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Assessment of the Role of Crop Rotation in Integrated Pest Management for Small-Scale Farmers

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

This article delves into the development and execution of integrated pest management (IPM) strategies for broadacre crop rotation in Tamil Nadu, India. It delves into global and Indian acceptance levels of IPM while recognizing variations due to method effectiveness, existing reliance on pesticide treatments, and a shortage of IPM advisors. Challenges in dealing with diverse pests are also acknowledged. The article discusses the collaborative efforts of farmers, agronomists, and entomologists in establishing and implementing IPM techniques for various products. Despite the absence of specific IPM techniques, the study reveals that there was enough information for Tamil Nadu's farmers to adopt IPM strategies. The article particularly assesses the role of crop rotation in IPM for small-scale farmers, focusing on practice transition and information sharing over entomological specifics.

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1. INTRODUCTION

As a consequence of the green revolution, India moved from being grain deficient to having food security for the vast bulk of its people [1]. “Despite extensive use of synthetic pesticides and other control measures, losses suffered as a result of bug and parasite populations were higher in the period following the green revolution. For the eight most valuable food and money goods, the projected worldwide farming losses for the post-green revolution period (1988-1990) totaled US$ 90 billion [2]. The losses that have happened since the green revolution have generally shown an upward trend, as compared to the losses that occurred before the green revolution. From the early 1960s to the early 2000s, the mortality rate increased from 7.2% to 23.3%. Cotton's loss increased by the largest margin, from 18.0 to 50.0%, followed by sorghum and millets (3.5 to 30.0), maize (5.0 to 25.0), and oilseeds (other than peanut) (5.0 to 25.0%) [3]. Celebrations were conducted in India in 2012 to commemorate the tenth anniversary of the widespread adoption of Bt cotton. Over the past five years, there has also been a notable increase in farming output. Cotton continues to be the product that has sustained the most damage, at 30%; this is followed by rice, at 25%; sugarcane, at 20%; rapeseed-mustard, at 20%; maize, at 18%; groundnut and legumes, at 15%; other oilseeds, at 12%; coarse cereals, at 5%; and wheat, at 5%. It is believed that bug pests cost India's farming industry around US$36 billion per year due to the damage they create in the country's farms. As the world's population rises, it becomes increasingly important to ensure that as many people as possible have access to food. Consequently, we must work tirelessly to reduce this loss to its absolute minimum.” In addition to exacerbating an already dire situation, climate change is altering the distribution of crop bugs, which could lead to even greater losses.

A farming system is the planned sequence [4] of crops grown on a given plot of land during a given growing season, as well as how these crops engage with one another and with other agrarian resources and businesses.

- Growing only one product is not recommended in any way.
- Multiple cropping techniques, including intercropping, mixed cropping, sequence cropping, relay cropping, multi-story/tier cropping, and mixed cropping in sequence. The two methods detailed below are two of the crop rotation system's potential contributions to effective pest management:

Top-down approach: This will work on pests by attracting, sustaining, and preserving natural opponents of pests. Top-down strategy. This is a roundabout method for lowering the number of pests in the environment.

Bottom-up approach: This will assist in the direct management of pests.

2. CROP ROTATION AND MANAGEMENT

Crop rotation is a “practice that is used in all sustainable agricultural techniques. It's useful for a wide variety of reasons, including preventing damage to the landscape and keeping pests at bay. Crop rotation refers to the technique of growing different crops on the same plot of ground in successive years. Both cyclical rotations, in which a field's farming cycle is constantly repeated, and noncyclical rotations, in which the farmer's business and management objectives are changed, are referred to simply as rotation throughout this book. A certain amount of circuits of the field are assigned to each grower.

Agricultural rotation methods necessitate careful, long-term planning. The product that will be produced in a field does not have to be decided upon many years in advance of the planting season. Many factors can alter the plans, such as the economy, the supply of workers, and even the weather. However, serious issues, like soil-borne farming diseases or nitrogen shortages, can arise from insufficient preparation. In addition to adding time and money, issues of this type can make it impossible to satisfy a market that has been meticulously nurtured. Over the span of several years, improper rotation can occur and take even the most seasoned makers by surprise. Most rotation issues only become apparent after organic farming has already been performed. The organic movement is a departure from traditional agricultural practices and their related issues due to the unique and varied products produced by organic fields. Most farmers face pressure to grow too much of their most lucrative commodity or to devote large swaths of territory to a single crop. These methods often lead to costly complications that stick around for a long time. To improve soil quality, decrease bug populations, and produce flourishing fields that support happy families, this book is written to aid farmers and agricultural experts in controlling crop cycles, averting issues, and employing crop rotation.

There are many benefits to alternating between cash crops and cover crops, but it can be difficult to handle. Diversified veggie farms and mixed vegetable-grain businesses can produce a wide variety of foods. As a consequence, a vast array of potential field configurations is produced analytically. If a farm produces ten goods, each of those products can be followed by any of the other nine, for a total of 90 cycles, each lasting two years. The same ten items can be used for 5,040 cycles of four years! Avoiding producing successive veggie crops from the same plant family is one trend that can be broken through experience or general norms of behavior. However, there is still a huge variety of options available. Certain products are grown on a greater quantity of land due to market considerations, which complicates matters. Before larger-scale crops can occur, a series of smaller-scale goods must be produced." Given that crop growth is affected by several factors—including soil, drainage, terrain, and others—the selection of fruitful crop patterns and the spread of those patterns across various areas is a daunting task.

2.1 Importance of Crop Rotation

Crop rotations are the backbone of eco-friendly farming [5]. The practice of crop rotation is not foreign to organic farmers. Professional producers often use crop rotations to raise their yields and profits. Food rotation, along with a plan and documentation, is needed to keep organic accreditation current. The objectives and benefits of farming rotations are well-described in a wide variety of literature and online resources. When planning crop rotations, our crew of seasoned farmers avoids rotating crops for extended periods in favor of managerial priorities. Statistics and long-term goals span several years' worth of work as the yearly rotation is planned. Our experts devise, implement, and modify the schedules of crops grown on their farms, but not all of them follow regular crop rotations.

2.2 Crop Rotation and Farm Management

Crop rotation requires "complicated understanding [6]. Managing rotation requires familiarity with the farm as a whole and with each region, as well as decision management at both the field and the farm scale (Fig. 1). Continuous planning is essential for successful agricultural rotations. The best farmers always strike an equilibrium between decisions made in the immediate and long term. Decisions must optimize annual earnings and financial flow. According to seasoned farmers, the opportunities presented by the market and the procedures involved may, at any given time, be more important than the biological concerns. Crop rotations encompass a lot of different elements, all of which are handled by specialists. When it comes to resolving problems and maintaining field production, organic farmers depend more heavily on rotations and long-term soil quality than they do on the use of fertilizers and pest control products. They manage based on biological principles. Many experienced farmers are experimenting with crop rotation biology to satisfy management and business requirements.

Yearly, seasonal, and even last-minute rotations are all planned by experienced farmers [6]. Their annual objectives are given top priority. The farm needs to produce a sufficient amount of valuable products each year to stay in business. Farmers need to carefully consider how to successfully shift equipment and manpower across the entirety of their agricultural business while also selecting the rotational sequence for each region. Crop cultural and harvest characteristics—including labor-intensive cleaning or multiple harvests; vehicle access; and safeguarding commodities like melons or flowers from thieves, criminals, and wildlife—must be managed across the farm and field. Agricultural concerns such as market demand and revenue flow, among others, need to be factored into field selection decisions. The agricultural rotations and combinations used by experienced farmers are always subject to change depending on the climate. The majority of farmers only specialize in one or two primary revenue products. Each year, knowledgeable farmers plant their most important products in the most productive regions of their fields without compromising the quality of the land or the quantity of their harvest. Crop-to-field matches are determined by variables related to the market as well as realistic considerations. After that, knowledgeable farmers consider biological reasons to alter their trajectory. Through their years of experience and extensive knowledge, they verify what not to do. Farmers meticulously manage their production and ground resources in the regions that are most productive for them. Each year, experienced farmers select the produce that will be grown in each field based on their knowledge of the fields, crops, and general agricultural practices.

Each year, the sustainability of the produce is influenced by both the field's history and the weather [7]. Many properties in the northeastern United States have grounds that cannot be transferred. Both the primary substance of the soil and the position of the topography affect fields and meadows. Even though the grounds are comparable, the microclimates, irrigation systems, and proximity to roadways and storage facilities are what make some places perfect for growing particular products. Certain regions are more fertile than others, while others have records or problems that prohibit certain products or rotations from being grown there. Experienced farmers are aware that effective environmental management in the fields is essential to the success of their agricultural companies. They manage crop rotation to reduce the amount of damage done to the soil.

The decisions that are made are heavily influenced by biological principles [8]. When there is a problem, biological principles are taken into consideration. Experienced farmers plan agricultural seasons so that they can get ready for important commodities in the future while still satisfying present production requirements. To begin the early planting of a crop with small seeds, such as carrots, the rotation process needs to be carefully scheduled. This ensures that the refuse from the previous crop is completely broken down, providing an appropriate seedbed for the crop that comes after it.” In some seasons, an overwintering cover crop can have a significant growth spurt in the spring before being replaced by a heavy-feeding income crop. For instance, in the current year, a field could be sown with sweet maize so that in the following year, in the spring, a heavy-feeding cucurbit could be grown there and receive nitrogen from a cover crop of shaggy vetch that would have developed in the autumn. The rotation of the farm is frequently determined by high-value, difficult-to-grow crops because of their significance to the farm's business as well as its natural environment.

The “Crop Rotation System Chart [9]as shown in Fig. 2, was created to illustrate how experienced organic farmers approach crop rotations. This chart illustrates how experienced farmers prepare for and carry out their farms by incorporating various agricultural rotation options. The chart provides an overview of the crop rotations that should be used on an organic farm. The administration of crop rotation is broken down into eight key responsibilities, which are

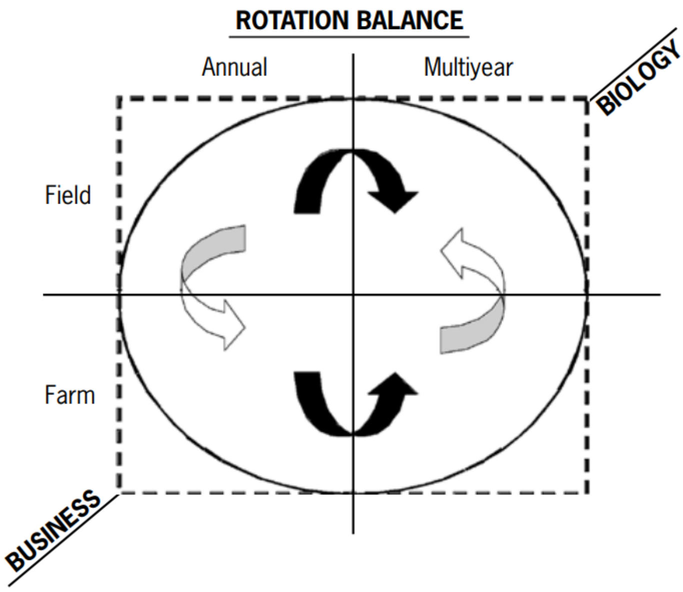

Fig. 1. Rotation planning combines yearly and multi-year land and farm decisions. Annual farm choices prioritize commerce. Multi-year decisions prioritize cellular needs

listed in the left column of the graphic. The tasks associated with each important responsibility are listed in the spaces that run across the page. These are the occupations that necessitate responsibility. Even though the chart is organized in a quasi-chronological fashion, the choices and actions of farmers change between many of the tasks and responsibilities. The more experienced farmers plan everything out and write it down. The majority bring around field charts. Some people work on personal computers. Only a select few can recall everything. The majority of the group farmers thought that farmers ought to write down field notes and plans. There are a great number of essential occupations that require critical thinking, observation, and information. The most successful farmers advise taking frequent and accurate field observations.

2.3 Crop Rotation System Chart

The significance of crop rotation in cultivation is illustrated in Fig. 2 [10]. Only those aspects of farm management that farmers regarded as being most important when choosing rotation and that were linked to rotation management are included on the chart. Certain tasks and important responsibilities affect the entire farm, while others affect the rotation of the land." The cerebral "desk task" B-13, "Review regulations," contrasts with the physical "plant crops" F-10. "Plant crops." Some of them include processing information (G6, "Assess disease control"), while others include making decisions (E-7, "Determine crop quantities"). Conduct an annual review of every responsibility that has been documented. Responsibilities A through E primarily take place during the relatively quiet winter months, when production and marketing pressures are less intense and time is available to take stock and look to the growing seasons ahead; responsibility F (the actual execution and implementation of the rotation) begins in early spring and continues throughout the growing season; and the responsibilities G and H become more intense during the summer. These responsibilities do not need to be addressed in the order listed, but they do primarily take place during the relatively quiet winter months.

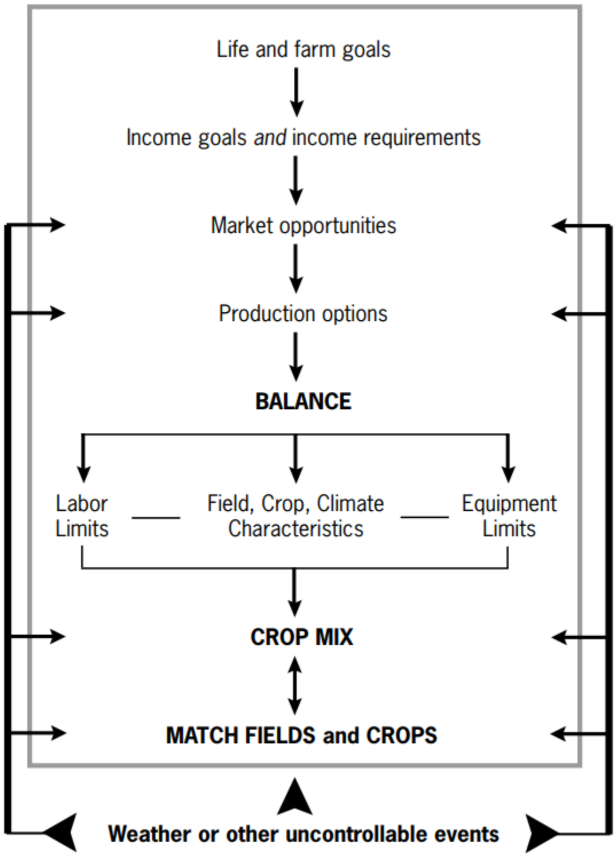

Fig. 2. Diagram of crop rotation. When the weather or other unforeseen circumstances cause a change, seasoned farmers reevaluate their rotation strategy

3. INTEGRATED PEST MANAGEMENT

IPM, which stands for "integrated pest management, has at least 21 distinct definitions (Bajwa and Kogan 1996; Food and Agriculture Organization [11], but in this context, it refers to the use of biological, behavioral, and chemical control methods to deal with pests [12]. IPM is backed by the United Nations, the World Bank, the Food and Agriculture Organization, and government organizations [13]. Invertebrate parasites and declining pesticide use were the primary topics of this research. Animals, plants, pathogens, or even invertebrates can all take the form of a pest. Because herbicides are harmful to a wide variety of species, the first step in a combined approach is to lessen our reliance on them. IPM is commonly used in the agricultural industry, but it is not utilized in broadacre cultivation in India [13]. In a recent report on India integrated pest management [13], broadacre cultivation was not addressed." IPM has several disadvantages, which are outlined , and many entomologists who have conducted research have discovered that it is not widely used around the world [14]. Even in horticulture, where integrated pest management (IPM) theory is well established, agricultural adoption is challenging. Entomologists in Victoria conceived of and put IPM practices into action in broadacre agricultural production by making use of tested dissemination principles.

4. IPM IN CROP ROTATIONS

IPM Technologies [15] "entomologists started working with a group of 15 collaborating farmers and their agronomists close to India in 2020 to evaluate the practicality of IPM in broadacre farming. This group advocated for pesticide-free agricultural practices. A fundamental IPM strategy was developed using entomological data, conversations with farmers and agronomists, and observations made in the field. The goal was to increase permanent beneficial species to control foundation pests and use transitory beneficial species to control ephemeral pests without affecting either category. (i) the accurate identification of both pests and beneficial; (ii) the removal of pesticide dosages when insufficient pests were present; (iii) the application of insecticides in the manner that causes the least amount of disruption; and (iv) the utilization of cultural controls such as the timing of planting. As a result of a perceived increase in pest problems, there was also an interest in finding ways to control pests in systems that preserved the residue.

Three paddocks were chosen for industrial integrated pest management (IPM) [14] by a group of farmers who worked together: one each for Brassica napus (canola), Triticumaestivum (wheat), and Hordeumvulgare (barley). The farmer's designated paddocks were observed by entomologists and agronomists respectively. The agronomist's monitoring was complemented by the use of pitfall traps, direct viewing, and suction sampling. Monitoring revealed beneficial insects and parasites, as well as predators and the relative abundance of the two. A decision was taken collectively each week during the canola foundation and at critical periods for wheat and barley. The decision was based on monitoring, previous experience, and the impacts of pesticides on biological pest management. The first year of applying this strategy in an industrial setting resulted in a reduction in the use of insecticides, as well as improved pest management, primarily as a result of improved pest identification. Because the farmers and agronomists were pleased with the outcomes, they decided to implement IPM on a greater number of paddocks the following year. Despite the simplicity of the pest control methods utilized at these locations, enormous gains were made. The farmers implement IPM across their entire property and use fewer herbicides as a result. In some fields, herbicides have not been applied via boom spraying for the past 5 years.

5. CROP ROTATION APPROACHES

Crop rotation is most useful for reducing the presence [15] of pests that are localized, monophagous, and/or spend the winter in or near farming areas. Some plant illnesses can also be prevented through crop rotation. For instance, its efficacy drops dramatically against the far-traveling cabbage worm, Delia radicum. Crop rotation on a regional scale, which is usually unfeasible, maybe the only realistic option in such a situation.

5.1 Secondary Plants

Secondary plants affect the multitrophic interactions that occur in an agricultural region by providing protection for or food for beneficial organisms. In an agricultural environment with sustenance, insect pests, and their natural enemies at the first, second, and third trophic levels, these plants can be separated into two categories according to the function that they play in the management of insect pests.

i). Top-down approach

- Insectary Plants
- Banker Plants”

ii). Bottom-up approach

- Indicators
- Barriers
- Repellents
- Traps
- Companions

Plants that are “indirectly used as biocontrol agents are called biocontrol plants [16]. Biocontrol plants are also known as secondary plants. These plants are introduced into an agricultural region to attract natural predators of pests and to moderate pest populations; this enhances biological control techniques and the amount of food produced. These plants should have a high rate of growth, not be competitive with the main crop, be readily cultivable, compatible with the main crop's requirements for temperature, moisture, and sunshine, and be forgiving of heat and water stress.

5.1.1 Top-down approaches:

i). Banker plants: For parasitoid-inoculated greenhouse tomato products, Stacey [17] coined the term banker plant. According to Goolsby and Ciomperlink [18], the definition of the term is an ongoing procession of adversaries posed by nature. The term open rearing was coined by Ramakers and Voet [19], who also suggested the use of Ricinuscommunis as a technique for open-rearing carnivorous mites in gardens. Banker plants are responsible for the upkeep of an expanding population of natural enemies, which helps to decrease the number of parasites in a food system over time [20]. Banker plant systems are systems that are purposefully put up in cultivated areas to raise and disperse insects to control pest populations. This technique was investigated to determine whether there were any errors. The traditional form of biological management makes use of banking plants to strengthen natural enemies. Banker plants are plants that support and safeguard natural enemies, increasing the likelihood that agricultural plant systems will contain biocontrol agents. Parasitoids proliferate in the hosts that are banking plants, which results in the release of natural enemies and ensures long-term pest management. Banker plants are responsible for the dissemination of biological control agents throughout the containment as they proliferate. A natural adversary mini-rearing gadget. Therefore, banking plants can maintain a distinct natural foe or the right diversity of predators and parasitoids by providing them with a variety of distinct alternative resources. The cost of augmentative biological control, which consists of continually unleashing more natural enemies to confine a pest, can be quite high. An advantage that banking plant systems have over augmentative biological control is the ability to practice preventative control without allowing natural enemies to repeatedly escape their grasp. The manual release method is outperformed by this [21].

ii). Insectary plants: The nectar and pollen of an insectary plant are what attract and potentially retain natural enemies that aid in the control of agricultural pests [22]. This type of flowering plant is known as an insectary. Insectivorous plants are plants that are grown specifically to provide nectar and pollen for insects that are considered to be pests. flowers that produce pollen and nectar in extrafloral nectaries or flowers attract beneficial insects like parasitoid wasps and ravenous flies. Insects have discerning tastes. The selection of floral resources by hoverflies was influenced by factors such as blossom color, shape, scent, size, quality of nectar and pollen, flower abundance and age, and indications left by previous visitors. A lot of valuable creatures may suffer. Therefore, a large diversity of flowering plants is required for a diversified system of predators and parasites. Insectivorous plants can attract and unleash predatory insects that protect crops and sustenance from pests.” Not only the morphology of the mouthparts and the structure of the flowers but also empirical facts are required to establish whether or not the target species can utilize the flowering resource. Plants such as sweet alyssum, buckwheat, and licorice mint are used as insectary plants. These plants provide parasitoid wasps with sugar and glucose, which in turn extends their lifespans. Bugg provides a long collection of helpful examples [23]

5.1.2 Bottom-up approaches:

i). Indicator plants: By identifying pests early, “indicator plants assist farmers in saving money. By monitoring weedy plants in various environments, ecologists studying vegetation and soil use something called indicator plants to determine the condition of the soil and other biological variables. A plant that generates particular signals in reaction to viruses or other exterior variables is referred to as an indicator marker in the field of plant virology. In the context of integrated pest management, indicator plants are defined by Lamb [24] as species or varieties that are more susceptible to pests or illnesses than the crop. They attract pests and are useful for diagnosing diseases. They might also capture insects. Tomatoes and eggplants are two vegetables that can indicate an infestation of whiteflies in poinsettia harvests [25]. Tomatoes can lure whitefly away from poinsettias and then assist in capturing them. The presence of the greenhouse tomato carmine spider mite can be determined by the presence of bean seedlings, also known as Phaseolus vulgaris. IPM has sufficient time to purchase and distribute natural enemies for spider mite management on tomatoes before the pest establishes itself on beans five weeks before it does on tomatoes. This allows IPM to be effective.

ii). Barrier plants: Barrier plants help protect primary products from disease and protect them from pests and pathogens [26]. It is possible that the spread of illness can be slowed by using barrier plants or products to trap insects and pathogens. Barrier crops are planted along the field boundaries. The barrier crop theory, also known as the physical obstruction hypothesis, proposes that elevated non-host plants should be used to prevent pest bugs from entering agricultural systems. (Perrin and Phillips 1978. Viruliferous growth is stifled by barrier vegetation.

5.2 Intercropping Techniques

Reduced levels of Sitobionavenae were seen after treatment [27] with garlic oil blend (GOB), diallyl disulfide (DD), and wheat-garlic intercropping (WGI). The populations of natural enemies are increased by intercropping and the use of poisonous chemicals. The weight of 1000 grains and the output increased when compared to the reference.

5.3 Cotton-Based Crop Rotation [28]

Over 180 hectares were successfully replanted with a maize+cowpea boundary crop and a Setaria(10:1) intercrop by the Ashta cotton IPM initiative. Intercropping strategies for ladybird beetles, chrysoprase, and syrphid flies in the Central and South Zones:

Cotton + Cowpea
Cotton + Soybean
Cotton + Groundnut
Cotton + Pulses

It is also recommended that products like okra, Canabinus, castor, marigold (Tagetes), early pigeon pea, coriander, jowar, and maize be used as traps."

6. CONCLUSION

Crop rotations provide more effective pest management and pest reduction, as well as diversity, interoperability with other IPM components, and smaller burdens of specialized carnivores than monocultures. "The characteristics of the pests must be understood, non-host crops must be rotated, intercropping must take place, and there must be an interaction between crops, pests, and NE secondary plants. An agricultural system that has been carefully designed can sustain food production even in changing temperatures and with increasing populations.

The following considerations bring this research to a close. The outcomes of the IPM implementation are supported by scientific research. Herbert [29] described the majority of these problems, the majority of which are still present more than a decade later. Even though the problems still exist, we do now have some choices.

1) There is sufficient information about insects to begin IPM in industrial broadacre agriculture and deal with problems as they arise. This can be done with the help of the availability of this information.
2) This article presents a case study that demonstrates a successful technique and that is consistent with what is already known about how to convince people to use IPM. In comparison to general tendencies across the globe, the rate of expansion is significantly faster than average. A collaborative effort between the cultivator, the horticulturist, and the entomologist is required to achieve the desired outcomes.
3) According to the FAO [30], integrated pest management cannot be packaged like seeds, and it needs to be effective for each individual. In the presented case study, entomologists provided farmers and agronomists with direct guidance based on the situation that they found themselves in.
4) It is the responsibility of advisers to make meaning of the information and simplify it so that it can be comprehended by their clients if IPM is difficult to grasp.

5) Even after IPM has been implemented, entomologists, farmers, and agronomists must continue to collaborate so that IPM is not merely viewed as an alternative pesticide program. This is necessary to prevent IPM from being derided as ineffective." After integrated pest management has been applied to control insect pests, it can be reapplied to control a broader variety of other pests in a manner that is more comprehensive.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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