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Effectiveness of Integrated Pest Management (IPM) Adoption in Pakistani Farming Systems

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ABSTRACT

Integrated Pest Management (IPM) is an environmentally friendly and sustainable method of managing pests in agricultural systems and minimizing the use of chemical pesticides to sustain crop production. In Pakistan, the traditional pest control systems have resulted in environmental degradation, pest resistance and health hazards. This study assesses the effectiveness of IPM adoption in major farming systems by the Pakistanis, with specific reference to the consequence of its uptake in terms of pest incidence, crop yield, economic return and environmental safety. Field surveys were carried out in three provinces i.e. Punjab, Sindh and Khyber Pakhtunkhwa in order to gather data from farmers practising IPM and conventional pest management techniques. Results show that the use of IPM can lead to a significant reduction of pest population, as well as a reduction in pesticide use by up to 40%, in addition to increased crop yield. Farmers enforcing IPM had been determined to have better internet go back due to decreased farm enter fees and decreased losses of crops. The key elements recognized withinside the examine to persuade IPM adoption are the information of the farmers, extension support, availability of bio manage retailers and education programmes. The effects of this have a look at offer a effective reminder of the significance of advancing empty philosophy in country wide in all elements the arena so that you can develop sustainable agriculture, beautify meals safety, and guard farmer livelihoods.

Introduction

Agricultural productivity in Pakistan has been dependent on chemical pesticides for a long time to fight insect pest, weeds and diseases. While these chemicals have been provided short term effects, the over use has caused environmental pollution, pest resistance and also poses health hazards to farmworkers and consumers (Ahmad et al., 2017; Ali et al., 2019). Over use of chemical inputs has also led to secondary pest outbreaks, soil degradation and contamination of water bodies (Iqbal et al, 2018; Farooq et al, 2015). In response, the concept of Integrated Pest Management (IPM) has developed internationally and is based on a holistic approach to preventing and controlling pest populations at economically acceptable levels with a minimum impact on the environment engendering integration of biological, cultural, mechanical and chemical strategies (Kogan, 1998; van Lantern, 2012).

Adoption of IPM practises is small in Pakistan - Cloutier-Brook, A. and Efferle, H.-L. (2013) IPM adoption in Pakistan despite documented advantages.IPM adoption in Pakistan remains small despite documented advantages. Cloutier-Brook, A. and Efferle, H.-L. (2013) IPM adoption in Pakistan despite documented advantages. Due to socio-economic constraints, lack of farmer awareness, poor extension services, lack of biological control agents there is a low rate of implementation (Raza et al., 2018; Javed et al., 2020). Studies display that IPM can lessen the usage of insecticides via way of means of 30-50% and might

boom the yield of crop manufacturing, however, adoption charges are much less than 20% withinside the majority of cropping zones (Hameed et al. 2016, Khan et al. 2017). This low adoption places into query the viable environmental advantages, monetary blessings and fitness enhancements from sustainable pest control practices.

The fundamental practices of IPM are practiced in agriculture in Pakistan which might be normal checking of pest levels, the usage of resistant cropping varieties, crop rotation techniques, launch of herbal predators, use of pheromone traps and the intervention of selective insecticides at focused times (Shah et al., 2019; Ahmad et al., 2020). Farmers that undertake IPM record much less pest incidents, soil because of extra fitness, and yield balance than traditional practices the use of frequently chemical based practices (Iqbal et al., 2018; Tariq et al., 2017). IPM additionally enables to enhance the protection of meals with the aid of using lowering pesticide residues in harvested vegetation, that's an essential thing of public fitness (Farooq et al., 2015; Ali et al., 2019).

Economic elements are a primary element withinside the adoption process. IPM lower the expenditure on chemical inputs and limit lack of plants because of pests that results in doable profitability for farmers withinside the end (Raza et al., 2018; Khan et al., 2017). In the case of cotton and wheat, using IPM practices complements the pleasant of yields and decreases the wide variety of chemical sprays required to make sure pest manipulate on them (Hameed et al., 2016; Ahmad et al., 2017). Environmental sustainability is some other essential advantage, as much less pesticide use ends in upkeep of useful organisms, decrease pollution, and greenhouse fueloline emissions because of the manufacturing and alertness of insecticides (Pretty, Bharucha, 2015; Peshin, Dhawan 2009).

Despite those blessings, however, there are demanding situations to Ipm adoption. Limited get right of entry to to biocontrol agents, a lack of know-how of pest ecology, pressures withinside the agricultural markets to have vegetation covered immediately, and the range in weather situations make farmers much less influenced to use IPM to the fullest (Shah et al., 2019; Farooq et al., 2015). Additionally, shifting pest scenarios because of the climate change also require adaptive IPM strategies and ongoing research support (Iqbal et al., 2018; Javed et al., 2020).

Government as well as NGO-led initiatives to promote IPM through farmer training, demonstration plots and subsidies to buy biocontrol agents have shown promising results and it is seen that farmers trained in IPM in Punjab and Sindh have higher adoption rates and better crops outcomes (Ahmad et al., 2020; Raza et al., 2018). Nevertheless, scaling up these interventions across the region requires integrated policies, sustained education of the farmers as well as a monitoring mechanism to ensure sustainability in the use of IPM practices (Ali et al., 2019; van Lenteren, 2012).

This research will work out the competence of the IPM introduction in Pakistani farming system in terms of efficacy of pest controlling, yield enhancement, reduction in pesticide usage and saving. By analysing data for and across different cropping zones and identifying consistently factors that influence adoption, the research aims at offering usable guidelines for promotion of sustainable pest management practices and improvement of resilience of Pakistani agriculture (Ahmad et al., 2020; Ali et al., 2019; Raza et al., 2018; Khan et al., 2017).

Literature Review

Integrated Pest Management (IPM) has been accepted by many and widely recognized as a sustainable way of managing the pest in agricultural system through biological, cultural, mechanical and chemical strategies so as to achieve an economically acceptable pest population level (Kogan, 1998; van Lenteren, 2012). Globally, the implementation of IPM has helped improve pesticide overuse, increase crop productivity and minimise environmentally associated hazards (Peshin & Dhawan, 2009; Pretty & Bharucha, 2015).

In Pakistan, hypoxic by conventional pest control practices heavily rely on the application of chemical pesticides thereby causing environmental contamination, resistance to-dose chemical controls and adverse health effect on farmers and consumers (Ahmad et al., 2017; Ali et al., 2019). Indiscriminate use of pesticides has caused secondary pest outbreak, water body contamination and soil degradation (Iqbal et al. 2018; Farooq et al. 2015). In contrast, in IPM, the focus is on measures used in economic and ecological benefits like use of pest resistant crop varieties, crop rotation, biological control as well as careful use of pesticides (Shah et al., 2019; Ahmad et al., 2020).

Field studies have been conducted in Punjab, Sindh, and Khyber Pakhtunkhwa which has shown the effectiveness of adoption of IPM. As an example, among 30-50% discounts in pest populace is located in farmers the use of IPM in opposition to traditional practices in cotton and wheat (Hameed et al., 2016; Raza et al., 2018). IPM additionally brings down considerably the pesticide enter value at the same time as preserving or enhancing yield, this offers better internet returns to farmers (Tariq et al., 2017; Khan et al., 2017). Similarly, rice growers adopting IPM practices skilled profits in grain excellent and discount in pesticide residue content, indicating the boom in IPM in reaching meals safety (Farooq et al., 2015; Ali et al., 2019).

The socio-monetary and institutional elements influencing IPM adoption in Pakistan were well-documented. Farmer education, availability of extension services, cognizance of IPM principles, and availability of biocontrol marketers are very sturdy influencing elements for adoption rates (Javed et al., 2020; van Lenteren, 2012). It is observed that the extent of information and involvement in education packages will increase the opportunity for powerful adoption of IPM practices in farms through farmers (Ahmad et al., 2020; Iqbal et al., 2018). On the opposite hand, low get entry to to extension services, unavailability of resources, and danger prevention discourage the large adoption, specifically amongst smallholders (Raza et al. 2018; Shah et al. 2019).

Economic research have time and again proven the advantages of the adoption of IPM: Cotton farmers the use of IPM had extra boll yield and higher fibre nice with much less variety of pesticide sprays (Hameed et al., 2016; Ahmad et al., 2017). Wheat and rice farmers completed more desirable grain yield and progressed crop fitness below IPM and this translated in stepped forward profitability and decreased prices on chemical inputs (Farooq et al., 2015; Tariq et al., 2017). IPM adoption has also been associated with decreased crop losses from pests which plays a role in food security and sustainable farm incomes (Ali et al., 2019; Khan et al., 2017).

Benefits on the environment for IPM are huge. Less use of pesticides, which will reduce pollution of water, soil and air, and protections of useful organisms and greenhouse gases emissions, both of which are related to chemicals production and use (Pretty and Bharucha, 2015; Peshin and Dhawan, 2009). Ecological balance and the proper management of the pest population is carried out by biological control agents that include predator, parasitoid, and microbial bioagents (van Lenteren, 2012; Ahmad et al., 2020).

Despite the benefits, there are number of challenges that restrict the adoption of IPM in Pakistan. Limited availability of biological control agents, poor farmers knowledge of pest ecology, market pressures for immediate crop protection and climate variability discourage the total adoption of IPM (Shah et al., 2019; Farooq et al., 2015). Also, erratic climatic conditions and changing pest management situation have called for adaptive and region specific IPM strategies (Iqbal et al., 2018; Javed et al., 2020).

Government and NGOs initiatives in promoting IPM have concentrated on farmer education, demonstration plots and subsidized biocontrol agents (Ahmad et al., 2020; Raza et al., 2018). Such programs in Punjab and Sindh have resulted in an improvement rate of adoption among trained farmers with measurable improvement in crop yield and reduction of pesticide use (Hameed et al., 2016; Tariq et al., 2017). Scaling up these interventions on national levels involves policy support, agricultural education of the farmers, and constant monitoring of the deployed technologies to achieve sustainability (Ali et al. 2019; van Lenteren 2012).

Engagement methods with farmers and extension workers and researchers appear to be useful to facilitate knowledge exchange of IPM and its acceptance (Shah et al., 2019; Iqbal et al., 2018). Research notes that effective implementation of IPM is essential because socio-economic elements, including the perception of farming, credit access, market incentives and risk-preferences should be incorporated (Javed et al, 2020; Ahmad et al, 2017). An integrated method comprising of technical, economic and social intervention can help increase the adoption rates significantly and enable the IPM practices to be more sustainable to the long-term Pakistan agriculture.

To conclude, based on the available literature, it is evident that there are numerous benefits of adoption of IPM in Pakistan including enhanced pest management, productivity, reduced use of chemicals or preservation of the environment.

Nevertheless, the widespread adoption has not been enabled by socio-economic, institutional and technical constraints. Education, extension support, resource and policy incentive should be addressed to address these barriers to nuclear pests management to encourage sustainable pest management practices among the farming systems of Pakistan (Ahmad et al. 2020; Ali et al 2019; Raza et al 2018; Khan et al 2017).

Methodology

Research Design

This study has employed quantitative field based survey research design in order to determine the effectiveness of IPM adoption in the Pakistani farming systems. The research work was aimed at evaluating the pest control efforts, yield improvement of the crop along with decreasing the pesticide use, earnings the economic returns that one can associate with the practices of IPM when contrasted with the conventional pest management practices and methods.

Study Area

Primary data was collected from the City of Faisalabad from Faisalbad District in Punjab which are important center of agriculture where cotton, wheat and vegetables are grown in quantity. Faisalabad was selected because of the intensive farming system, various type of crops and a variety of farmers adopting and not adopting IPM. Focusing on one district ensured the possibility to get detailed and context specific data collection and controlling for agroclimatic variability.

Sampling Procedure

A stratified random sampling technique was used to insure representation of both IPM adopters and non-adopters. Farmers were categorized based on the type of crops (cotton, wheat, vegetables) and size of the farm (smallholder vs. large-scale). A total of 150 farmers were surveyed of whom 75 IPM and 75 conventional farmers. Stratification provided for even-handedness in comparing the kinds of crops and sizes of farms.

Data Collection issues Problems Instruments

Data collection was with the help of structured questionnaires, observation and informal interview. The questions included information on socio-economic variables of respondents, crop management practices, pest occurrence, pesticide use, crop yield and perceived economic returns. Field observations were made to take note of the pest density, health of crops and presence of natural enemies. Informal interviews were held with local agriculture officers and information on IPM training and resources on biocontrol was sourced.

Variables Measured

The following variables were the object of the study:

- oPest Incidence: Incidence, severity of pest infestation of crops.
- oCrop Yield: A measure of yield in units of kg per hectare, as is indicated for the type of crop going to be grown
- oPesticide Use Quantity and frequency of pesticide use per crop cycle.
- oEconomic Benefits Net income gains determining from cost of inputs Vs amount of crop returns.
- IPM Adoption Factors Farmer knowledge Extension support Availability of training and bio control agents.

Data Analysis

Data was coded and analyzed using the statistical software, version 28 of the Statistical Package for Social Science (SPSS) of IBM. Descriptive statistics (mean, standard deviation, frequencies) was used to sum up habitat characteristics of the individual farmers, pesticide use, crop performance. t-test and ANOVA were used for the comparisons of crop yield, pest incidence and economical gain of crop outcome of IPM adopters and non-adopters. Correlation analysis was employed in

checking correlation between IPM adoption and yield improvement, pesticide reduction and economic benefit. Factors affecting IPM Adoption Regression analysis was done identifying the factors affecting IPM adoption in Faisalabad District.

Ethical Considerations

Participation was voluntary and all of the respondents gave their own informed consent. Farmers information was kept secret and information was only used for research purposes. The research study was done under the ethical guidelines of research in the human subjects such as anonymity and privacy.

Data Analysis and Findings

The analysis of primary information obtained from 150 farmers in city of Faisalabad revealed different level of variation found in demographic factors, agronomic criteria and behavioural characteristics of farmers adopting Integrated Pest Management (IPM) as compared to farmers not adopting IPM. The descriptive results suggested that the IPM adopters were generally younger, slightly more educated and were farming somewhat larger landholdings. These differences are summarized in table 1 which reflects the average age of the adopters was 42.6 years, as compared with 44.1 for the non-adopters, while their average level of education was 9.8 years as compared with only 6.2 years with the non-adopters. Access to training was also a strong contrast in the two groups i.e. 78% of adopters reported on at least one exposure of IPM's related training sessions as compared to 15% of non-adopters.

Table 1. Descriptive Summary of Farmers (N = 150)

Variable	IPM Adopters (n=75)	Non-Adopters (n=75)
Average Age	42.6 years	44.1 years
Education Level	9.8 years	6.2 years
Farm Size	14.2 acres	11.6 acres
Access to Training	78%	15%

A detailed comparison of pest incidence revealed a significant effect of IPM practices on reduction of infestation level in cotton, wheat and vegetables crops. Weekly field observations showed reduced pest pressure that was consistently experienced by farmers who were using IPM strategies. The average pest incidence of cotton in IPM fields was 3.1 on a 10-point scale and the non-IPM fields had a 6.4 level of pest incidence. Similar trends were seen for wheat and vegetables, with IPM adopters indicating the incidence score to be 2.7 and 3.5 respectively compared to 5.1 and 7.2 for non-adopters as depicted in Table 2. Statistical testing of the data using Independent Samples t-tests proved these differences to be significant at $p < 0.01$ showing that IPM approaches significantly reduce pest populations under the agro climatic conditions of Faisalabad.

Table 2. Pest Incidence Levels (Scale 1–10)

Crop	IPM Adopters	Non-Adopters
Cotton	3.1	6.4
Wheat	2.7	5.1
Vegetables	3.5	7.2

The data also showed large differences in the amount of pesticides used by the two groups. Farmers that used IPM practiced fewer chemical sprays per season, applied lower volumes of pesticides, and had lower chemical costs. Address SPrays The IPM adopters had on average conducted 4.3 sprays per season compared with 8.6 sprays among non-adopters. Similarly, quantity of pesticide per acre was much lower among adopters (2.1 litres/acre) than among non-adopters (5.8 litres/acre). This reduced in terms of cost-saving, since the adopters had to spend PKR 6800 on chemicals against PKR 18400 by non-adopters as shown in Table 3. These results are the basis of the economic gain that originates from decreased pesticide dependency as well as the contribution of knowledge-based pest control strategies to reduced input costs.

Table 3. Pesticide Use per Season

Variable	IPM Adopters	Non-Adopters
Number of Sprays	4.3	8.6
Liters of Pesticides Used	2.1 L/acre	5.8 L/acre
Cost of Chemicals (PKR)	6,800	18,400

Yield analysis also contributed to the evidence that IPM works. Adopters always had better crop yields in all major crops examined in the study period. Cotton yield in the IPM users averaged 927 kg/acre, which is 782 kg/acre for the non-users. Wheat production also showed the same trend with yield of 1,274 kg/acre as compared to 1,115 kg/acre. Vegetable yield grew to a phenomenal difference where IPM-adopters harvested 1,982 kg/acre of vegetable production as compared to 1,501 kg/acre by non-adopters. These results which were summarized in table 4 were statistically significant at $p<0.05$ as was confirmed using the help of analysis of variance (ANOVA). Greater yields on the other hand were directly correlated to reduced pest pressure, reduced crop damage and improved plant health under IPM regimes.

Table 4. Yield Comparison (kg/acre)

Crop	IPM Adopters	Non-Adopters
Cotton	927	782
Wheat	1,274	1,115
Vegetables	1,982	1,501

Economic analysis showed the combination of lower costs for pesticides and increased yields resulted in a great deal more profitability for IPM adopters. The total cost of input per acre on IPM users was PKR 32,500 against PKR 47,000 of non-adopters. More so, consequent to improved crop performance, the IPM farmers earned revenues of PKR 89,300 per acre as against PKR 68,700 for non-adopters. This amounted to a net return of PKR 56,800 for adopters and a net return of PKR 21,700 for the non-IPM group as shown in table 5. These margins indicate the financial benefit to the switch to IPM, especially in areas where chemical dependency has been an economic burden for small holder farmers as these inputs are typically expensive.

Table 5. Net Economic Returns per Acre (PKR)

Category	IPM Adopters	Non-Adopters
Total Input Cost	32,500	47,000
Total Revenue	89,300	68,700
Net Return	56,800	21,700

Correlation evaluation indicated large relationships among key variables as education get right of entry to remarkably advanced probabilities of IPM adoption ($r= 0.71$). IPM adoption turned into inversely related to pesticide ($r = -0.66$), displaying that growing expertise primarily based totally pest techniques are in truth powerful in lowering chemical dependency. Higher crop yield turned into fairly and undoubtedly related to IPM adoption ($r = 0.59$) and negatively related to pest Incidences ($r = -0.54$). These findings have been reinforced in regression evaluation in which IPM adoption become determined to be the satisfactory predictor of yield with a beta coefficient of 0.48 ($p = 0.000$). Access to education and farm length had been additionally great predictors at the same time as pesticide use had a bad effect on yield outcomes.

Faisalabad data overall validates the empirical patterns linked to the adoption of IPM, showing that the adoption of IPM systematically increases agricultural performance in terms of biological, economic, and environmental dimensions. The combined evidence of pest incidence reduction, minimized pesticide use, increased yields, and increased profitability have shown that IPM is a very effective and sustainable farming strategy in the intensive agricultural zones in Pakistan.

Discussion

The outcomes of the existing take a look at display that organic, agronomic and monetary consequences withinside the IPM adoption of farming structures of Faisalabad are appreciably stepped forward than traditional pest manipulate practices. The lower in pest prevalence on cotton, wheat and vegetable plants suggests that IPM's awareness on ecological balance, organic

manage sellers and cultural practices is higher while applied than in depending totally on chemical insecticides. These consequences are regular with preceding research displaying that included techniques are much less at risk of pest buildup, sluggish pest resistance development, and are much more likely to cause wholesome crop boom (Khan et al., 2021; Ullah & Javed, 2020). The appreciably decreased pesticide packages via way of means of the adopters confirms now no longer simplest an environmental gain however additionally a conduct extrade a number of the farmers that obtained suitable education. Access to extension offerings emerged as a important determinant of adoption, which helps the current studies which claims that institutional assist shapes the mindset of farmers in addition to their potential to enforce contemporary-day practices (Shahbaz et al., 2022). The sizable increase in yields of adopters results in even greater a factor of the agronomic power of IPM, as more healthy flowers with much less chemical aggressions are greater green in water allocation to effective biomass. Economic evaluation additionally brought in addition weight to the case for IPM in phrases of better internet returns, which have been primarily based totally on each decrease charges and better revenues. This economic gain is especially vital for positive regions along with Punjab, wherein small and medium farmers generally tend to paintings with scarce assets and at excessive enter expenses. Overall, the evaluation suggests that IPM isn't always most effective an environmental method however a innovative agricultural exercise with advantages to growth the sustainability, income and resiliency of farming structures.

Conclusion

This examine concludes that the Integrated Pest Management has appreciably advanced farm's productiveness and financial profitability with the discount of chemical dependency in agricultural panorama of Faisalabad. By combining organic, cultural and mechanical manage practices, IPM customers have been capable of gain discounts in pest infestation, fewer packages of insecticides and more crop yields for a number of plants. The statistical findings aid in a totally robust empirical manner the function of IPM as a scientifically-confirmed and economically feasible pest manipulate strategy. The fulfillment of IPM model on this examine turned into intently associated with schooling and farmer awareness, which shows that information dissemination performs an critical element in agricultural transformation. Given the wonderful outcomes said in phrases of pest suppression, yield enhancement and monetary returns, adoption of IPM is a important pathway to convert the Pakistani agriculture in the direction of a sustainable pathway of development. The take a look at provides testimony to the reality that for a few regions of the world, which include Punjab, in which there's considerable misuse of insecticides and degradation of farming soils, IPM is a sensible and impactful opportunity to the cutting-edge agricultural system, reaping rewards farmers and the broader environmental system.

Recommendations

Based on the empirical evidence, this study suggests that government agencies, agricultural extension department as well as non-governmental organizations to increase IPM-specific training programs in Faisalabad and similar agricultural district(s). Since training demonstrated a strong influence on adoption, structured capacity building undertakings, including demonstration plots, field days and farmer-to-farmer learning should be prioritized in order to overcome knowledge gaps. The availability of biological control agents, pheromone traps and IPM kits has to be enhanced through the agriculture offices nearest to farmers so the farmers have access to the tools needed to practice IPM effectively. Policy interventions in this respect should also include incentives to farmers to minimise the use of chemicals through credits for bio-pesticides and encouragement for certification systems for low-chemical produce. Strengthening extension service with up-to-date curricular on ecological agriculture can be another way of supporting the adoption. Future research is advised looking at longitudinal research to assess the long-term ecological effects of IPM and broadening the scope of work to other areas with varying cropping systems. Overall, coordinated engagement of institutions, policy makers and farming communities is the key to mainstream IPM at the different farming systems across Pakistan.

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