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Impact of Climate Variability on Insect Pest Incidence and Farmers' Adaptive Strategies

[*1]Muhammad Saleem
[2]Samrat Sikdar
[1]Ph.D. Agricultural Extension
[2]School of Human Sciences, College of Agriculture & Life Sciences, Mississippi State University, Starkville, MS 39762, USA
[*1]saleemshykh@gmail.com

Abstract

Climate variability is a major problem to agricultural productivity as it changes the pest patterns and endangers the crop yield. This paper explores how Impact of Climate Variability on Insect Pest Incidence and Farmers' Adaptive Strategies in South Punjab, Pakistan. Three divisions (Multan, Bahawalpur and Dera Ghazi Khan) were randomly sampled to include 120 farmers who were surveyed on the pest incidence, climate perception, contact on extension and adaptation response. The data were analyzed using descriptive statistics, correlation, Chi-square tests, binary logistic regression, and multiple linear regression. Findings show a high incidence of pests with an average of 72.5 percent of farmers reporting on higher incidences of pests in the past few years, and the common ones being sucking pests and bollworms. Binary logistic regression identified significant positive increases in the probability of pests to occur on Climate Variability Index ($B = 1.284$, $Exp(B) = 3.61$, $p < 0.001$) and negative significant mitigating effects of extension contact on pest increase ($B = -0.743$, $Exp(B) = 0.48$, $p = 0.009$). Experience in farming and farm size had a positive correlation with incidence of pests. The multiple linear regression indicated adaptive strategy by farmers had strong impacts of perception of climate variation ($b = 0.431$, $p < 0.001$), extension contact ($b = 0.297$, $p < 0.001$), education ($b = 0.215$, $p = 0.005$) and the size of the farm ($b = 0.143$, $p = 0.047$). These results highlight the high importance of climate-sensitive extension services in increasing the adaptive capacity of farmers and encouraging sustainable pest control. Specific advisory services, knowledge sharing, and climate robust interventions are suggested to reduce the risks of pests and enhance the sustainability of agriculture in the new climatic conditions.

Keywords: Climate Change, Insect-pest, alternatives, Yield

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Corresponding Authors*
Muhammad Saleem

Introduction

The issue of climate change and climate variability have become some of the most topical challenges that global agricultural systems have to face. Climate has always been varied over the 4-5 billion-year history of Earth, but the most recent changes have been caused by anthropogenic factors, especially by the growing concentration of greenhouse gases (GHGs), namely CO_2, CH_4, and N_2O (Khan et al., 2009). These emissions, which are mostly facilitated by fossil fuel combustion and modification of land use, have enhanced global warming causing changes in temperature regimes, change of precipitation patterns, melting of glaciers, rising sea levels and increased occurrence of extreme weather events like droughts and heat waves (Nega, 2025). These are not mere environmental issues but they also bring a lot of danger to agricultural productivity, food security, stability of the ecosystem and the wellbeing of human beings.

Both biotic and abiotic stresses are especially susceptible to agriculture in the changing climatic conditions. Insect pests, weeds and diseases are some of the most important biotic stresses that limit crop productivity and quality. The insect pests alone contribute about 20-37% of yield losses around the world, which equates to almost US 70 billion yearly (Arshad et al., 2019). Herbivorous insects are very adaptable and can colonize and spread very fast depending on the presence of hosts and environmental alterations in agro-ecosystems. Climate variability- which is a movement in temperature, rainfall, and extreme weather conditions- has a direct impact on the physiology of insects, their population, survival, reproduction, and range. Since insects are ectothermic, minor changes in temperature can make them grow faster, produce more generations per season, enhance overwintering conditions, and expand their range to previously inhospitable places (Skendzic et al., 2021; FAO, 2022; Abebaw, 2025). In addition, any change in climatic conditions can interfere with the ecological interactions among the pests, the host plants and the natural enemies and this may lead to increased and severe pest outbreaks.

In Pakistan, an agrarian economy where agriculture has a significant contribution to GDP and a huge labor force working in the rural areas, climate variability has made the prevailing situation of crop protection much complicated. Over the past decades, there has been an increase in temperature, inconsistent rainfall patterns, extended droughts, and frequent floods in the various agro-ecological zones of the country. These climate changes have had a great impact on pesting in the major crops. It is shown that there is availing pest pressure in cotton-based agricultural systems where the high temperatures during summer and unpredictable rainfall conditions contribute to the proliferation of sucking insects pests (Arshad et al., 2009). Empirical observations in Khyber Pakhtunkhwa also indicate that because of the rise in temperatures and a reduction in rainfall, the pest incidence and the damage of the crop have significantly increased (Bukhari, 2025). Also, massive migratory pests like desert locusts have shown an increased outbreak under climate-related unpredictable weather patterns, increasing the pressure on the livelihoods of farmers (Reuters/AP analysis, 2024). Not only they lead to direct losses in yield, but also to the rise in dependence on chemical pesticides, which provokes doubts about the risk of developing resistance, the worsening of the environment, or the sustainability of such a model in the long term.

Pakistani farmers are on the frontline of climate variability and risks of pests at the farm level. To counter this, they have taken a number of adaptive measures to prevent being vulnerable. They comprise a change in the sowing dates, climate-smart farming, crop varieties, better irrigation and water management, enhanced soil conservation, and change in the approaches of managing pests (Abid et al., 2015; Shahzad et al., 2021; Javed et al., 2025). Nevertheless, these adaptation strategies can be successful under varying socio-economic settings, institutional aids, and access to extension services, as well as climate information availability (Md. et al., 2022; Javed et al., 2025). The adaptive capacity of farmers is usually limited by finances, poor implementation of the policies, and lack of technical guidance, and given the rising rate of climate variation and the magnitude of effect on the occurrence of insect pests, the interrelationship between climate variation and pest dynamics and adaptive responses of farmers demands an understanding. These linkages need to be thoroughly evaluated to ensure the development of the resilient pest management strategies, the extension of agricultural systems, and the creation of the evidence-based policies to promote sustainable development of agriculture in Pakistan.

Methodology

To conduct the study, the South Punjab area was chosen because it is an agricultural region. The area includes three divisions namely Multan, Bahawalpur, and Dera Ghazi Khan. A total of 40 farmers from every division was randomly selected making 120 farmers in total to collect data.

1. Measurement of Key Variables

The pest incidence in this research was considered the dependent variable and it was adapted as asking the farmer whether the attack by insect pests had increased, decreased or stayed the same in the past five years. To conduct the binary logistic regression analysis (Table 8), the variable was binaryized into a binary outcome (1 = increase in pest incidence and 0 = no change or decrease). The Climate Variability Perception Index was a composite scale or a Likert Scale that had responses of the farmers in terms of observed variations in temperature, rainfall irregularity, and extended dry spells (1 = Strongly Disagree to 5 = Strongly Agree). This index was computed by averaging the standardized scores of the items in question, which gave a continuous outcome of perceived climatic variability of farmers. The extension contact was determined by the rate of contacts with extension agents in the previous cropping season; this was in terms of the number of visits per season; this is a measure of the accessibility of the farmers to technical advice and advisory services. The Adaptive Strategy Index (Table 9) was derived by adding the count of the adaptation measures that were adopted by farmers where the adoption involved practices like the adoption of Integrated Pest Management (IPM), changing the spray timing, planting resistant crops, and crop diversification. This index was considered as a continuous variable in order to evaluate the level of adaptive behavior. Also, control variables were added to check the differences on an individual and farm-level, namely, the years of experience in farming, farm size in acres, and level of education in years of schooling, because these variables are most likely to affect both the pest management practices and the decisions on adaptation.

2- Correlation Analysis (Table 6)

The Pearson Product-Moment Correlation test was used to test the linear association between pest incidence, the perception of climate variability, the contact with extensions, the farming experience and the farm size. Both the magnitude and the direction of relationships were determined using the correlation coefficient (r). Significance of the statistics was done at 5% and 10% probability. To evaluate assumptions of normality and multicollinearity, skewness, kurtosis, and Variance Inflation Factor (VIF) diagnostics were evaluated before analysis.

3- Chi-Square Test of Association (Table 7)
The Chi-square (χ^2) test of independence was employed to examine the association between categorical climate variability indicators (temperature increase, irregular rainfall, dry spells) and perceived increase in insect pest incidence.
The test statistic was calculated as:

$$\chi 2=\sum E(O-E)2 \quad /E$$

Where:
O = Observed frequency
E = Expected frequency
Degrees of freedom were calculated as (r−1)(c−1). A p-value less than 0.05 was considered statistically significant.
4-Binary Logistic Regression Analysis (Table 8)
Binary logistic regression was applied to identify determinants influencing the likelihood of increased pest incidence.
The logistic regression model was specified as:

$$\ln(1-PP \quad)=\beta o \quad +\beta 1 \quad CVI+\beta 2 \quad EC+\beta 3 \quad FE+\beta 4 \quad FS+\epsilon$$

Where:
P = Probability of increased pest incidence
CVI = Climate Variability Index
EC = Extension Contact
FE = Farming Experience
FS = Farm Size
β_0 = Constant
ε = Error term
The Wald statistic was used to test the significance of individual predictors. Model fitness was evaluated using:
-2 Log Likelihood
Nagelkerke R^2
Classification accuracy
Odds ratios (Exp(B)) were interpreted to explain the likelihood of pest increase.
5-Multiple Linear Regression Analysis (Table 9)
Multiple linear regressions was used to assess factors influencing the Adaptive Strategy Index.
The regression equation was:

$$Y=\alpha+\beta 1 \quad CVI+\beta 2 \quad EC+\beta 3 \quad EDU+\beta 4 \quad FS+\mu$$

Where:
Y = Adaptive Strategy Score
CVI = Climate Variability Perception
EC = Extension Contact
EDU = Education Level
FS = Farm Size
μ = Error term

Results and Discussion

Table 1: ***Socioeconomic Characteristics of Respondents***

Variable	Category	(f)	(%)
Age (Years)	Below 30	26	21.7
	31–50	75	62.5
	Above 50	19	15.8

Education Level	Illiterate	22	18.4
	Primary	33	27.5
	Secondary	43	35.8
	Higher Secondary & Above	22	18.3
Farming Experience	≤10 years	38	31.7
	>10 years	82	68.3
Farm Size	Small (≤5 acres)	56	46.7
	Medium (6–12 acres)	46	38.3
	Large (>12 acres)	18	15.0

The socio-demographic features of respondents help to provide significant information about the organization and potential of the farming community. Most of the farmers (62.5) are between 31-50 years old which means that most of the respondents are on their productive and active years in life. The proportion of those less than 30 years (21.7%), and less than 50 years (15.8%) is much lower, indicating moderate youth involvement and slow generation change in agriculture. Education wise, 35.8% of the farmers have secondary education, 27.5% primary education, 18.3% higher secondary education, and above and 18.4% is illiterate. It indicates that the largest percentage of farmers have basic formal education and this can have a positive impact on their perception of climate variability, pest management, and adoption of adaptive practices, though the illiteracy of farmers may restrain successful transfer of technical knowledge. In terms of farming experience, most of them (68.3% have over 10 years of experience in farming, which implies that they have much practical experience and are familiar with production and pest issues related to crops. This experience can serve as a strength to detecting climate-related pest alterations; the experience can have an impact as well on dependence on traditional practices. The size distribution of farm sizes reveals that almost half of the sample (46.7) are small farmers with owning ≤5 acres, 38.3 are medium farmers with owning 6-12 acres, and only 15.0 % are large farmers with owning (>12 acres). The fact that small and medium landholdings are predominant indicates the characteristic agrarian nature of Pakistan and implies that it could be susceptible to climatic changes and pest outbreaks because of the low financial and technological capacities. In general, the results reveal that the farming population is characterized by middle-aged, moderately educated, experienced, and small-scale farmers and it has significant effects on development of specific extension and climate-resistant pest management interventions.

Table 2: ***Farmers' Perceptions of Climate Variability***

Statement	**Yes (f)**	**Yes (%)**	**No (f)**	**No (%)**
Increase in temperature over last decade	94	78.3	26	21.7
Irregular rainfall pattern	86	71.7	34	28.3
Prolonged dry spells	77	64.2	43	35.8
Rising temperature increases pest attacks	83	69.2	37	30.8
Seasonal shifts affecting pest life cycle	89	74.1	31	25.9

The results that were found in Table 2 show that a significant proportion of the farmers believe that they could observe the changes in the climatic conditions during the last ten years. Approximately, 78.3 percent of the respondents indicated that they had experienced an increase in the temperature, whereas 71.7 percent indicated that they had experienced irregular rain patterns. Likewise, 64.2 percent of farmers felt that there were long dry seasons, which indicated that there is general understanding of climatic unpredictability in the study region. These images imply that the majority of farmers are experiencing and appreciating climate variability in their immediate surroundings and this might affect their agricultural decision making. Regarding the pest dynamics, 69.2% had an opinion that the increase in temperatures has been increasing the pests attacks and 74.1% thought that the seasonal changes are also influencing the pest-life cycles. Such results show that the perceived connection between climate variability and shifts in the occurrence of insect pests is high. It is also possible that farmers feel more pressure on pests because of higher temperatures and season disruptions, and they would think more about pests. Altogether, the findings indicate that farmers are extremely conscious about changes in the climate and its effects on crop protection, and the necessity to incorporate climate knowledge and adaptive pest management plans into agricultural extension programs is great.

Table 3: ***Change in Insect Pest Incidence Compared to Previous Years***

Response	Frequency (f)	Percentage (%)
Increased	87	72.5
No Major Change	22	18.3
Decreased	11	9.2
Total	120	

Table 3 findings indicate that a stressed majority of farmers (72.5) noted that there has been an upsurge in the incidence of insect pests over the last few years. This shows that majority of respondents will believe that there is an increasing trend in the pest pressure and this can be linked to the changing climatic conditions like increased temperature, irregular rainfall and change in the seasons. The rise in the pest infestation that is reported by the farmers corresponds with the previous perceptions that farmers had that climatic variability was becoming a factor that affects pest attacks and life cycles. In the meantime, 18.3% of the respondents claimed that there has been no significant change in pest occurrence and it might indicate that the climatic effects may be location-specific or system-specific. The percentage (9.2) that had experienced lower incidence of pests has been attributed to better pest management practices, diversification of crops or localized environmental conditions. Altogether, the results indicate that the rise in incidence of insect pests is a major concern amongst farmers, and there is a necessity to tackle the problems of pest management based on climate-resilient strategies and enhanced agricultural extension services.

Table 4: ***Major Insect Pests Reported by Farmers***

Pest Type	f	%
Sucking pests (aphids, whitefly, jassid)	92	76.7
Bollworms / Borers	74	61.7
Leaf miners	58	48.3
Mealy bugs	63	52.5
Armyworms	41	34.2

*Multiple responses were allowed.

According to the results of Table 4, the most widespread reported insect pests include sucking pests, including aphids, whitefly, and jassids, most likely due to the insects being identified by 76.7 percent of farmers as a major concern. This large prevalence means that sucking pests are very dispersed and constituted a serious menace to crop productivity, especially when the temperature and the humidity are increasing, which are the conditions favorable to their quick multiplication. Their feeding habits not only make plants weak through extracting sap but also infects viral diseases hence multiplying losses in production. The prevalence rate of bollworms and borers was reported to be 61.7 percent and showed that they remained vital pests that destroy crops such as cotton and maize. Such pests will inflict direct harm by doing a bore into plant tissues and this will affect yield and quality. Mealy bugs (52.5) and leaf miners (48.3), in turn, were also frequently cited, which represents moderate yet significant pest pressure. Their rising prevalence can be associated with the changes in climate that improve the survival and reproduction rates. Armyworms were reported by 34.2 percent of the farmers, which is rather lower but still very high of concern, especially in the favorable environment conditions which provoke the outbreak. Altogether, the prevalence of sucking pests and bollworms implies the necessity of enhanced integrated pest management (IPM), climate-based pest monitoring, and prompt extension advising. The variety of the pests listed also indicate that farmers are experiencing a number of pests at the same time which can also raise the cost of production and use of chemical pesticides

Table 5: ***Farmers' Adaptive Strategies to Manage Increased Pest Incidence***

Adaptive Strategy	f	%
Increased pesticide application	95	79.2
Changed spray schedule	82	68.3
Adoption of Integrated Pest Management (IPM)	54	45.0
Use of resistant varieties	47	39.2
Crop diversification	36	30.0
Consultation with extension staff	61	50.8

*Multiple responses were allowed.

The findings show that farmers heavily use chemical-based interventions to deal with augmenting pest pressure. The most common adaptive strategy adopted (79.2) was the increment of pesticide application. This indicates that chemical control is perceived as the most convenient and the fastest response that farmers can give to the increasing pest incidence. On the same note, 68.3 percent of the respondents claimed that they had altered their spraying schedules probably changing the frequency and time according to the changes in pest life cycles and seasonal changes. Although these measures might offer short term containment, long-term pesticide use might cause high production expenses, rapid development of pest resistance and cause environmental and health hazards. Conversely, there was a low number of farmers who stated to be more sustainable and preventive in their approach. The adoption of Integrated Pest Management (IPM) was at only 45.0% and those using resistant crop varieties was at 39.2%. Only 30.0% of respondents implemented crop diversification, which can help to decrease the accumulation of pests and increase the resilience of the system. Moderate use of formal advisory services was indicated by 50.8% of farmers reporting consultation with the extension staff. The fact that IPM, resistant varieties, and diversification are less adopted means that there may be gaps in the dissemination of knowledge, technical service, or availability of resources. In general, the results indicate that farmers are proactively addressing the rising pest pressures, but their adaptive mechanisms remain mostly reactive and chemical-dependent, which implies the necessity to make extension services more robust and advance the climate-resilient and sustainable strategies of pest control in the future.

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Table 6: *Correlation Matrix among Key Variables*

Variables	Pest Incidence	Climate Variability Perception	Extension Contact	Farming Exp.	Farm Size
Pest Incidence	1.000	-	-	-	-
Climate Variability Perception	0.621**	1.000	-	-	-
Extension Contact	-0.314**	-0.205*	1.000	-	-
Farming Experience	0.289**	0.174	-0.121	1.000	-
Farm Size	0.247*	0.198*	0.142	0.233*	1.000

Table 6 demonstrates the correlations between the essential variables in the study and gives valuable information about the dynamics of pest incidence and the factors. The incidence of pests is significantly correlated positively to climate variability perception ($r = 0.621$, $p < 0.01$), meaning that those farmers who perceive more change in the weather conditions are also likely to report high incidence of insect pests. This indicates that there is a significant correlation between perceived climatic change in pest outbreaks which adds credence to the claim that climate variability is indeed affecting pest dynamics in the study region. The extension contact is significantly and negatively correlated with pest incidence ($r = -0.314$, $p < 0.01$), which means that the farmers who have more frequent contact with extension services are less likely to have pest incidence. This can be indicative of the success of the advisory support, better pest management information, and technical advice in time minimizing the pressure of pests. On the same note, extension contact is found to be related negatively with climate variability perception ($r = -0.205$, $p < 0.05$), indicating that farmers who have a higher institutional support might be in a better position to address or cope with climate-related issues. The correlation between farming experience and pest incidence is positive and significant ($r = 0.289$, $p < 0.01$), which means that the more experienced farmers are reported to experience pest incidence. It may be due to the fact that the experienced farmers are better placed to detect pest changes or they might be practicing farming methods that puts them at a disadvantage of constant pest attacks. Pest incidence also has a positive relationship with the farm size ($r = 0.247$, $p < 0.05$), and this is because bigger farms might be exposed to more pest problems because they have more cropped land and are at a higher risk of encountering pests. Also, there is a positive correlation between the size of a farm and the experience of farming ($r = 0.233$, $p < 0.05$), whereby more experienced farmers could have acquired larger farms over the years.

Table 7: *Chi-Square Analysis: Climate Variability and Pest Increase*

Variables	χ^2 value	df	p-value
Perceived Temperature Increase × Pest Increase	18.64	2	0.000
Irregular Rainfall × Pest Increase	14.27	2	0.001
Dry Spells × Pest	11.53	2	0.003

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Increase

The Chi-square test as in Table 7 shows that there are significant relationships between the perceptions of the farmers about climate variability and the reported rise in the pest levels of incidence. In particular, the correlation between the perceived temperature change and pest change is significant ($\chi^2 = 18.64$, df = 2, $p < 0.001$), which means that farmers who reported to have experienced an increase in temperatures tend to report a significant increase in pest incidence. Likewise, pest increase is also closely correlated with irregular rainfall ($\chi^2 = 14.27$, df = 2, p = 0.001), which means that anomalies in the regular precipitation patterns also lead to increased pest pressure. It was also discovered that prolonged dry spells were largely associated with increases in the pests too ($\chi^2 = 11.53$, df = 2, p = 0.003), which supports the effect of moisture stress on changing the pest population patterns. All these results point to the idea that farmers view climate variability, such as warmer temperatures, unpredictable rainfall, and prolonged droughts, as one of the causes of insect pest outbreaks. The statistically significant findings have highlighted the role of considering climate perception data in the pest management planning and formulation of adaptive strategies to minimize crop vulnerability.

Table 8: ***Binary Logistic Regression Analysis of Factors Affecting Increased Pest Incidence***

Variable	B	S.E.	Wald	Exp(B)	p-value
Climate Variability Index	1.284	0.312	16.92	3.61	0.000
Extension Contact	-0.743	0.285	6.80	0.48	0.009
Farming Experience	0.056	0.021	7.11	1.06	0.008
Farm Size	0.118	0.064	3.39	1.12	0.065
Constant	-2.174	0.754	8.30	-	0.004

(Dependent Variable: 1 = Increased Pest Incidence, 0 = No/Decreased)

Results of the binary logistic regression as in Table 8 reveal the factors that affect the probability of more incidences of insect pests among farmers. The dependent variable will be coded 1 where there is more pest incidence and 0 where there will be no or reduced incidence. The Climate Variability Index is a good and meaningful positive predictor of high pest incidence (B = 1.284, Wald = 16.92, Exp(B) = 3.61, $p < 0.001$), and it implies that there is a one-unit increase in pest incidence, the odds of which are increased 3.61 times. This testifies to the fact that farmers correlate the presence of higher temperatures, unequal precipitation, and the changes in seasons with the increase in the pressure of pests. There is a significant negative impact of extension contact (B = -0.743, Wald = 6.80, Exp(B) = 0.48, p = 0.009), indicating that those farmers having higher contact with extension services have less likely an increased pest incidence. It means that the extension support should be effective to enhance pest management practices and reduce the effects of climate variability. There is a positive relationship between the experience of farming and the higher pest incidence (B = 0.056, Wald = 7.11, Exp(B) = 1.06, p = 0.008) indicating that more experienced farmers have a slight higher probability of reporting higher pest incidence, perhaps because they are in a better position to notice the pests changes and report them. There is a positive, but nonsignificant impact of farm size (B = 0.118, Wald = 3.39, Exp(B) = 1.12, p = 0.065) which suggests that large farms can be slightly predisposed to the increased pest incidence which might be because of bigger size of the farm and greater risk of exposure.

The negative coefficient (B = -2.174, p = 0.004) is the odds of an increase in pest incidence in the case where all predictors take the value of zero. All in all, the model identifies climate variability as the strongest driver of pest incidence, whereas extension contact is the most important mitigating factor, that is, proactive advisory and climate-related pest management responses are necessary.

Table 9: ***Multiple Linear Regression: Determinants of Farmers' Adaptive Strategy Index***
(Dependent Variable: Adaptive Strategy Score)

Variable	β	t-value	p-value
Climate Variability Perception	0.431	5.82	0.000
Extension Contact	0.297	3.94	0.000
Education Level	0.215	2.88	0.005
Farm Size	0.143	2.01	0.047
R^2	0.52	-	-
F-value	32.74	-	0.000

The multiple linear regression analysis (Table 9) can help to determine the most important determinants that can affect the adoption of adaptive strategies by farmers as the index of the Adaptive Strategy. The model accounts for 52 percent of the variance in the adaptive strategy score (R2 = 0.52) which means that it fits well. The F-value (32.74, $p < 0.001$) proves that the model is not insignificant and the predictors included in it have joint effects on the adaptive behavior of farmers. Climate variability perception holds also the most significant positive impact on adaptive strategies adoption (b = 0.431, t = 5.82, $p < 0.001$), which means that the more farmers are conscious of how changes in climate, rainfall, and seasonal shifts are taking place, the more they tend to adopt strategies to address the pest pressure and other climate-related issues. Another important positive factor is also the extension contact (b = 0.297, t = 3.94, $p < 0.001$), as the extension services play a significant role in knowledge transfer, advisory support, and technical guidance stimulating a proactive adaptation. The level of education also significantly influences (b = 0.215, t = 2.88, p = 0.005) higher education levels of the farmers can contribute to the adoption of the appropriate pest management and adaptive practices through better understanding of the practices. The size of the farm is also a weak, but significant, positive predictor (b = 0.143, t = 2.01, p = 0.047) which indicates that bigger farmers might possess more resources and flexibility to adopt several adaptation measures. In general, the findings suggest that awareness of climate variability, availability of extension services, education, and farm resources are all related to adaptive behavior among the farmers. These results demonstrate the relevance of the targeted extension interventions, capacity building programs, and dissemination of knowledge to increase climate resilient farming practices and the effective management of pests.

Discussion

Socio demographic profile of the respondents show structural aspects of the respondents that affect their perceptions and adaptive responses to climatic variability and pest challenges. The sample was mainly composed of economically active producers with majority of farmers (62.5 %) being between the ages of 31 and 50. This is consistent with the rural Pakistan results that middle aged farmers are more involved in farm decisions making and more inclined to adopt agricultural changes as compared to younger and older groups (Abid et al., 2015; Chaudhry et al., 2012). The fact that the proportion of farmers below 30 years (21.7) is lower implies they might not have the youth engagement in farming, which might limit the entry of new ideas and long term sustainability in rural agriculture-also observed in the literature on youth engagement in Pakistani agriculture (Ahmad et al., 2020).

The respondents had diverse levels of education with 35.8% having secondary school education, 27.5% primary school education, 18.3% higher secondary education and above and 18.4% illiterate. The moderate education has always been revealed to raise the capacity of farmers to comprehend complicated problems like climate variability, pest ecology, and adaptability in adopting better practices, and illiteracy limits access to technical information and diminishes flexibility to adopt better practices (Abid et al., 2015; Rehman et al., 2019). Literacy and formal education have also been linked positively to enable farmers to participate in climate adaptation and sustainable management of pests in Pakistan (Khan et al., 2019).

As to the farming experience, the highest percentage of the farmers (68.3-68.3) was more than 10 years of experience which indicates a lot of practical experience. Mostly, experienced farmers can identify tendencies in pest infestation and climate deviations, but they can also be more attached to traditional methods without constant capacity development (Ashfaq et al., 2018; Hassan et al., 2018). The distribution of farms size indicates that, 46.7 percent of farmers operate smallholdings ([?]5 acres), 38.3 percent large farmers operate medium farms (6-12 acres) and only 15.0 percent of large farms (>12 acres). Such prevalence of small and medium scale farming is also consistent with the overall agrarian system in Pakistan and has a consequence of the adaptive capacity of farmers, with smallholders having a lower access to credit, input markets, and extension services than big landholders, limiting their capacity to use climate resilient pest control methods (Abid et al., 2015; Hussain et al., 2020).

Extension contact was significantly negatively correlated with greater pest incidence ($B = -0.743$, $Exp(B) = 0.48$, $p = .009$) indicating that the more farmers were in contact with the extension agents, the less likely they were to report escalated pest problems. This confirms the results that agricultural extension and advisory services can positively affect the adoption of integrated pest management (IPM) and climate adapted practices by farmers, which have the potential to reduce outbreaks of the pest by improving the decisions made about how to manage the pest during its early detection (Abid et al., 2015). Experience in farming was also positively correlated with high incidences of pests ($B = 0.056$, $Exp(B) = 1.06$ $p =.008$). More seasoned farmers can be in a better position to note and report pest dynamics changes over time, which are in line with the research which has found out that experience increases the capacity of farmers to identify the impact of climate variations on biological stressors (Abid et al., 2015). The size of the farm affected the pressures of the pests positively yet insignificantly ($B = 0.118$, $Exp(B) = 1.12$, $p = .065$), indicating that larger cultivated areas tend to experience more significant pest pressures though was not a very strong effect in the model.

Conclusion

This paper has discussed how climate variability affects the incidence and adaptive measures undertaken by farmers against insect pests in South Punjab, Pakistan. The results convincingly indicate that climate variability especially increase in temperatures, uneven amount of rainfall and long dry seasons are closely related to the high incidence of pests among insects. Most of the farmers indicated an increase in the pressure of pests over the last few years, and the sucking pests and bollworms formed the biggest challenges. Statistical tests proved that the perceptions of climate variability by farmers are critical in increasing the chances that they report an increase in the level of pests, which indicates that climate change is a major cause of changing pest patterns in the area. The mitigating factor that appeared to be critical was the extension contact. Farmers who were more in contact with extension services would be expected to be much less prone to report high levels of pest incidence and be more apt to have adaptive approaches. This highlights the importance of the agricultural advisory systems in enhancing the ability of farmers to deal with the pest challenges that occur as a result of climatic changes. Adaptive behavior was also found to have a positive effect on education level and farm size, indicating that access to knowledge and the availability of resources lead to resilience. Nonetheless, researchers find out that the majority of farmers use chemical pesticides as a main response tool and use of sustainable measures, like Integrated Pest Management (IPM) or resistant varieties and diversification of crops, is not relatively high. The environmental sustainability, resistance in pests and the cost of production are issues that are raised about this reactive and chemical-dependent approach.

Recommendations

The results indicate that the agricultural extension services provided on the impacts of climatic changes should be reinforced so that farmers can be able to deal with the risks of the pests due to climatic effects with greater care. The use of Integrated Pest Management (IPM) and a decrease in the use of chemical pesticides to an excessive degree should also be encouraged as a way of sustainable crop protection efforts. Farmers can be better educated, access more timely information about climatic conditions and pests and be assisted by credit facilities and resistant types of crops to improve adaptive capacity significantly. Altogether, the collaborative work of extension agencies, researchers and policymakers is needed to advance climate-resistant and sustainable pest management in South Punjab, Pakistan.

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