Enhancing Cucumber Production Sustainability by Incorporated Pest Management: A Comparative Evaluation of Cost and Profitability

Ravi Shankar Raman[1*], *Gopu* Srilekha[2], *Santosh* Kumar B[3], *Navdeep* Singh[4], *Pradeep* Kumar Chandra[5], *Ahmed* sabah Abed AL-Zahra Jabbar[6]

[1]Department of Mechanical Engineering, ABES Engineering College, Ghaziabad-201009, UP, India.
[2]Department of Computer Science and Engineering, Institute of Aeronautical Engineering, Hyderabad, Telangana, India
[3]Department of Computer Science Engineering, New Horizon College of Engineering, Bangalore, India
[4]Lovely Professional University, Phagwara, Punjab, India.
[5]Lloyd Institute of Engineering & Technology, Knowledge Park II, Greater Noida, Uttar Pradesh, India.
[6]Medical Laboratory Technology Department, College of Medical Technology, The Islamic University, Najaf, Iraq.

Abstract. This research investigates the efficacy of integrated Pest management (IPM) techniques in cucumber cultivation, focusing at the utilization of natural control strategies to reduce pest-associated losses and improve crop productivity. No matter the growing emphasis on biological strategies, their adoption remains limited because of several challenges, including market pressures, regulatory hurdles, and pest resistance. But, through promoting awareness, expertise, and collaboration among organic and IPM communities, barriers to adoption may be overcome. The study underscores the importance of monetary useful resource for natural control and advocates for its integration into sustainable crop protection practices. Through a comparative evaluation of IPM and non-IPM farming processes, the studies highlight the fee implications and profitability of implementing biological control measures in cucumber production. Findings reveal that even as IPM farmers incur higher initial expenses, they reap advanced internet returns and benefit-cost ratios in comparison to non-IPM counterparts, demonstrating the monetary viability and sustainability of IPM strategies in cucumber farming.

Keyword-: IPM, Pest control, ecosystem, cucumber production, costing

1 Introduction

Integrated Pest Management (IPM) is a practical and eco-friendly method of controlling pests using a blend of common sense techniques. IPM programs make use of up-to-date, thorough

---

[*] Corresponding Author : ravi.raman@abes.ac.in

data about the life cycles of pests and how they interact with the environment. IPM, or integrated pest management, is an ecosystem-based approach that employs a variety of tactics, including biological control, habitat alteration, cultural practice transformation, and the adoption of resistant cultivars, to prevent pests or the harm they cause over the long run as shown in Fig.1. In accordance with established rules, pesticides are only used when monitoring shows they are necessary, and treatments are designed to eradicate the target organism exclusively. The selection and application of pest control agents minimizes hazards to the environment, beneficial and nontarget creatures, and human health. The IPM paradigm has to be re-examined, taking into account factors of management, business, and sustainability, with a focus on research and outreach, given that it is now impacted by globalization, consumer trends, and contemporary technological advances in agriculture. In order to handle pest control, knowledge, information management, decision-making, and dissemination, as well as the human, environmental, social, and economic elements impacting food production, the new IPM concept combines management, business, and sustainability components [1].

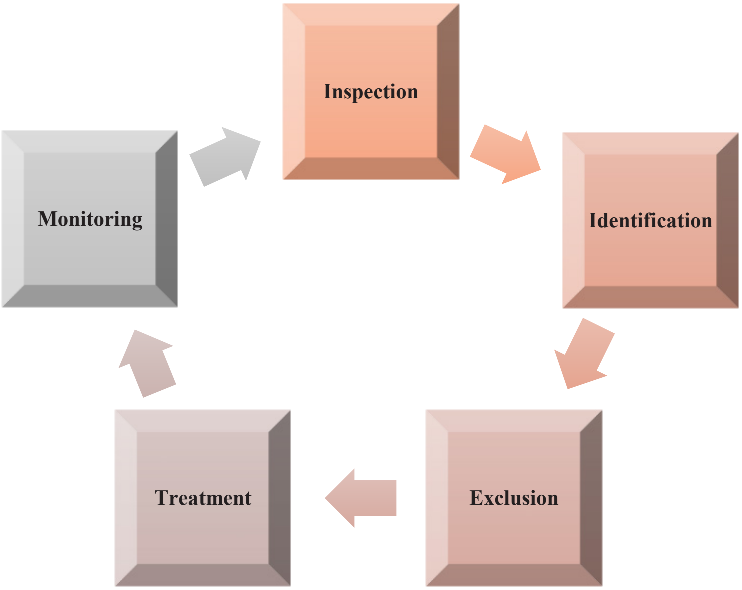

Fig. 1. Procedure of Integrated Pest Management

The study conducted in [2] examines integrated pest management (IPM) programs, discusses current studies, and contrasts approaches to IPM decision-making for insects discovered in stored products. If the cost of control is less than the loss of the pest's market value, IPM is economicalBy eliminating needless chemical applications and utilizing nonchemical control techniques, IPM programs can lower the usage of pesticides. To satisfy consumer and regulatory needs, the food sector will require additional IPM initiatives. Developed in the late 1960s, integrated pest management (IPM) aims to safeguard the environment and provide food and fiber crop farmers with maximum economic advantages through the selection and application of pest control techniques Ecological data and cost-benefit evaluations for crop production systems and pest complexes are key components in the creation of integrated pest management (IPM) systems, which help farmers use IPM techniques [3]. More robust and sustainable methods are required to decrease crop output losses brought on by pests and to lessen their effects on the environment and public health. Sustainable agriculture places a high priority on biological control, biopesticides, biostimulants, and pheromones. These methods still only make up a small portion of crop protection worldwide, nevertheless, because of acceptance hurdles. With more knowledge, common objectives, and policy, organic and inorganic pest control (IPM) may be adopted more quickly. Among the tactics are cost-benefit analysis, public-private sector policies that support biological control, and instruction on biological control choices [4].

2 Biodiversity and Pest Control Mechanism

The effects of crop and non-crop habitats, as well as the dietary, dispersal, and overwintering traits of species, affected configuration effects, which led to opposing responses to landscape variables, according to a study looking at the effects of landscape composition and configuration on arthropods in European landscapes. In European agroecosystems, high edge density enhances yields, pollination, and controlling pests while supporting functional biodiversity and ecosystem services, particularly in areas with a strong agricultural component [5]. Pesticides that pose a risk to human health are hazardous because they enter the food chain and slowly affect people. Farmers employ these pesticides in agricultural areas to suppress unwanted bacteria during food production, harvesting, and storage. Farmers and field workers can profit from microbial resources' considerable degradation of dangerous substances. Chronic illnesses like diabetes and hypertension, which may not be identified until testing, might result from prolonged exposure to these substances. New information on the role of microbes in chemical pesticide remediation has been revealed by the identification of these microbes as efficient sources for the breakdown of several pesticides, including Actinobacteria, Ascomycota, Bacteroidetes, Basidiomycota, Chlorophyta, Cyanobacteria, Firmicutes, and Proteobacteria [6]. Research in agroecology advances knowledge of the advantages and drivers of the environment, encouraging multifunctional agriculture. It facilitates comprehension of the influences on beneficial insects and ecosystem services at the local and landscape levels. Empirical evidence indicates that increased agricultural intensity results in decreased populations the pollinators, natural enemies, and biodiversity. It is possible that the composition and arrangement of the landscape moderate these impacts.Agroecology, conservation, and ecosystem service research are all intertwined, and [7] highlights how their impacts cascade into one another through the proposal of five research themes.Using 487 arthropod food webs gathered from two grass diversity trials in Europe and North America, the study explores the potential of boosting plant variety to lessen herbivore harm to plantsIn high-diversity mixes as opposed to monocultures, plants lose less energy to arthropod herbivores, underscoring the significance of plant variety preservation for organic pest management in food webs [8].The loss of world biodiversity is largely caused by invading pest species, with invasive animals having the worst effect on endemic biota. Over a two-decade period and across several trophic levels, a national meta-analysis of 447 biodiversity outcomes across 16 replacements indicated considerable benefits. Stronger reactions to pest management were shown in deeply endemic species, suggesting that controlling invasive pests is a useful strategy for restoring the ecosystem [9].Potential pest control technologies like synthetic gene drive methods are shaped more by underlying worldviews than by demography or scientific understanding. A nationwide poll conducted in New Zealand indicated that opinions about gene drive are explained by respondents' worldviews, with moderate support (32%). Comprehending these perspectives can facilitate a more compassionate involvement approach and enable the public to engage in knowledgeable decision-making on the application of gene drive technology to preserve biodiversity [10].Agriculture has undergone a transformation because to nanotechnology, which offers environmentally friendly pest management methods that work well. Novel nanopowders have surfaced, offering promise for sustainable food production. Chemical pesticides have negative effects and conventional pest management techniques are insufficient. For nanopesticides to meet the requirements of sufficient control, environmental effectiveness, and related advantages, a new regulatory paradigm is required. Studies have demonstrated advances in the application of nanopesticides in water, biocides, and insect identification [11].Crop productivity and the welfare of humans are at risk due to hazardous pesticides that farmers employ in agricultural fields to control unwanted bacteria during food production and storage. These substances have the potential to indirectly infiltrate the food chain and harm people's health. These substances can be broken down by microbiological resources, reducing their toxicity. Chronic illnesses like diabetes and hypertension can result from prolonged exposure to these substances. Pesticide breakdown is mostly dependent on a variety of microbe families, including Arthrobacter, Aspergillus, Bacillus, Burkholderia, Chlamydomonas, Methylobacterium, Nocardioides, Nostoc, Phanerochaete, Pseudomonas, Sphingobacterium, Sphingomonas, and Trichoderma [12].

3 Biological Control Methods for Integrated Pest Management (IPM)

Leaders and practitioners in sustainable agriculture are putting more emphasis on using biological techniques such as pheromones, biopesticides, biological control, and biostimulants in order to decrease crop production losses and lessen the effects of pest management. Biological techniques provide for a very minor portion of the protection of crops worldwide, despite market, regulatory, and pest resistance pressures. Adoption obstacles include those that are comparable to IPM strategies. Enhancement of consciousness and comprehension can surmount these obstacles. By working together, the organic and IPM communities may benefit from regulations that support biological control, cost-benefit analysis, and education as means of hastening its adoption [13].In order to maximize its utility and acceptance for sustainable crop protection, biological control—which includes traditional, augmentative, and conservation methods—needs a strong financial basis. Biological treatment is an essential part of integrated pest management. The study in [14] emphasizes the significance of appreciating conservation biological control, pointing out obstacles and chances for practical, cost-effective use in integrated pest management. It requires scientists and stakeholders to work together.It is simple for Integrated Pest Management programs to adopt natural enemy thresholds; but, in order to influence stakeholders decisions, ecological data, model validation, and an awareness of economic factors are needed. Natural enemy thresholds may be included into advanced IPM methods, according to recent research, which will improve stakeholder use and support site-specific biological control management suggestions [15].Eleven sites in Southwestern China, Laos, and Myanmar continue to generate biocontrol agents 1.5 years after the project's support ended, according to a study that evaluated the sustainability of two integrated pest management strategies in rice and maize crops. IPM based on biological control raised maize and rice yields somewhat but not significantly. Using Trichogramma egg-cards cut the amount of pesticides used in half. For Trichogramma to survive, institutional support—whether public or private—is essential. The biological regulating agents Trichogramma is have primarily positive effects. According to [16], motivating farmers to embrace integrated pest management (IPM) is essential to maximizing the benefits of interventions that lower the usage of synthetic pesticides and promote sustainable agricultural output. The presence of arthropods, especially stink bugs, makes effective pest management necessary for the production of soybeans. Up to 60% of pesticides used in Brazil are used to control these insects. While programs for augmentative biological control (ABC) can release biocontrol agents, conservation biological control (CBC) techniques aim to maintain or enhance the number of natural enemies.

Table 1: Comparison of biological control in integrated pest management (IPM)

Biological Technique	Challenges	Advancements	Case Studies	Future Directions
General Biological Control	Market, regulatory, and pest resistance pressures; low adoption rates	Enhancements through regulations, cost-benefit analysis, and education	-	Greater collaboration between organic and IPM communities; Financial support for biological control
Conservation Biological Control	Stakeholder decision-making influenced by lack of ecological data and economic understanding	Adoption of natural enemy thresholds; Integration into IPM	-	Collaboration among scientists and stakeholders; Model validation and economic analysis
Integrated Pest Management (IPM)	Institutional support needed for sustainability; Pesticide reduction challenges	Sustainable IPM strategies in rice and maize; Use of Trichogramma egg-cards	Southwestern China, Laos, Myanmar	Support for institutional frameworks; Enhance yield impact and reduce pesticide usage
Augmentative and Conservation Biological Control (ABC & CBC)	High pesticide usage, especially in soybean production	Reduction in pesticide use; Adoption of safe insecticides and resistant varieties	Brazil (soybeans)	Promotion of safer insecticides and pest-resistant crops; Implementation of ABC and CBC techniques
Pest Management in Grain Sector	Phosphine resistance; Health risks from pesticide residues	Research into biological control alternatives like parasitoid wasps	-	Focus on conserving natural parasitoid populations; Account for interactions and dispersion
Tomato Pinworm Management	Regional variability in management practices; Lack of agronomic research	Integrated management combining biological and biotechnical control	Various regions post-Tutaabsoluta invasion	Development of resistant crops and improved agronomic practices; Tailored management strategies based on regional experiences

Positive outcomes have been demonstrated by straightforward measures including decreasing the use of pesticides, giving preference to safe insecticides, and planting resistant soybean varieties [17]. The 20th century saw substantial developments in Asian agriculture, which resulted in the "green revolution" in foodgrains. However, owing to low productivity and ignorance of crop management and agricultural inputs, millions of people experience food shortages and hunger globally. Synthetic pesticides like DDT and BHC have been used, which has resulted in issues including insect resistance, environmental degradation, health risks, and the extinction of beneficial creatures. Numerous cotton crop failures in India caused by resistance to whiteflies and bollworms resulted in thousands of fatalities and injuries. Nearly three-quarters of deaths from chronic poisoning, which involves persistent exposure to toxicants, occur in underdeveloped nations. This poisoning is not well known [18]. The standard fumigant used in the grain sector to combat insect infestation is phosphine. Pesticide residues are a worry, too, as certain insect species show phosphine resistance. As an alternative, biological control—such as parasitoid wasps—is being investigated in [19]. The study's discovery of a high degree of parasitoid diversification in grain stockpiles suggests that these organisms may function under a variety of circumstances. Even though phosphine had an immediate detrimental effect, the parasitoid wasps did not significantly lower the host population. Pest-management techniques should take interactions and dispersion into account while conserving and increasing the naturally existing parasitoid population in order to lessen this. The South American tomato pinworm Tutaabsoluta poses a danger to tomato crops globally. Programs for integrated pest management (IPM) have been created and put into place in a number of locations. The most effective methods are biological control and biotechnical control based on sex pheromones. Research on agronomic management is only being started, and it seems that IPM effectiveness might be increased by breeding resistant crops, fertilizing the soil, and providing irrigation. According to grower survey replies, control programs changed depending on the region and amount of time following invasion. Improved management of recently invaded regions might be facilitated by information gathered from native and early invaded areas [20].

The comparison of biological control in integrated pest management (IPM) in Table 1 reveals challenges, advancements, case studies, and future directions. General biological control faces market, regulatory, and pest resistance pressures, while conservation biological control relies on stakeholder collaboration and economic understanding. IPM strategies in rice and maize require institutional support for sustainability. Augmentative and Conservation Biological Control (ABC & CBC) strategies reduce pesticide use, promote safer insecticides, and address phosphate resistance in the grain sector.

4 Pest Identification and Monitoring Techniques

To identify high levels of defoliation and changed canopy reflection signatures in oaks impacted by the oak splendor beetle infestation, the study employs a tiny Unmanned Aerial System (UAS) with a digital camera. This helps to improve forest management: Small-scale, privately maintained commercial forests were the target of flying campaigns carried out in rural Germany. Methods for object-based picture categorization, georeferencing, mosaicking, and CIR/NIR image capture were employed in [21]. This method distinguished five plant health groups and produced a low-cost option for sustainable forest management. Agriculture is greatly impacted by climate change and global warming, which also has an effect on insect pests, plant survival, distribution, and interspecific interactions. These alterations may result in a higher chance of invasion, a rise in illnesses spread by insects, and a decrease in the efficiency of biological control—particularly that provided by natural enemies. Because of the dynamics of insect populations, agricultural economics and human food security are at danger from climate change. Modified pest control strategies, climate monitoring, and modeling prediction tools should be the main areas of future study [22]. A demonstration program (EDP) spanning all of Europe was carried out to track the impacts of micropollutants in surface waters. The program's objectives were to correlate biological effects to target substances, quantify the danger to aquatic biota, and use a streamlined approach for effect-directed research. 50 L of surface water were extracted on-site from 18 sample locations as part of the EDPMost bioassays failed to explain its most important impacts, which included estrogenicity, toxicity to algae, and toxicity to fish embryos, according to the report. The two components that contributed the most were found to be estrone and nonylphenoxyacetic acid. Priority was given to 21 target chemicals. Six chemicals now covered by European regulation and fifteen micropollutants are included in the EDP priority list for surface water monitoring in the future. This list presents a streamlined approach for effect-based monitoring [23]. The study in [24] examines the state-of-the-art research on image processing and machine learning methods for agricultural pest and disease identification. It highlights how crucial quick and precise plant disease diagnosis is to long-term agricultural output. The review seeks to offer useful resources for scholars working in this areaThe research concentrates on the cheap cost and wide availability of RGB pictures for the identification of leaf diseases. Instead of creating features by hand, researchers have turned to deep learning; nonetheless, under various datasets and field circumstances, performance suffered. Ten CNN designs' performances are demonstrated through experimental findings, along with suggestions for appropriate deployment in traditional and mobile computing contextsIn order to develop useful automatic plant disease detection systems that are appropriate for field use, the debate points out open issues that require attention.

5 Environmental Impacts and Sustainability of IPM

According to the study in [25], various crop rotations and practices are encouraged by integrated pest management, or IPM, which is tailored to local conditions. It implies that IPM-based methods that employ less pesticides can offset production declines by lowering the cost of pesticides and their application. In order to create sustainable IPM systems, regional policies should involve regional advisory services [26]. Ex-post analysis revealed limitations in IPM1 and IPM2 systems, such as fewer varied crop rotations and pesticide use-related environmental and economic problems. Yield penalty may arise from low pesticide application or non-chemical approaches [27]. For local and regional conversations on adopting IPM and creating sustainable agricultural systems, identifying limits is essential. Another study in [28] looks at how integrated pest management (IPM) affects an agroecosystem of rice, emphasizing the advantages it has for the environment. Approximately 80% of farmers apply pesticides, and tiller health, hills, and grain weight are impacted by IPM techniques [29-32]. The best percentages of dead heart and white head were found in 7.4 tonne/ha of rice produced in IPM-treated plots, indicating that this method is beneficial in producing large rice yields while preserving the environment. Maintaining a sustainable rice agroecosystem necessitates continuous study and IPM training [33]. A sustainable substitute for synthetic pesticides is integrated pest management, or IPM, especially for smallholders in tropical regions [34-36]. IPM techniques help farmers, the environment, and public health despite the fact that the world uses 3.5 billion kg of pesticides annually85 IPM initiatives in 24 Asian and African countries were evaluated, and the results showed a mean yield gain of 40.9% and a decrease in pesticide use to 30.7%, with 35 out of 115 crop combinations moving toward pesticide-free practices. According to the study in [37], most agroecosystems use 50% more pesticides than necessary, yet legislative support for integrated pest management (IPM) is scarce, counter-interventions are frequent, and the problem is never totally solved. Agronomy is moving toward sustainability as a result of the urgency of climate change. In order to demonstrate the beneficial effects of sustainable farming methods on biodiversity, water quality, and soil health, this study looks at conservation tillage, crop rotation, and organic farming. The study in [38-40] presents case studies from India and outside to illustrate the successful implementation of sustainable practices in real-world scenarios, weighs policy implications, and contrasts them with traditional ways. The adoption of sustainable agronomy is beset by obstacles such as obsolete curriculum, insufficient support networks, and budgetary restraints, especially for small-scale farmers. Future research on affordable technology, educational changes, and alternative finance methods are suggested by the assessment as ways to help farmers in the face of difficulties [41-43].

6 Producing Cucumbers Profitably and Determining Various Expenses for IPM and Non-IPM Cucumber Growers

In the agricultural landscape of Tangail Sadar Upazila, the expense of human labor per hectare for sowing and planting is notably steep. Cucumber cultivators engage laborers extensively for various tasks such as planting, weeding, harvesting, and other essential activities. Analysis presented in Table 2 demonstrates that for IPM (Integrated Pest Management) farmers, the expenditure on human labor for cucumber cultivation stands at USD 1033.91, whereas for non-IPM farmers, it reaches USD 1112.96. Moreover, the study reveals nuances in other cost factors. IPM farmers, often operating larger farms and opting for organic fertilizers, incur higher costs for seeds/seedlings, cow dung, and oilcake. Conversely, non-IPM farmers face escalated expenses in inorganic fertilizers like Urea, TSP, and MoP. Solely IPM practitioners invest in pheromone traps, with a per-hectare cost of USD 105.51, constituting 4.3% of the total production cost. Insecticide costs are nearly doubled for non-IPM farmers [44].

Table 2. Per hectare production cost and return of cucumber for both IPM and non-IPM farmers (USD)

Particulars	IPM Farmers	Non-IPM Farmers
Labor	1040.21(42.0)	1082.96(42.4)
Seed	101.33(4.6)	97.10(2.9)
Power tiller cost	69.83(2.98)	91.53(2.8)
Organic fertilizer	120.87(5.3)	88.12(3.7)
Cow dung	191.91(3.7)	61.95(2.5)
Oilcake	139.19(1.6)	45.37(1.2)
Inorganic fertilizer	275.82(9.1)	50.29(14.7)
Urea	79.86(3.6)	174.40(6.7)
TSP	88.49(3.8)	136.84(5.2)
MoP	29.55(1.7)	87.05(2.8)
Pheromone trap	105.51(4.3)	0.00
Insecticide	110.76(3.8)	201.13(6.9)(5.1)
Trellis making	120.80(5.2)	164.50(5.1)
Irrigation	133.91(5.4)	196.99(5.3)
Total Variable cost	2098.77(82.8)	2871.01(83.8)
Interest on operating capital	51.00(2.1)	51.93(2.1)
Land use cost	300.10(15.1)	370.50(4.1)
Total Fixed cost	591.49	721.93
Total cost	2001.27	2722.44
Gross Return	4914.99	4973.90
Gross Margin	2475.42	1876.89
Net Return	2153.62	1451.47
BCR	2.0	1.6

N.B.: Values in parenthesis indicate the percentage of total cost

Despite similar land use costs, the total per-hectare expenditure for cucumber production is lower for IPM farmers, totaling USD 2461.27 compared to USD 2622.44 for non-IPM counterparts. This discrepancy is reflected in the gross returns and margins, with IPM farmers achieving higher net returns of USD 2453.72 compared to USD 1451.47 for non-IPM farmers. The benefit-cost ratio also favors IPM practices, standing at 1.9 compared to 1.6 for non-IPM methods, underscoring the superior profitability of IPM farming in cucumber cultivation.

Table 2 provides a comprehensive breakdown of the costs and returns associated with cucumber cultivation per hectare for both Integrated Pest Management (IPM) and non-IPM farmers, delineated in USD. Labor costs encompass various tasks related to farming and are presented both in total and as a percentage of the total variable cost. Similarly, expenses for seeds, power tiller usage, organic fertilizers (including cow dung and oilcake), and inorganic fertilizers (such as Urea, TSP, and MoP) are detailed alongside their respective percentages.

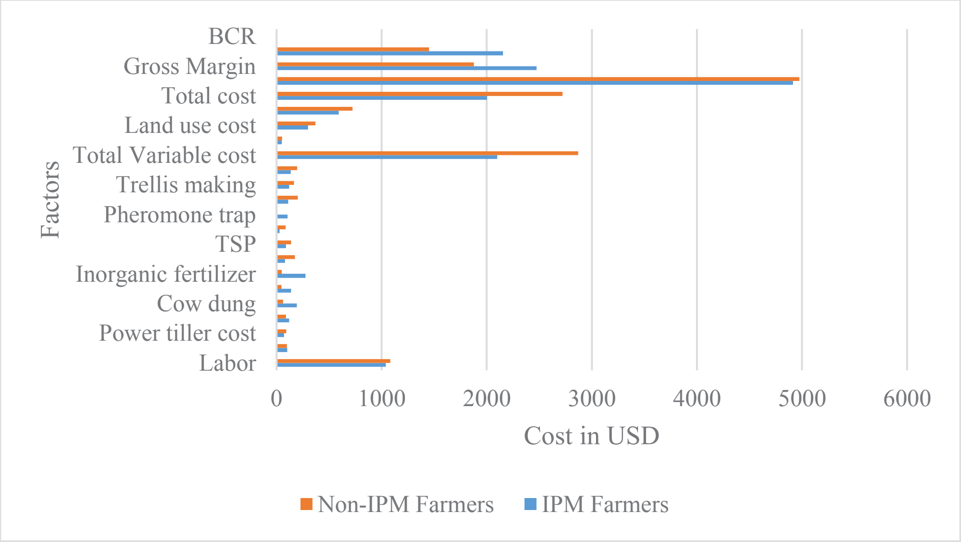

Fig. 2. Cucumber production costs and returns per hectare for both IPM and non-IPM growers

Notably, IPM farmers invest in pheromone traps for pest control, while non-IPM farmers do not incur this expense as shown in Fig.2. Costs for insecticides, trellis construction, and irrigation are also outlined. Total variable costs represent the sum of all variable expenses, while fixed costs include interest on operating capital and land use costs. Gross returns, gross margins, net returns, and benefit-cost ratios are provided for both farming approaches, offering a comparative view of their profitability.

6 Conclusion

Integrated Pest management represents a pivotal method within the quest for sustainable agriculture, skillfully balancing the need for effective pest manage with ecological maintenance. The study underscores the pivotal function of organic control methods inside the framework of integrated Pest management, offering a sustainable technique to mitigate crop losses and reduce reliance on synthetic pesticides. By leveraging organic techniques inclusive of pheromones, biopesticides, and conservation techniques, farmers can efficiently control pests whilst minimizing environmental affects and maintaining natural ecosystems. Regardless of initial investment challenges, the studies demonstrate that IPM practices yield vast financial advantages, ultimately improving the profitability and sustainability of cucumber manufacturing. Moving forward, concerted efforts are needed to facilitate the enormous adoption of IPM strategies, which includes coverage support, economic incentives, and educational initiatives, to ensure the long-term resilience of agricultural systems in the face of evolving pest pressures and climate change.

References

1. Dara, Surendra K. "The new integrated pest management paradigm for the modern age." Journal of Integrated Pest Management 10, 1 (2019): 12.
2. Hagstrum, David W., and Paul W. Flinn. "Integrated pest management." In Integrated management of insects in store,x ,0078. Products, pp. 399-407. CRC Press, 2018.
3. Kogan, M., 2020. Integrated pest management. In Landscape and Land Capacity (pp. 155-160). CRC Press.
4. Baker, Brian P., Thomas A. Green, and Ali J. Loker. "Biological control and integrated pest management in organic and conventional systems." Biological Control 140 (2020): 104095.
5. Manohar, T., Prashantha, S. C., Nagaswarupa, H. P., Naik, R., Nagabhushana, H., Anantharaju, K. S., ... &Premkumar, H. B. (2017). White light emitting lanthanum aluminate nanophosphor: near ultra violet excited photoluminescence and photometric characteristics. Journal of Luminescence, 190, 279-288.
6. Martin, Emily A., Matteo Dainese, Yann Clough, AndrásBáldi, Riccardo Bommarco, Vesna Gagic, Michael PD Garratt et al. "The interplay of landscape composition and configuration: new pathways to manage functional biodiversity and agroecosystem services across Europe." Ecology letters 22, 7 (2019): 1083-1094.
7. Kumar, Manish, Ajar Nath Yadav, Raghvendra Saxena, Diby Paul, and Rajesh Singh Tomar. "Biodiversity of pesticides degrading microbial communities and their environmental impact." Biocatalysis and Agricultural Biotechnology 31 (2021): 101883.
8. Ashwini, S., Prashantha, S. C., Naik, R., &Nagabhushana, H. (2019). Enhancement of luminescence intensity and spectroscopic analysis of Eu3+ activated and Li+ charge-compensated Bi2O3 nanophosphors for solid-state lighting. Journal of Rare Earths, 37(4), 356-364.
9. Liere, Heidi, Shalene Jha, and Stacy M. Philpott. "Intersection between biodiversity conservation, agroecology, and ecosystem services." Agroecology and Sustainable Food Systems 41, 7 (2017): 723-760.
10. Barnes, Andrew D., C. Scherber, Ulrich Brose, E. T. Borer, A. Ebeling, B. Gauzens, D. P. Giling et al. "Biodiversity enhances the multitrophic control of arthropod herbivory." Science Advances 6, 45 (2020): eabb6603.
11. Binny, Rachelle N., John Innes, Neil Fitzgerald, Roger Pech, Alex James, Robbie Price, Craig Gillies, and Andrea E. Byrom. "Long-term biodiversity trajectories for pest-managed ecological restorations: eradication vs. suppression." Ecological Monographs 91, 2 (2021): e01439.
12. MacDonald, Edith A., Jovana Balanovic, Eric D. Edwards, Wokje Abrahamse, Bob Frame, Alison Greenaway, Robyn Kannemeyer et al. "Public opinion towards gene drive as a pest control approach for biodiversity conservation and the association of underlying worldviews." Environmental Communication 14, 7 (2020): 904-918.
13. Shekhar, Shashank, Shreya Sharma, Amit Kumar, Anjali Taneja, and Bhasha Sharma. "The framework of nanopesticides: a paradigm in biodiversity." Materials Advances 2, 20 (2021): 6569-6588.
14. Kumar, Manish, Ajar Nath Yadav, Raghvendra Saxena, Diby Paul, and Rajesh Singh Tomar. "Biodiversity of pesticides degrading microbial communities and their environmental impact." Biocatalysis and Agricultural Biotechnology 31 (2021): 101883.
15. Kumar, C. P., Raghu, M. S., Prathibha, B. S., Prashanth, M. K., Kanthimathi, G., Kumar, K. Y., ... &Alharthi, F. A. (2021). Discovery of a novel series of substituted quinolines

acting as anticancer agents and selective EGFR blocker: Molecular docking study. Bioorganic & Medicinal Chemistry Letters, 44, 128118.

16. Baker, Brian P., Thomas A. Green, and Ali J. Loker. "Biological control and integrated pest management in organic and conventional systems." Biological Control 140 (2020): 104095.
17. Naranjo, Steven E., Peter C. Ellsworth, and George B. Frisvold. "Economic value of biological control in integrated pest management of managed plant systems." Annual review of entomology 60 (2015): 621-645.
18. Yue, L., Jayapal, M., Cheng, X., Zhang, T., Chen, J., Ma, X., ... & Zhang, W. (2020). Highly dispersed ultra-small nano Sn-SnSb nanoparticles anchored on N-doped graphene sheets as high performance anode for sodium ion batteries. Applied Surface Science, 512, 145686.
19. Indira, D. N. V. S. L. S., Ganiya, R. K., Ashok Babu, P., Xavier, A., Kavisankar, L., Hemalatha, S., ... & Yeshitla, A. (2022). Improved artificial neural network with state order dataset estimation for brain cancer cell diagnosis. BioMed Research International, 2022.
20. Jeffers, Andrew, and JuangHorng Chong. "Biological control strategies in integrated pest management (IPM) programs." Clemson Univ. Cooperative, Land-Grant Press Clemson Ext., LGP 1111 (2021): 1-9.
21. Babendreier, Dirk, Min Wan, Rui Tang, Rui Gu, Justice Tambo, Zhi Liu, Manfred Grossrieder et al. "Impact assessment of biological control-based integrated pest management in rice and maize in the greater Mekong subregion." Insects 10, 8 (2019): 226.
22. Ramprasad, P., Basavapoornima, C., Depuru, S. R., & Jayasankar, C. K. (2022). Spectral investigations of Nd3+: Ba (PO3) 2+ La2O3 glasses for infrared laser gain media applications. Optical Materials, 129, 112482.
23. Bueno, Adeney de F., Weidson P. Sutil, Simone M. Jahnke, Geraldo A. Carvalho, Maria Fernanda Cingolani, Yelitza C. Colmenarez, and Natália Corniani. "Biological Control as Part of the Soybean Integrated Pest Management (IPM): Potential and Challenges." Agronomy 13, 10 (2023): 2532.
24. Ragunathan, V., and B. J. Divakar. "Integrated pest management strategies." In Molecular Biology of the Biological Control of Pests and Diseases of Plants, pp. 173-196. CRC Press, 2020.
25. Harush, Avichai, Elazar Quinn, Anatoly Trostanetsky, Aviv Rapaport, Moshe Kostyukovsky, and Daphna Gottlieb. "Integrated pest management for stored grain: potential natural biological control by a parasitoid wasp community." Insects 12, 11 (2021): 1038.
26. Jaidass, N., Moorthi, C. K., Babu, A. M., & Babu, M. R. (2018). Luminescence properties of Dy3+ doped lithium zinc borosilicate glasses for photonic applications. Heliyon, 4(3).
27. Lakshmi, L., Reddy, M. P., Santhaiah, C., & Reddy, U. J. (2021). Smart phishing detection in web pages using supervised deep learning classification and optimization technique ADAM. Wireless Personal Communications, 118(4), 3549-3564.
28. Desneux, Nicolas, Peng Han, Ramzi Mansour, JuditArnó, Thierry Brévault, Mateus R. Campos, Anais Chailleux et al. "Integrated pest management of Tutaabsoluta: practical implementations across different world regions." Journal of Pest Science (2022): 1-23.
29. Lehmann, Jan Rudolf Karl, Felix Nieberding, Torsten Prinz, and Christian Knoth. "Analysis of unmanned aerial system-based CIR images in forestry—A new perspective to monitor pest infestation levels." Forests 6, 3 (2015): 594-612.

30. Spandana, K., & Rao, V. S. (2018). Internet of Things (Iot) Based smart water quality monitoring system. International Journal of Engineering and Technology (UAE), 7(3), 259-262.
31. Kumar, K. U., Babu, P., Basavapoornima, C., Praveena, R., Rani, D. S., & Jayasankar, C. K. (2022). Spectroscopic properties of Nd3+-doped boro-bismuth glasses for laser applications. Physica B: Condensed Matter, 646, 414327.
32. Alkorbi, A. S., Kumar, K. Y., Prashanth, M. K., Parashuram, L., Abate, A., Alharti, F. A., ... & Raghu, M. S. (2022). Samarium vanadate affixed sulfur self doped g-C3N4 heterojunction; photocatalytic, photoelectrocatalytic hydrogen evolution and dye degradation. International Journal of Hydrogen Energy, 47(26), 12988-13003.
33. Skendžić, Sandra, Monika Zovko, Ivana PajačŽivković, VinkoLešić, and Darija Lemić. "The impact of climate change on agricultural insect pests." Insects 12, 5 (2021): 440.
34. Tousova, Zuzana, Peter Oswald, Jaroslav Slobodnik, Ludek Blaha, MelisMuz, Meng Hu, Werner Brack et al. "European demonstration program on the effect-based and chemical identification and monitoring of organic pollutants in European surface waters." Science of the Total Environment 601 (2017): 1849-1868.
35. Ngugi, Lawrence C., MoatazAbelwahab, and Mohammed Abo-Zahhad. "Recent advances in image processing techniques for automated leaf pest and disease recognition–A review." Information processing in agriculture 8, 1 (2021): 27-51.
36. Vasileiadis, V. P., Silke Dachbrodt-Saaydeh, Per Kudsk, Caroline Colnenne-David, Florence Leprince, Imre J. Holb, Roman Kierzek et al. "Sustainability of European winter wheat-and maize-based cropping systems: Economic, environmental and social ex-post assessment of conventional and IPM-based systems." Crop protection 97 (2017): 60-69.
37. Srinivasan, K., Porkumaran, K., &Sainarayanan, G. (2009, August). Improved background subtraction techniques for security in video applications. In 2009 3rd International Conference on Anti-counterfeiting, Security, and Identification in Communication (pp. 114-117). IEEE.
38. Bhukya, M. N., Kota, V. R., & Depuru, S. R. (2019). A simple, efficient, and novel standalone photovoltaic inverter configuration with reduced harmonic distortion. IEEE access, 7, 43831-43845.
39. Alam, Mohammad Zahangeer, Md Manjurul Haque, Md Sirajul Islam, Emran Hossain, SabihaBinta Hasan, ShahelaBinte Hasan, and Md Sakhawat Hossain. "Comparative study of integrated pest management and farmers practices on sustainable environment in the rice ecosystem." International journal of zoology 2016 (2016).
40. Pretty, Jules, and Zareen Pervez Bharucha. "Integrated pest management for sustainable intensification of agriculture in Asia and Africa." Insects 6, 1 (2015): 152-182.
41. Rajput, Aashu, Shalini Roy, M. N. Waghmare, Swati Singh, Vineet Kumar Shukla, Vikash Singh, and Prachi Singh. "Exploring sustainable practices in modern agronomy and their environmental impact-A Review." International Journal of Environment and Climate Change 13, 11 (2023): 3146-3161.
42. Swarna, K. S. V., Vinayagam, A., Ananth, M. B. J., Kumar, P. V., Veerasamy, V., & Radhakrishnan, P. (2022). A KNN based random subspace ensemble classifier for detection and discrimination of high impedance fault in PV integrated power network. Measurement, 187, 110333.
43. Naresh, M., & Munaswamy, P. (2019). Smart agriculture system using IoT technology. International journal of recent technology and engineering, 7(5), 98-102.
44. Goud, J. S., Srilatha, P., Kumar, R. V., Kumar, K. T., Khan, U., Raizah, Z., ... & Galal, A. M. (2022). Role of ternary hybrid nanofluid in the thermal distribution of a dovetail fin with the internal generation of heat. Case Studies in Thermal Engineering, 35, 102113.