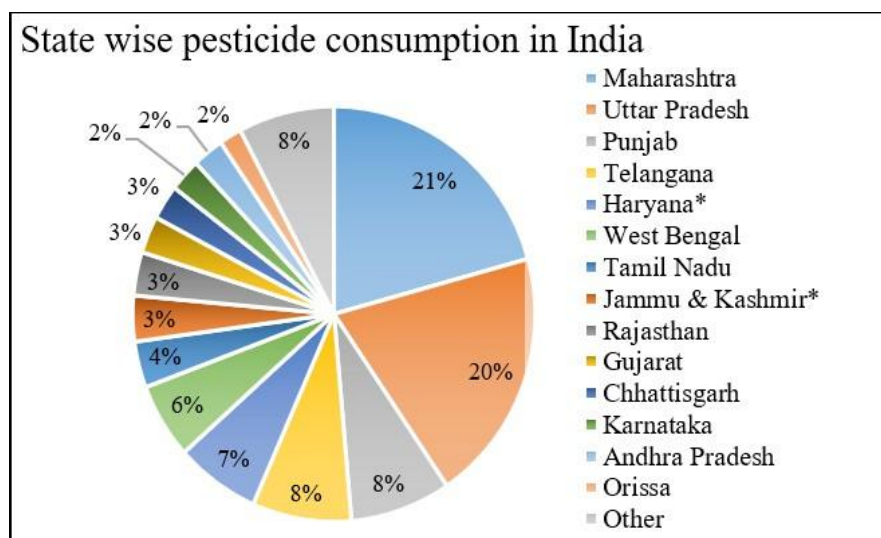


Fig. 2. State wise pesticide consumption in India

Source: [56]

5. INTERCROPPING AS AN ALTERNATIVE TO CHEMICAL PESTICIDES FOR SUSTAINABLE INSECT PEST MANAGEMENT

Intercropping, which involves growing two or more crop species together and allowing them to live for a while, is one of the most important cultural practices in pest control. It is based on the notion that increasing biodiversity in a particular region would result in a decrease in the incidence of insect pests [66].

Thus, lessening the damage caused by illnesses and pests as well as the demand for pesticides can be achieved by growing crops that can kill or repel pests, attract natural enemies, or gain antimicrobial activity in between the rows of profitable crops, as well as by using the right crop pairing for intercropping.

Compared to primary crops, intercropped crops are less likely to be infested by pests. Intercropping has the potential to function as a cultural practice-based pest control method by enhancing crop variety within a particular agro-ecosystem, hence reducing insect populations and the frequency of insect attacks on individual plants (Fig. 3).

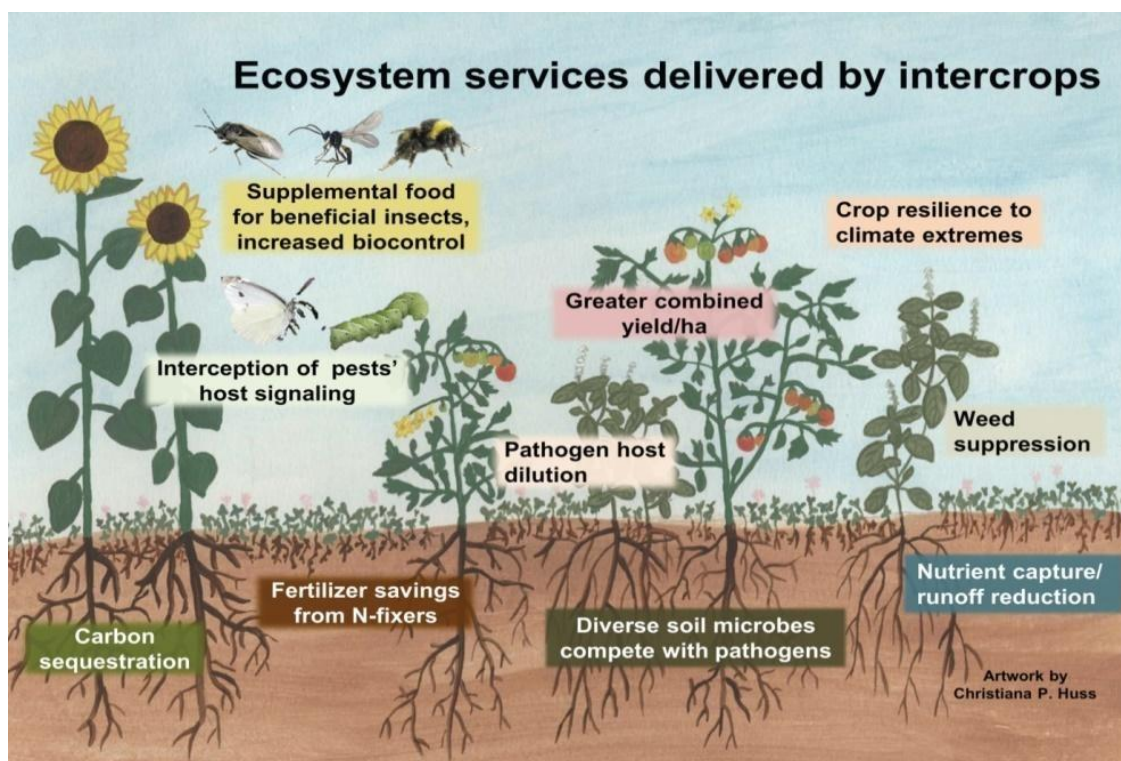


Fig. 3. Illustration of benefits of intercropping

6. TYPES OF INTERCROPPING

6.1 Row-Intercropping

planting two or more crops at simultaneously, one or more of which should be planted in straight rows, while the other crop or crops should be planted randomly or adjacent to each other.

6.2 Mixed- Intercropping

growing two or more crops in a field at the same time without following a set row layout. In pastures where grass and legumes are cultivated in symbiosis, this type may flourish. Planting a variety of crops together helps protect your primary crop from droughts, freezes, and storms.

6.3 Strip-Intercropping

Multi-cropping is the technique of growing two or more crop kinds on a single piece of land in thin strips that are both wide enough to support independent plantings and narrow enough to keep the plants from physically interacting.

6.4 Relay- Intercropping

Multiple crop cultivation during a single growing season. Planting a second crop occurs when the first has completed its reproductive cycle but is still a few months away from being harvested.

6.5 Alley Cropping **Planting rows of food between hedges, trees, or bushes. The strong root systems of taller plants protect the soil from erosion and roots of shorter plants.**

6.6 Trap Cropping

By ensnaring pests, the intercropping technique helps protect the main crop from harm. The underlying aim is to attract disease-causing organisms or pests to the secondary crops rather than the main income crop.

6.7 Repellent Intercropping

One sustainable pest management strategy that may be used in this farming is the use of plants that naturally repel pests. Predators are kept away from the cash crop by the inherent repelling qualities of some plants.

MECHANISMS OF REDUCTION IN PEST INCIDENCE BY INTERCROPPING

One of three ways related plants in an intercropping system might lessen pest or disease assaults is by slowing the attacking organism's rate of population increase. Plants of the attacked component suffer when an associate crop is present (e.g., the host component is smaller and less robust in the intercrop than when sole-cropped). The companion crop dilutes the host plant, making it harder for the attacking organism to cause damage.

The organism's natural predators profit from the associate crop's alteration of the host's habitat.

7. PUSH-PULL AGRICULTURAL PEST MANAGEMENT

"Push-pull technology," which involves intercropping repellent "push" plants with trap "pull" plants, is used to lower the quantity of agricultural pests. For example, a frequent pest of cereal crops such as sorghum and maize is stem borers (Fig. 4). While putting plants like Desmodium in the intervals between the rows of maize helps keep Striga under control and deters pests, spreading grasses around the perimeter of the crop attracts and traps the pests. The push-pull mechanism was developed by Rothamsted Research in the UK and ICIPE in Kenya.

7.1 Principles of Push-Pull Strategy of Insect Pest Management

The push-pull approach aims to minimise unforeseen environmental effects while maximising control efficacy, efficiency, sustainability, and production. A single application of a broad-spectrum pesticide

is more likely to reduce pest populations than any component of the plan. However, performance increases when push and pull components are combined [67]. By relocating them to a single central site, pests may be contained more successfully and their population can be decreased more quickly. For population reduction, biological control techniques or highly selective botanicals are preferred over the use of synthetic, broad-spectrum pesticides. The production of semiochemicals from renewable sources, such as plants, is advised and is becoming more feasible [68]. Harvestable intercrops or trap crops should be used in place of sacrifice crops if you wish to make the most of your farm without going over budget [69]. Developing dependable, durable, and sustainable push-pull methods requires an understanding of the biology of the pest and the behavioral/chemical ecology of its interactions with its hosts, conspecifics, and natural enemies. Every strategy Table 2. Recommended crops that impact the occurrence of pests under intercropping conditions

SL. No.	Intercrop	Major Taxa	Main pest	Reference
1.	Alfalfa, carrot, maize, mungbean, wheat, sunflower, sorghum	Aphids	<i>Aphis gossypii</i>	[70]
2.	Cowpea, safflower, sunflower	Plant bugs	<i>Lygus hesperus</i>	[71]
3.	Apricot	Thrips	<i>Thrips tabaci</i>	[72]
4.	Wheat	Predatory bugs	<i>Nabis sinoferus</i>	[73]
5.	Maize	Green Lacewings	<i>Chrysopa sinica</i>	[74]
6.	Soybean	Spider mite	<i>Tetranychus cinnabarinus</i>	[75]

Table 3. Examples of crop pests for which changes in the behavior or development of the population have been observed due to intercropping

Name of pest	Host plant	Type of intercropping	Changes in the pest behavior and pest population	Reference
<i>Acalymma vittata</i>	Cucumber	Inter-row cultivation, cucumber and corn or broccoli in separate rows	❖ Three times fewer beetles than in pure cucumber crop. ❖ Reduction in the reproductive rate and decrease in the period of foraging	[76]
<i>Phyllotreta cruciferae</i>	Broccoli	Inter-row cultivation, broccoli in rows and vetch and bean between rows	❖ Decrease in the foraging period ❖ Decreasing of the population	[77]
<i>Aphis craccivora</i>	Groundnut	Row-crop mixture, groundnut and common beans in separate rows	❖ Common bean's sticky tendrils kept aphids away ❖ A reduction in aphids by decreasing foraging time	[78]
<i>Oulema spp</i>	Oat, barley	Row-crop mixture of both cereals	❖ Mixed cultivation of each species reduces the degree of damage to oat leaves by 48% and barley by 51% compared with pure stands	[79]
<i>Sitobion avenae</i>	Barley	Row-crop mixture of barley with yellow lupine and pea	❖ The number of aphids on barley heads was 3–6 times lower in crops with legumes	[80]

Table 4. Examples of some intercrop used as trap crop in farming practices

SL. No.	Main crop	Trap crop	Pest controlled
1.	Bengal gram	Marigold	<i>Heliothis sp.</i>

2.	Cowpea	Cotton	<i>Heliothis</i> sp.
3.	Soybean	Corn	<i>Heliothis</i> sp.
4.	Beans	Soybean	Mexican bean beetle
5.	Sunflower	Cotton and Marigold	<i>Heliothis</i> sp.
6.	Groundnut	Cowpea	Leaf folder
7.	Mustard	Cabbage	Cabbage head borer
8.	Cotton	Marigold	<i>Heliothis</i> sp.
9.	Tomato	Cabbage	Diamond back moth
10.	Brinjal	Coriander	Shoot and Fruit borer
11.	Cabbage	Radish	Flea beetle
13.	Radish	Cabbage	Flea beetle
14.	Potato	Marigold	Nematodes

Source: [81]

Table 5. Intercropping for pest reduction – reported successful scientific trials

SL. No.	Crop	Intercrop	Pest reduced/controlled	Mechanisms
1.	Apple	<i>Phacelia</i> sp.	San Jose scale, aphid	Parasitic wasps
2.	Barley	Alfalfa, red clover	Aphid	Predators
3.	Bean	Goosegrass	Leafhopper	Chemical repellent
4.	Cabbage	Tomato	Diamondback moth	Uncertain
5.	Carrots	Onion	Carrot fly	Chemical repellent
6.	Cauliflower	White or red clover	Cabbage aphid	Predators
7.	Collards	Tomato	Flea beetle	Chemical repellent
8.	Corn	Beans	Leafhoppers, beetle, fall armyworm	Physical interference, Predators
9.	Cow pea	Sorghum	Leaf beetle	Chemical repellent
10.	Crucifers	Wild mustard	Cabbageworm	Parasitic wasps
11.	Fruit trees	Wheat, sorghum	European red mite	Predators
12.	Walnut	Weedy ground cover	Walnut aphid	Parasitic wasps

Source: [82]

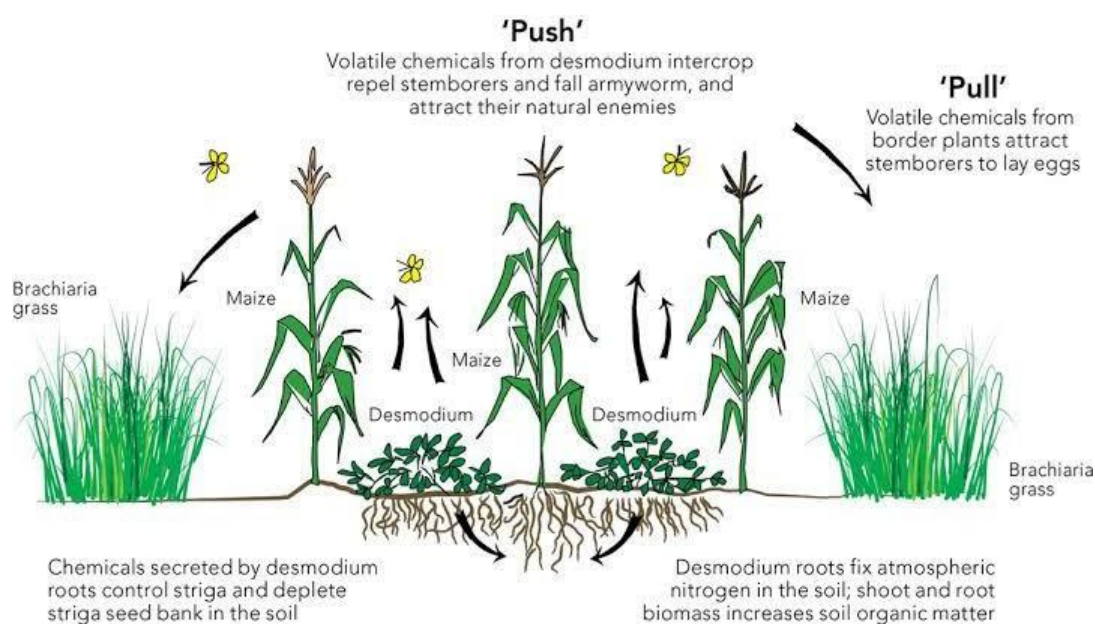


Fig. 4. Showing push-pull pest management in maize crop

uses a unique set of components that is tailored to the pest at hand (based on factors like its specificity, sensory abilities, and mobility) and the resource that is being guarded.

8. ADVANTAGES AND DISADVANTAGES OF INTERCROPPING SYSTEMS

The advantages and disadvantages of intercropping systems in agriculture are shown in Table 1. Crops that are suggested for their capacity to lessen pest incidence when cultivated in between other crops are included in Table 2. Table 3 lists a number of agricultural pests whose population dynamics have been shown to change as a result of intercropping. Intercropping as a tool crop in a particular agro-ecosystem can help reduce the insect population and, consequently, the risk of attack, making it a promising cultural practice for pest management. Table 4 presents some examples of intercrops used as trap crops in farming practices. Table 5 presents the findings of scientific trials. Intercropping protects the main crop in a few distinct ways. The effectiveness of intercropping for pest control depends on the selection of companion crops and their extra value after harvest, as well as the farmers' expertise and mechanisation techniques. Intercropping, a cultural technique utilised in the IPM system to lessen the need for pesticides, is the planting of many crop varieties in a single field. Intercropping was developed as an IPM technique as a result of worries about the harmful effects of pesticides on human health and the environment, pesticide resistance, insect pest comeback, and general agricultural productivity factors. Determining which crop combinations would lower insect abundance is a significant difficulty when attempting to choose the optimal intercrop combination for pest suppression since not all conceivable combinations have the intended impact. As a result, intercropping can be employed alone or in combination with other pest management techniques including chemical control, host-plant resistance, and supplemental biological control. In today's contemporary agriculture, intercropping for insect pest control requires a thorough understanding of how various crop traits and combinations may impact pest behaviour.

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