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IMPACT OF CLIMATE VARIABILITY AND CHANGE ON MANGO PRODUCTION: PERCEPTIONS, CHALLENGES AND ADAPTATION

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ABSTRACT

Growth and productivity of mango plants depend heavily on climatic factors such as storms, heat waves, hurricanes, floods, and droughts. Consequently, climate change poses a serious challenge to mango production in the country. To assess this impact, a study was conducted using data from Multan, Rahim Yar Khan, Muzaffargarh, and Khanewal. Findings revealed that mango growers who adapted to climate change had slightly higher education levels and more orchard management experience than non-adapters. Access to advisory services, market, and weather information was also greater among adapters. Approximately 93% of mango growers perceived climate change, and 59% specifically heatwaves, affected mango production in Punjab. Heatwaves compromised fruit quality through burning, splitting, and de-shaping, and reduced fruit size across varieties. A sudden temperature increase (39–43°C) in March significantly affected flower emergence and caused burning and drying. Varieties such as Dusheri, Fajri, and Kala Chaunsa showed normal yields, while Sindhri, Langra, Anwar Retaul, Late Retaul, and Chenab Gold had moderate crops. In contrast, SB Chaunsa, Sufaid Chaunsa, and Azeem Chaunsa suffered severe losses, with yields declining by 40%, 30%, and 22% respectively. Among the studied districts, Rahim Yar Khan was most affected by heat waves, followed by Muzaffargarh, Multan, and Khanewal. Regarding adaptation strategies, 15% of respondents applied nutrients to mitigate the impact, 7.5% used irrigation, and 6% adopted other measures. In conclusion, heat waves adversely affected mango production in Punjab, but timely irrigation and nutrient management could help reduce climate change impacts on mango cultivation.

Keywords: *Climate Variability, Mango, Adaptation, Heatwave, Punjab*

Introduction

Mango is the leading fruit crop of Pakistan after Citrus and is mainly grown in the provinces of Punjab and Sindh. It is grown on an area of 244.5 and 145 thousand acres, with annual production of 1,697 and 387 thousand tons in Punjab and Sindh provinces, respectively, during 2023-24 (AMIS, 2025; MNSFS, 2023). The average yield in Punjab is 6.94 tons per acre, while in Sindh it is 2.66 tons per acre (AMIS, 2025). The low yield in Sindh is due to a slightly warm winter. Punjab contributes 81% while Sindh contributes 18% in total mango production in Pakistan (AMIS, 2025). In South Punjab, mangoes are mainly cultivated in the district of Multan. Muzaffargarh, Rahim Yar Khan, Khanewal, and Bahawalpur, while Vehari, D.G. Khan, Rajanpur, and Bahawalnagar also have mango in significant areas.

Almost 30 mango varieties are grown commercially in Punjab; however, 95% of the area is under 10 cultivars, namely Samar Bahisht Chaunsa (35%), Sindhri (18%). Sufaid Chaunsa (16%), Dusheri (6%), Kala Chaunsa (6%). Anwar Retaul and Late Retaul No. 12 (6%), Langra, Chenab Gold and Azeem Chaunsa (8%) and the remaining 5% area is under over 20 varieties i.e., Fajri. Sensation, Sanglakhi, Lahotya, Yakta. Malda, Pohilot etc. More precisely, the first 5 varieties are grown on 80% area and about 70% area is under 3 varieties, SB Chaunsa, Sindhri and Sufaid Chaunsa.

Climate change is one of the major worldwide environmental challenges facing mortality, impacting food production, natural ecologies, freshwater supplies, health, and more. The negative effects of climate change are now demonstrating everywhere on the earth in the form of radical climate actions, such as storms, hurricanes, floods, and droughts are increasing in frequency and intensity. Based on current scientific valuations, the Earth's climate has changed significantly globally and locally since the pre-industrial revolution. The Intergovernmental Panel on Climate Change (IPCC) estimates that the average global temperature could rise by 1.4°C to 5.8°C by the end of the century. This unparalleled rise is anticipated to have serious consequences for the world's hydrological systems, ecosystems, sea levels, harvest production, and relevant progressions.

The influence will be intensely severe in the tropics, which comprise most of the developing world, including Pakistan (Mustafa, 2011). Large-scale mango farmers have a variety of methods that can assist them to surmount severe environmental change, earn a living, and actively manage the environment (Stringer *et al.*, 2010). The condition is unique and precarious for smallholder mango farmers who must make ends meet with subsistence farming but lack the adaptability (Chinwe Ifejika Speranza, 2010; Stringer *et al.*, 2012). As a result of these circumstances, how can rural poor farmers respond to the pressing challenge of climate change and modify their farming techniques to face new threats from climate change in the future?

Climate variability and change are extremely disturbing agricultural productivity, food security situation, ecosystem, and livelihood of the rural population, as well as in Pakistan. Pakistan ranked 18th in the Inform Risk Index due to being highly exposed to several severe climatic events, such as variations in temperature, frost, droughts, floods, fog, smog, and uncertain rainfall (WB and ADB, 2023).

These climatic changes significantly affect the mango crop during fruit growth and development and other phenological stages and may damage the crop to any extent. Mango can be grown in a diversified climate; though, the range of suitable temperatures for successful crop production is 6°C to 42°C ± 2°C (Litz, 2009). The temperature extremes beyond this limit may affect the plant's health and performance.

Moreover, climate variability and changes are likely to become more intense and persistent in the coming years, which will have devastating impacts on the major cash crops, including mango, and the livelihood of the rural population. Consequently, understanding how mango growers prepare for and are affected by climate variability and change, as well as what strategies they may use to build their resilience in the future, is critical for future adaptation. This research explores mango growers of South Punjab's climate change perceptions, productivity, income, and intention to adapt. The objectives of the present study are 1) to assess the extent of production variability due to the heat wave over the last year, 2) to explore the perception of mango farmers regarding climate change and its impacts, and 3) to investigate the factors affecting adaptation to climate change on mango productivity. The study would highlight the possible way forward to cope with these situations.

Materials and Methods

This research was carried out in the Southern part of the Punjab province of Pakistan. The four districts (i.e., Multan, Rahim Yar Khan, Muzaffargarh, and Khanewal) were purposively selected. A survey was developed and piloted with a small sample (n=10) of farmers in June 2024. Then, the survey was deployed by the university graduate students enrolled in master's programs during July 2024 in the selected districts. A total of

69 farmers participated out of 80 surveyed for a response rate of 88.7%.

The variety-wise production of mango in 2023 and 2024 was compared using a mean comparison t-test. The estimates of mean comparison describe the impact of climate change on different varieties of mango during 2023 and 2024. To determine the factors affecting adaptation to climate change were investigated by logistic regression as used by (Abid *et al.*, 2015a; Ahmed *et al.*, 2017).

$$logit\,(y_i) = \beta_0 + \beta_1 X_i + \mu_i$$

Where β_0 depicts the intercept of the model, β_i are the estimated coefficients of the independent variables, which are denoted by X_i vector and μ_i is the error term. Whereas the descriptive statistic indicates the difference in the production of mango between adopters and non-adopters. It also describes the difference in socio-economic factors between adopters and non-adopters.

Results and Discussion

Table 1 presents the description and summary statistics of the variables used in the study. The difference in characteristics of adapters and non-adapters shows how important these factors are to understanding local adaptation to climate change. Table 1 shows that mango yield, education level of farmers, and experience of farming were found to be slightly higher in the case of adapters than of non-adapters. Likewise, adapters had more access to advisory services, market information, and weather information. These results are in line with the findings of studies of (Bastakoti *et al.*, 2014; Abid *et al.*, 2015b, 2016), which found that educated and experienced farmers adapted more as compared to the less educated and less experienced farmers.

It might be possible that educated and experienced farmers were more observant and better informed than less educated and less experienced ones about the ongoing changes in the environment and ultimately adapted more. Likewise, adapters had larger-scale farms and more access to institutional services (e.g., extension and market information, weather forecasting) than non-adapters. These findings confirm that access to institutional services may have a positive impact on the farmers' adaptation decisions. These results are in line with the results of Bastakoti et al. (2014) and Bryan et al. (2013).

Table 1: Descriptive Statistics

Variable	Adopters N=42		Non-Adopters N=27		Total N=69		Difference in Mean
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	
Yield	131.07	11.41	123.48	8.05	128.10	10.83	-7.59
Education	11.24	2.53	7.04	4.21	9.59	3.86	-4.20
Experience	21.21	9.22	15.70	7.87	19.06	9.07	-5.51
Distance to Market	21.71	4.94	25.44	6.97	23.17	6.05	3.73
Access Advisory Services	0.76	0.43	0.33	0.48	0.59	0.49	-0.43
Market Info.	0.91	0.30	0.44	0.51	0.72	0.45	-0.46
Weather Info.	0.79	0.42	0.26	0.45	0.58	0.50	-0.53

It was recorded that the heat wave in April and May damaged the fruiting and affected the fruit quality, e.g., burning (black spots) on Sufaid Chaunsa fruits facing the sun, splitting and fruit curve in Sindhri, de-shaping of Chaunsa Duschri and Anwar Retaul in previous years. The heat waves simultaneously reduced the fruit size in all varieties. The year 2023 was highly favorable for the mango crop, and the country was blessed with an excellent crop. However, the maximum infestation of mango fruit borer and scale was observed in 2024 and 2023 due to the rainfall during the fruiting season. In the year 2023, the percentage of fruit with sunburn was low, and undersized and deformed fruits in mango were relatively less because of the favorable temperature during April, May, and June. During 2023, due to the bumper crop, the harvesting was delayed, principally delay in fruit harvesting reduces next year's fruiting; hence, less crop in 2023 was expected, especially in Chaunsa Samar Bahisht.

As expected, the flowering had emerged slightly delayed, which is a natural impact of last year's heavy fruiting. During February and 1st week of

March, the flower initiation and flowering were excellent; however, the sudden rise in temperature (39-43°C) during 11th to 17th March had dried out the prevailing flowers, and later the temperature settled down and flower emergence started again. However, the sudden rise in temperature in the last week of March and 1st week of April again damaged the remaining flowers. It is pertinent to mention that a 6-7°C rise in temperature in March and April was recorded, and such a high temperature regime in these days was never noticed (Figure 4). This situation dried the flowers as well as the tiny fruit in most of the varieties.

Figure 1 indicates the area under the orchard of different mango varieties during the years 2023 and 2024. The area under SB Chaunsa, Black Chaunsa, and Dusehri decreases, whereas the area under Sindhri, Sufaid Chaunsa, Anwar Rataul / Rataul 12, and other varieties increases during 2024 as compared to the year 2023. The area under Sufaid Chaunsa, Sindhri, Anwar Rataul / Rataul 12, and other varieties of mango increases by 2.8%, 2.4%, 2.3%, and 1.9% respectively.

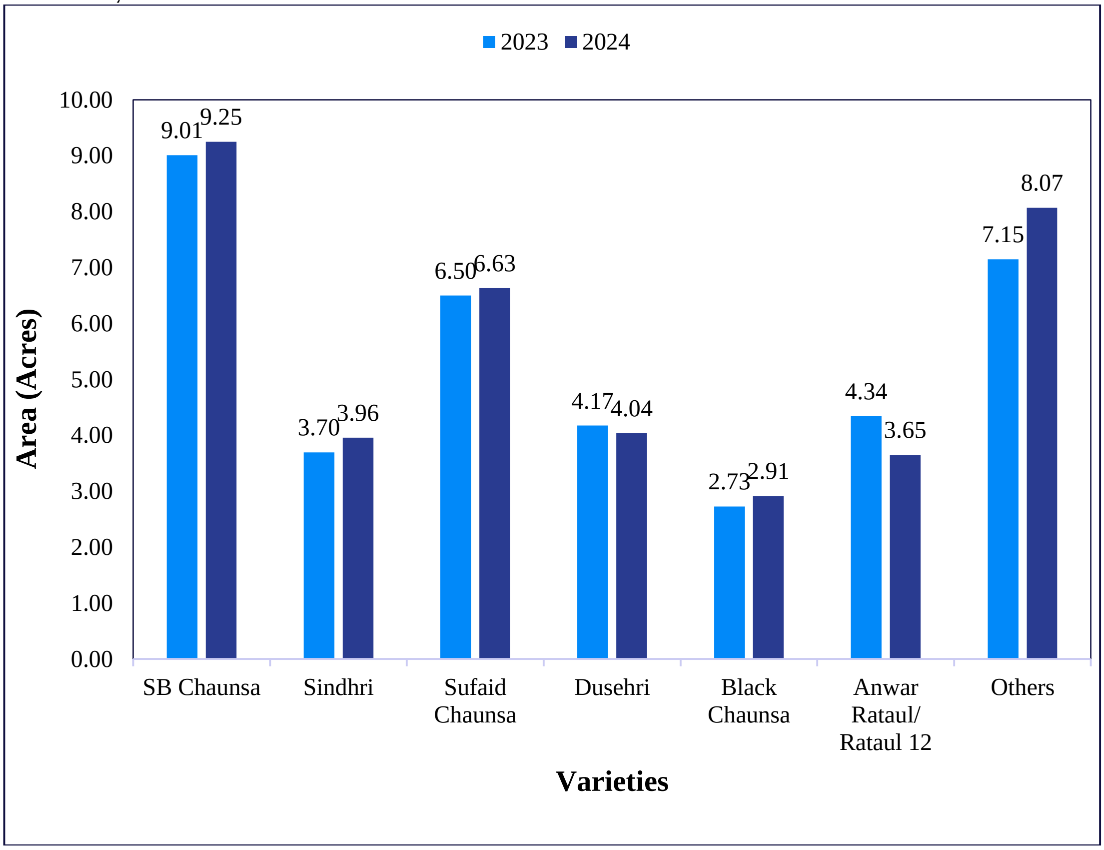

Figure 1: Average Area (Variety Wise) in 2023 and 2024

It was also documented that the crop production is significantly low, and the quality of fruit has also been compromised with size variation, de-shaping, and undersized fruit. Among the mango cultivars, Dusheri. Fajri and Kala Chaunsa are holding an almost normal crop. However, these varieties have just grown on 12% area, hence cannot make a significant impact on overall crop production. While Sindhri, Langra. Anwar Rataul. Late Rataul and Chenab Gold hold a reasonable crop, and these were also grown on 30% area and may be unsuccessful in creating a bigger impact. The maximum damage has been observed in SB Chaunsa, Sufaid Chaunsa, and Azeem Chaunsa, which were grown on >55% area, and this huge acreage affects many matters in production. It is pertinent to mention that the two main exportable varieties, Sindhri and Sufaid Chaunsa, have a fair crop for export purposes. However, the size and cosmetic look of fruit may have slight limitations for export quality.

Figure 2 shows the production of different varieties during the years 2023 and 2024. The states indicate that the production of SB Chaunsa, Sufaid Chaunsa, and Black Chaunsa decreases by 40%, 30% and 30% respectively during 2024 as compared to the year 2023. Whereas a production loss of 25% in Anwar Rataul / Rataul 12, 20% in

Sindhri, 11% in Dusheri, and 22% in others was observed during 2024 than previous year (2023).

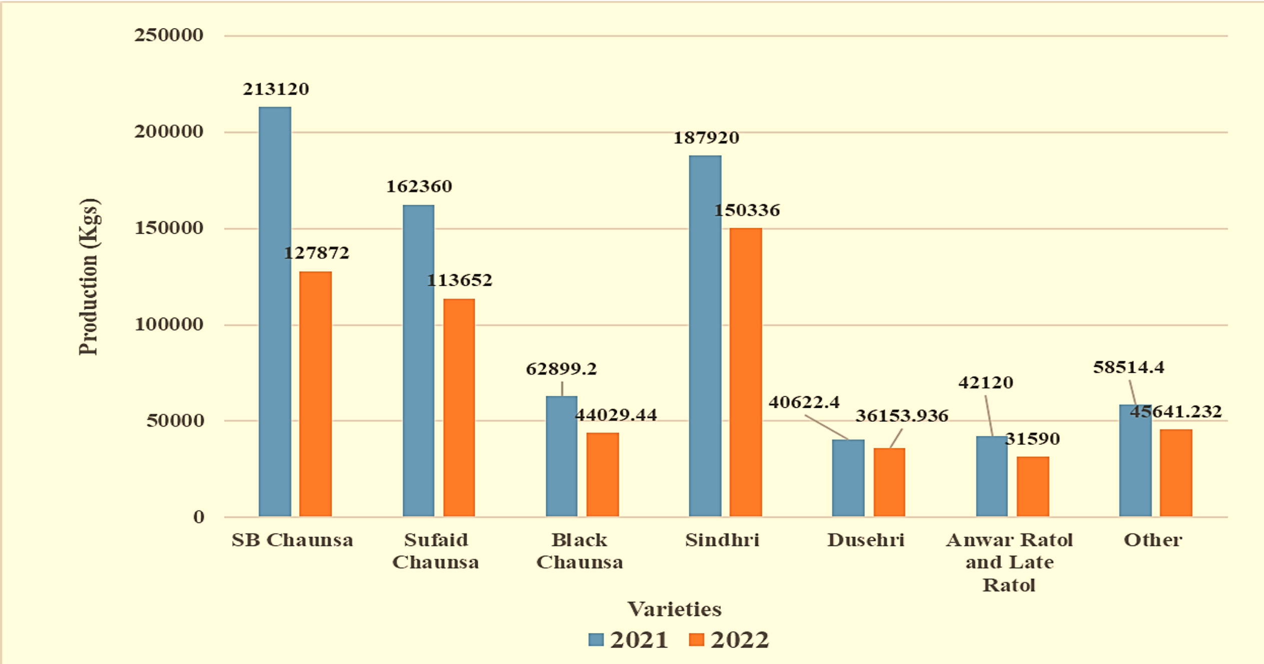

Figure 2: Variety wise production of Mango in 2023 and 2024

A significant impact of climate change has been observed in the mango production areas of South Punjab (Figure 3). Most affected district was Rahim Yar Khan (46.63%) followed by Muzaffar Garh (47.59%), Khanewal (45.37%) and Multan (41.56%).

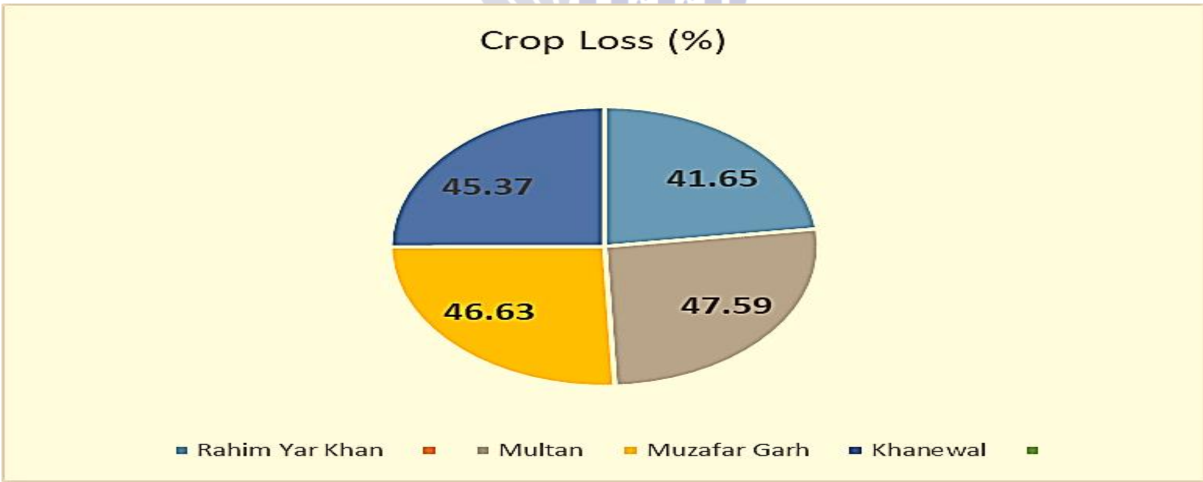

Figure 3: Crop loss (Percent) in Study Area

Table 2: Mango Production Mean Comparison

Mango Variety	Year 2023			Year 2024		
	t-stat	Mean Difference	Std. Deviation	t-stat	Mean Difference	Std. Deviation
SB Chaunsa	9.985***	165760	129640	6.613***	122997	145267
Sindhri	9.336***	162360	79694	2.402**	116840	206416
Sufaid Chaunsa	2.986**	62900	72982	2.648**	54120	67793
Dusheri	7.403***	187920	91528	6.976***	153965	73200
Black Chaunsa	1.957*	40622	65656	2.440**	36224	44543

Anwar Rataul / Rataul 12	14.537***	42120	7666	11.066***	34704	7013
Others	5.716***	58514	22889	6.299***	47745	16950

Table 2 shows the mean comparison of various mango varieties' production in 2023 and 2024. The estimates indicate that in 2023, all the varieties of mango have significant higher production, whereas in 2024, the production of mango varieties significantly reduced as compared to 2023 in the study area. The results show that all varieties have a significant mean difference for the years 2023 and 2024.

IMSCCS= Do you believe the irrigation method is suitable for current climatic scenario? **CHAMP=** Do you think that current season heatwave adversely affects the mango production? **APPMHCC=** Do you think that you have the ability and resources to protect mango from hazard of climate change? **INPICC=** Do you think you have the information necessary to prepare for the impacts of climate change? **SOBPM=** In your opinion, are there any obstacles and barriers to protect mango from negative consequences of climate change? (Perceived barriers) **PPCCSPM=**Do you think that personal preparation for climate change save the production of mango? (Perceived benefits) **CCPAM=** Do you believe climate change could affect the production of mango? (Perceived susceptibility)

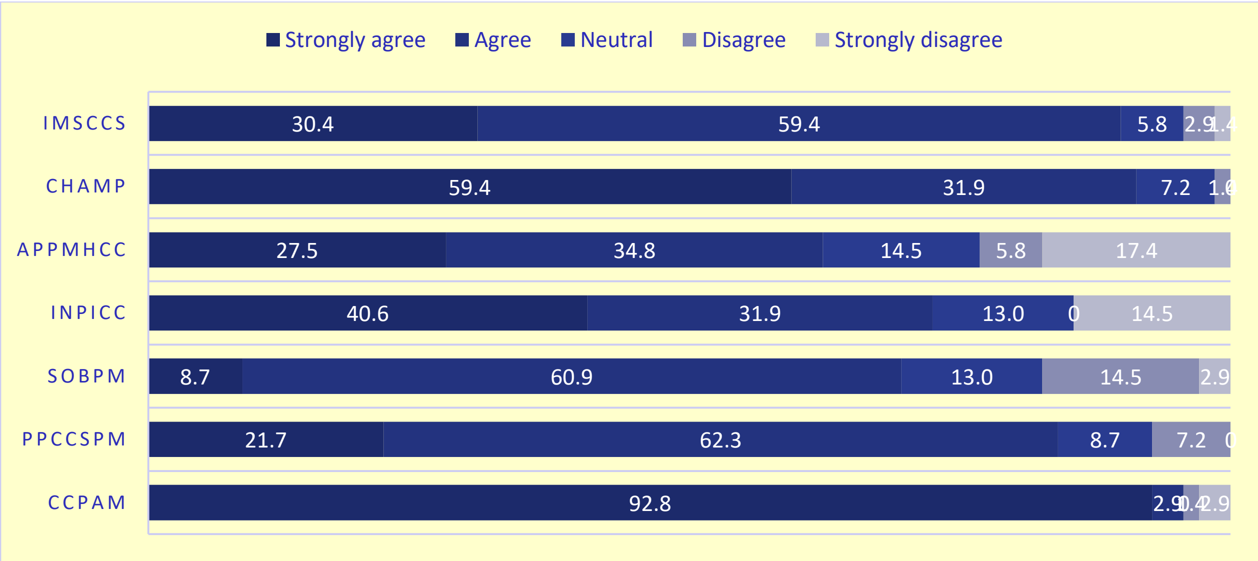

Figure 4: Farmers' Climate Change Perceptions

As the climate variability and change has adversely affected the agriculture as well as the mango growers, and different growers have different perception about impacts of climate change. So, in this regard we asked growers about their perception regarding impact of climate change. The Figure 4 indicates the percentage of farmers who have different perceptions about climate change. The states indicates that the 92.8% of the mango growers have perception that the climate change could affects the production of mango, and 59.4% growers have perception that current heatwave affects the mango production. In addition, 40.6% growers agreed that they have sufficient information necessary to prepare for the impacts of climate change, and 30.4% growers agreed that they have adequate irrigation method in prevailing climate change scenario. Whereas 27.5% growers claimed that they have ability and power to protect mango from the hazard of climate change, 21.7% growers stated that they can personally protect the production of mango from climate change.

Figure 5 shows the use of adaptation strategies by the respondents to cope with the climate change. It is evident that most of the respondents didn't have any awareness about the adaptation measures. About 15 percent of respondents apply nutrients to offset the effects of climate change while 7.5 percent irrigate the orchards and 6 percent applied other measures.

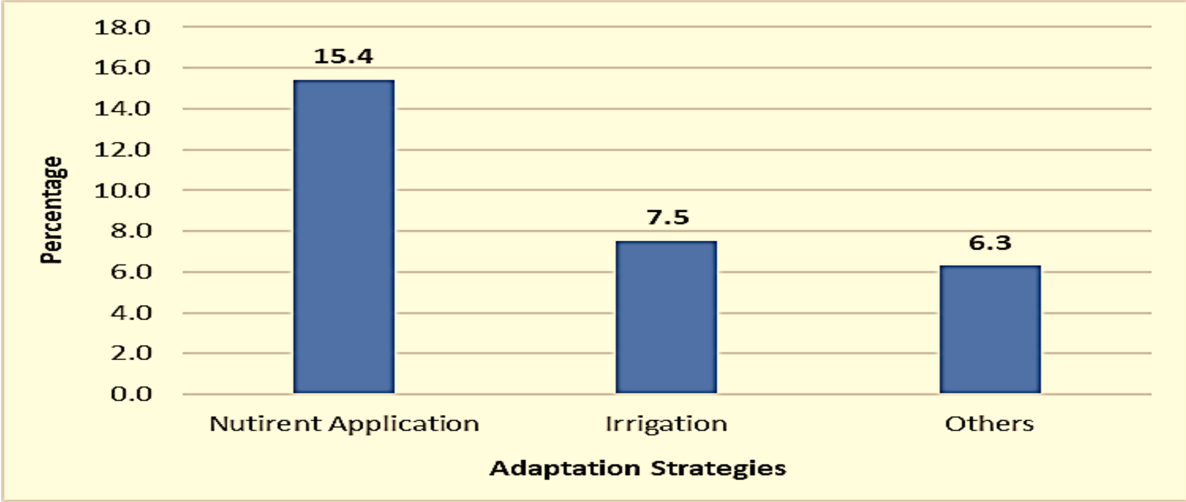

Figure 5: Adaptation Strategies used by the respondents

The probability of adapting to climate change was regressed to several covariates using logistic regression. The results of the regression are reported in Table 3.

Table 3: Logistic Regression

Variable	Coefficient	Odds Ratio	z	p>|z|
Education	0.416 (0.171)	1.515 (0.260)	2.43	0.015
Experience	0.105 (0.062)	1.111 (0.069)	1.70	0.089
Distance to Market	-0.009 (0.070)	0.991 (0.070)	-0.13	0.900
Access to Advisory Services	2.073 (0.959)	7.948 (7.625)	2.16	0.031
Market Info.	2.358 (1.105)	10.571 (11.680)	2.13	0.033
Weather Info.	2.528 (0.916)	12.522 (11.472)	2.76	0.006
Constant	-9.636 (4.017)	0.0001 (0.0003)	-2.40	0.016
Number of Observations	69			
LR chi^2 (6)	54.15			
Prob > chi^2	0.000			
Pseudo R^2	0.5863			
Log Likelihood	-19.106			

The results indicate that many of the household and extension-related variables influence the probability of climate change adaptation. Farming experience, education, market information, access to advisory services, and weather forecasting information have positive coefficients and tend to expedite adaptation to climate change. These findings agree with the findings of other studies (Abid *et al.*, 2016; Hossain *et al.*, 2016; Ali and Erenstein, 2017; Ahmad and Afzal, 2020). The estimated covariates indicate that a year increase in experience and education results in an increase in farmers' likelihood to adopt climate change mitigation practices. The estimated coefficients of access to advisory services, weather information, and market information also indicate that the likelihood of adoption increases with access to any of these services.

Conclusion and Recommendations

A significant impact of climate change (heat wave) has been observed on mango production in 2024. Mango varieties such as SB Chaunsa, Sufaid Chaunsa, and Azeem Chaunsa were severely affected by the heat wave as these grew on >55% area. Among the districts, Rahim Yar Khan was severely prone to heat waves, followed by Muzaffargarh, Multan, and Khanewal. On the other hand, spraying of water and nutrient applications at the proper time would help to reduce the impact of the heat wave on mango production in the county.

The mango growers are required to focus on the following practices to protect the crop from further damage.

(i) Ensure irrigation; however, avoid irrigation of the wet soil.

(ii) Preserve and ensure a green carpet of grass outside the plant canopy.

(iii) If the temperature is expected to be above 45°C on any day, spray water on the sun side of the fruited plants, especially in Sufaid Chaunsa and Sindhri.

(iv) Foliar spray of potash @ 2% is useful during the cool time of the day to protect the fruit from heatwave and splitting.

(v) Mulches under the canopy are extremely useful to manage the plant and fruit temperature.

Moreover, to protect the mango orchards from the adverse effects of climate change, it is imperative to screen out the mango varieties and review the production technologies for sustainable mango production.

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