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Research Article

Impact of Cotton Diseases on Yield: Farmers' Knowledge and Management Practices in Pakistan's Core Cotton Zone

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ABSTRACT

The yield of cotton in Pakistan remains well below its potential and lags behind that of major cotton-producing countries such as India, China, the United States, and Brazil. Although several factors contribute to this gap, the role of diseases, despite their significant impact on yield and quality, has not been adequately examined. Therefore, this study was conducted in the core cotton-growing zone of Punjab, with the district Rahim Yar Khan selected as the study area. A total of 392 randomly selected cotton growers and agricultural experts, including Assistant Directors and Agriculture Officers, were interviewed through face-to-face surveys. Quantitative data were analyzed using SPSS, while qualitative data were examined through content analysis. The Chi-square test was applied to test the study hypotheses. The results revealed that Cotton Leaf Curl Virus (CLCuV) was the most widely recognized disease, whereas awareness of root rot and boll rot was relatively low. Awareness of *Verticillium* wilt, collar rot, bacterial leaf blight, and para wilt was also limited. However, CLCuV, *Verticillium* wilt, and root rot were perceived to have a severe negative impact on cotton yield. High pesticide costs and poor-quality products, the cultivation of uncertified varieties, erratic rainfall, temperature fluctuations, and inappropriate spraying practices were found to significantly contribute to ineffective disease control ($P < 0.05$). Furthermore, socioeconomic characteristics, particularly age and education, were significantly associated with farmers' awareness of cotton diseases. This study recommends the implementation of intensive awareness campaigns and the promotion of sustainable disease management strategies to improve cotton productivity.

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Introduction

Agriculture is widely regarded as the backbone of Pakistan's national economy. The sector contributes about 23.5% to the national gross domestic product (GDP), provides employment to nearly 37% of the population, ensures food security, and supplies raw materials to agro-based industries (Government of Pakistan, 2025). Within the agricultural sector, major crops, cotton, sugarcane, wheat, rice, and maize, account for 17.82% of agricultural value addition and 4.19% of the national GDP (Government of Pakistan, 2025).

Cotton is among the most important cash crops of Pakistan and serves as the driving force of the textile industry (Sial et al., 2014; Khan et al., 2020). However, during 2024-25, the area under cotton cultivation declined by 15.7%, from 2.4 million hectares to 2.04 million hectares, accompanied by a 30.7% reduction in production, from 10.22 million bales to 7.08 million bales (Government of Pakistan, 2025). According to the Government of Pakistan (2023), this decline was largely attributed to climate change-related factors such as floods, extreme heat waves, and widespread leaf wilting. Among biotic stresses, Cotton Leaf Curl Virus (CLCuV) emerged as the most destructive disease, substantially reducing cotton productivity (Malik and Ahsan, 2016).

Plant diseases are recognized as major contributors to yield losses in cotton. Although these diseases originate from diverse causal agents, their combined effect results in considerable production declines. Climate change has further intensified disease outbreaks by facilitating the spread of pathogens and their vectors (Jones, 2009; Chaloner et al., 2021). Major cotton diseases, including *Fusarium* wilt, *Verticillium* wilt, boll rot, *Alternaria* leaf spot, leaf curl disease, and bacterial blight, are responsible for substantial yield reductions (Chohan et al., 2020). Sekhon et al. (2008) reported nearly 30 diseases affecting cotton, of which 17 are caused by fungi, four by bacteria, two by nematodes, and several by viruses and physiological disorders. Among these, bacterial blight has been identified as one of the most severe diseases, causing yield losses of approximately 30-40% (Kalpana et al., 2004), while Raj and Verma (1988) reported up to a 35% reduction in boll yield due to this disease. In addition, Dyer et al. (2020) documented a 50% yield reduction (equivalent to 2,225 kg ha^{-1}) in cotton due to the reniform nematode, *Rotylenchulus reniformis*, a semi-endoparasitic sedentary nematode with a wide host range exceeding 314 plant species, including cotton (Showmaker et al., 2019).

Estimates by the Food and Agriculture Organization of the United Nations indicate that diseases alone can cause up to 24% losses in cotton production, highlighting the urgent need for effective disease management strategies (Dubey et al., 2018). Protecting crops from disease-induced yield losses remains a major challenge, as 20-40% of global crop production is lost annually to pests and diseases (Savary et al., 2019). In cotton, disease management practices are often influenced by the socioeconomic conditions of farmers, which determine their access to inputs, knowledge, and control options (Hillocks, 1998).

Despite the prevalence of numerous bacterial and fungal diseases in cotton fields (Memon et al., 2022), systematic research on cotton diseases and their field-level impacts in Pakistan remains limited. In contrast, considerable attention has been given to insect pests of cotton. Understanding farmers' perceptions and experiences is therefore crucial for identifying priority disease problems, guiding research efforts, and informing policy interventions. Accordingly, the present exploratory study was conducted in cotton-growing areas of Punjab province to assess farmers' perceptions of cotton diseases and their associated yield losses. The study focused on district Rahim Yar Khan, a major cotton-producing area within the core cotton zone. In recent years, many farmers in this region have shifted from cotton to sugarcane cultivation for various reasons. In this study, it was hypothesized that disease infestation is a key factor influencing farmers' decisions to replace cotton with alternative crops such as sugarcane.

Materials and Methods

Study area

Punjab Province comprises approximately forty districts, which are broadly classified into three major crop production zones: northern, central, and southern Punjab (PARC, 2004). Southern Punjab is traditionally recognized as the main cotton-producing region of the province due to its favorable agro-climatic conditions (Figure 1). The core cotton-producing districts include: (i) Muzaffargarh, (ii) Multan, (iii) Bahawalnagar, (iv) Bahawalpur, (v) Vehari, (vi) Rahim Yar Khan, (vii) Dera Ghazi Khan, (viii) Layyah, and (ix) Sahiwal.

In recent years, the area under cotton cultivation within this core cotton zone has shown a gradual but consistent decline. Farmers in several districts have increasingly shifted their cropping patterns toward alternative crops that are perceived to be more profitable than cotton. Among these districts, Rahim Yar Khan stands out as the most prominent example, where a substantial reduction in cotton acreage has been accompanied by a rapid expansion of sugarcane cultivation, largely at the expense of cotton. Owing to this pronounced shift in land use and cropping patterns, district Rahim Yar Khan was selected as the study area for the present investigation.

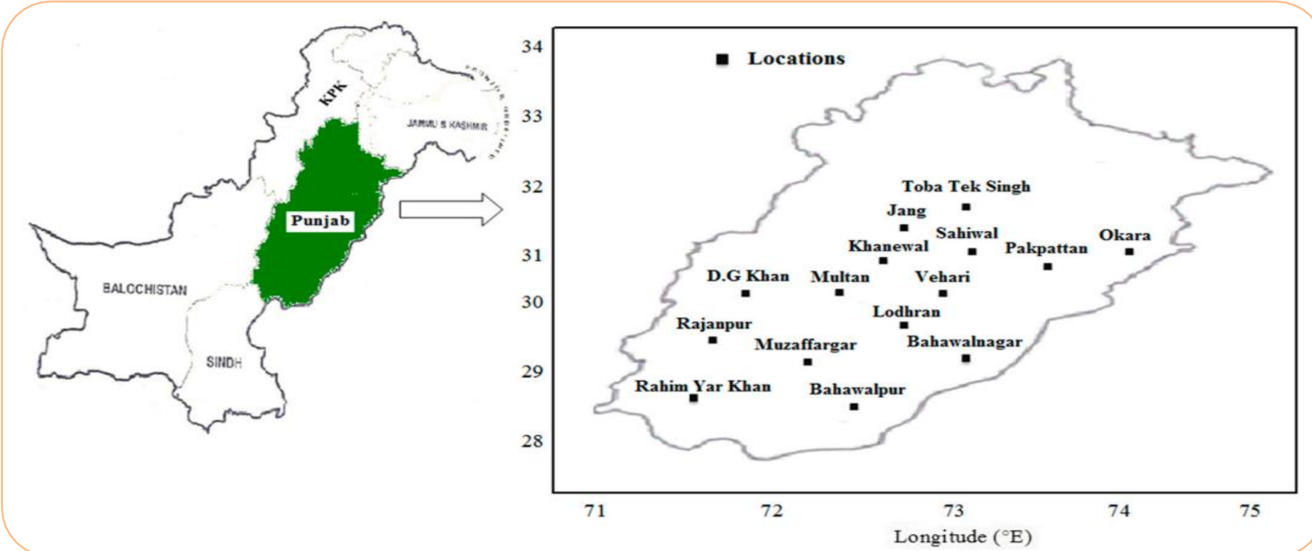

Figure 1. Map showing the cotton-growing districts of Punjab province.

Population and sample size

District Rahim Yar Khan comprises four tehsils: Rahim Yar Khan, Liaqat Pur, Khan Pur, and Sadiqabad. The study population included all cotton growers registered in the *Cotton Farmers Survey, Rahim Yar Khan (2020),* which documented a total of 20,498 cotton farmers in the district. According to this survey, tehsil Sadiqabad accounted for 4,745 farmers, Khan Pur for 1,467, Liaqat Pur for 11,627, and Rahim Yar Khan for 2,659 farmers.

Cotton farmers across the four tehsils operate under comparable agro-ecological conditions, particularly with respect to cotton production, and generally follow similar cropping patterns. Given this homogeneity, a representative sample of 392 cotton farmers was selected from the total population of 20,498 using the sample size determination formula proposed by Yamane (1967).

$$n = \frac{N}{1 + N(e)^2}$$

$$n = \frac{20498}{1 + 20498(0.05)^2}$$

$$n = \frac{20498}{1 + 20498\ (0.0025)}$$

$$n = \frac{20498}{1 + 20498\ (0.0025)}$$

$$n = \frac{20498}{1+51.245} = 392.34$$

N = 392

Sampling approach

A stratified proportionate sampling technique was employed to ensure adequate representation from each tehsil of the district. Accordingly, 91, 28, 222, and 51 cotton farmers were selected from Sadiqabad, Khan Pur, Liaqat Pur, and Rahim Yar Khan tehsils, respectively (Table 1). Within each stratum, respondents were chosen through simple random sampling. An official list of cotton farmers was used as the sampling frame, representing the population from which study participants were drawn. This approach allowed for unbiased selection of respondents and is consistent with standard sampling procedures described by Martínez-Mesa et al. (2016).

Table 1. Population and proportionate sample distribution in district Rahim Yar Khan.

Tehsils	Population (No. of farmers)	Proportionate sample
Sadiqabad	4745	91
Khan Pur	1467	28
Liaqat Pur	11627	222
Rahim Yar Khan	2659	51
Total Farmers	20498	392

Instrumentation, data collection, and data analysis

The primary tool for data collection in this study was an interview schedule, carefully designed to align with the research objectives. To develop a robust instrument, relevant scholarly articles, reports, and periodicals were critically reviewed. The instrument underwent validation by two experts from the Institute of Agricultural Extension, Education, and Rural Development, University of Agriculture, Faisalabad. Further validation was provided by an expert from the Department of Plant Pathology, University of Agriculture, Faisalabad, as well as the Plant Protection Officer of district Rahim Yar Khan.

Reliability of the instrument was assessed using Cronbach's alpha, which yielded a value of 0.886, indicating high reliability and exceeding the acceptable threshold of 0.6. The interview guide was specifically prepared to capture expert opinions from the Assistant Director of Agriculture (Extension) and Agriculture Officers from the respective tehsils.

Statistical analysis

Data were collected through face-to-face interviews and subsequently analyzed using the Statistical Package for the Social Sciences (SPSS). Descriptive statistical techniques, including frequency, percentage, mean, and standard deviation, were employed to summarize the data. The chi-square test was applied to examine the study hypotheses. Furthermore, qualitative data were analyzed using content analysis, and the insights obtained were used to support and validate the quantitative findings.

Ethical considerations

Before data collection, respondents provided formal verbal informed consent. They were informed about the study's objectives and assured that their information would be used solely for research purposes. Personal details and identities were maintained anonymously and treated with strict confidentiality.

Results

Area under cotton and sugarcane cultivation

Figure 2 illustrates the average land area allocated to cotton and sugarcane cultivation. On average, farmers cultivated approximately 13 acres of cotton and around 15 acres of sugarcane. Analysis of the frequency distribution shows that 56.1% of respondents grew cotton on less than 10 acres, while 64.3% devoted less than one acre to sugarcane cultivation. Among the surveyed farmers, 33.9% had cotton fields ranging from 11 to 20 acres, compared to 21.2% who cultivated sugarcane on 11-20 acres. Moreover, about 10% of respondents managed cotton cultivation on more than 20 acres, whereas 14.5% of farmers allocated over 20 acres to sugarcane. These results indicate a general preference for sugarcane over cotton, as reflected by the slightly larger average area dedicated to sugarcane cultivation.

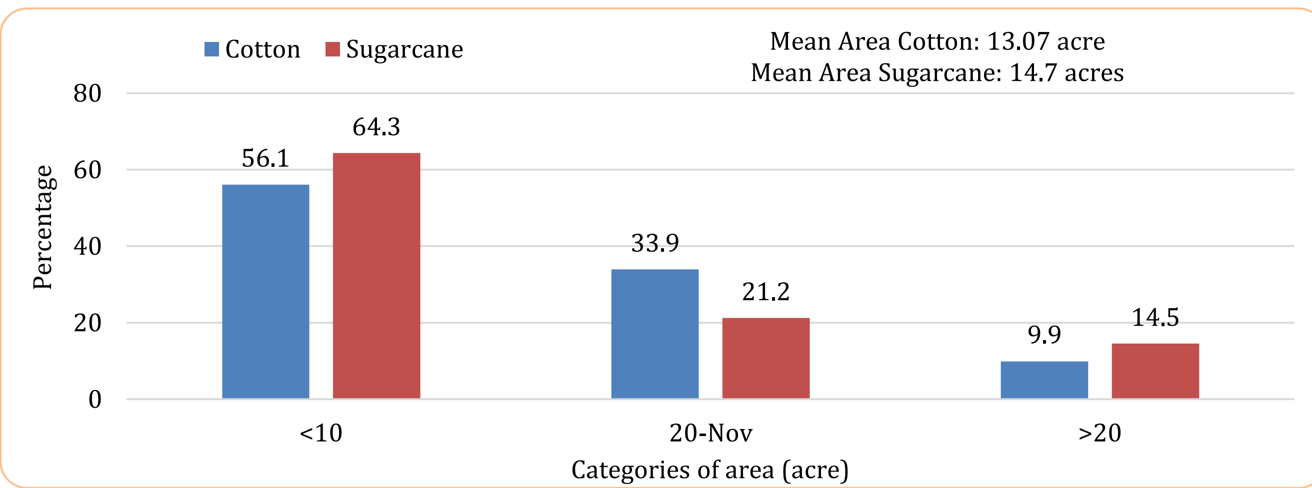

Figure 2. Area under cotton and sugarcane cultivation.

Awareness of cotton diseases

The data presented in Figure 3 indicate that farmers exhibited varying levels of awareness regarding cotton diseases. Among these, Cotton Leaf Curl Virus (CLCuV) was the most widely recognized, with 92% of farmers reporting familiarity with it, likely due to its frequent occurrence in local fields. During discussions, one respondent shared:

"I have been growing cotton for more than 15 years, and this virus is one of the most common diseases, causing considerable damage to the crop. Its symptoms are very prominent, making it easy for me to identify when CLCuV is affecting my cotton."

Another farmer noted:

"I am in regular contact with extension staff and pesticide companies, who usually alert me about CLCuV outbreaks and help me recognize its symptoms."

Awareness of other cotton diseases was lower. Root rot was recognized by 58.2% of farmers, followed by boll rot, known to 43.3%. During discussions, farmers highlighted that root rot often leads to the sudden death of cotton plants, which serves as a clear indicator of the disease. Other diseases, including collar rot, Verticillium wilt, bacterial leaf blight, para wilt, and twig blight, were reported to be known by 28%, 23.9%, 22.2%, 14.8%, and 10.7% of farmers, respectively.

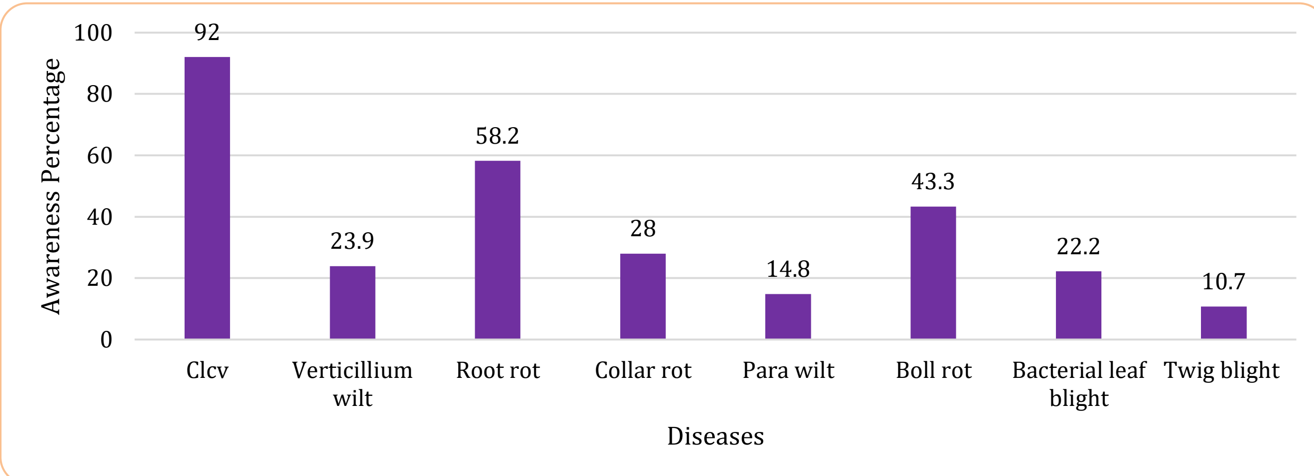

Figure 3. Farmers' awareness of cotton diseases.

Table 2 presents the varying impacts of different diseases on cotton production, as reported by farmers. The results showed that CLCv caused the most severe reduction in cotton yield ($\bar{X}$ = 4.29) and was also ranked 1st (Table 3). Farmers reported that CLCv had led to substantial losses in both production and net profits over the years (Figure 4). In addition to CLCuV, Verticillium wilt was identified as another disease that significantly affected cotton production. The Agriculture Officer explained:

"Verticillium wilt has become a serious problem in the area. It is a breeder issue, as none of the available varieties are resistant to this disease."

Farmers also highlighted a lack of awareness regarding the wilt and its management. One farmer stated:

"We do not have specific recommendations against Verticillium wilt; therefore, we treat it similarly to CLCuV and apply various amino acids to help the crop withstand its effects."

Root rot also exhibited a high level of negative impact on cotton production ($\bar{X}$ = 3.83). In contrast, collar rot, para wilt, boll rot, and bacterial leaf blight were reported to have moderate impacts, while twig blight had a relatively low impact on production.

Relationship between demographic attributes and farmers' awareness of cotton diseases

To examine the relationship, a chi-square test was conducted, considering the respondents' socio-economic attributes as independent variables and their awareness of cotton diseases as the dependent variable. The study hypothesized that farmers' awareness of cotton crop diseases was associated with their socio-economic characteristics.

Table 2. Farmers' perceptions of the impact of different diseases on cotton production.

Diseases	Mean ± SD	Impact
CLCuV	4.29± 0.516	High
Verticillium wilt	3.84± 0.840	High
Root rot	3.83±0.984	High
Collar rot	3.41± 0.922	Medium
Para wilt	3.32±0.936	Medium
Boll rot	3.02±1.220	Medium
Bacterial leaf blight	2.864±1.083	Medium
Twig blight	2.47± 1.372	Low

Scale: 1.0-2.4 (Low), 2.5-3.4 (Medium) 3.5-5.0 (High).

Null Hypothesis (H_0)

There was no significant relationship between farmers' socio-economic attributes and their level of awareness.

Alternative Hypothesis (H_1)

There was a significant relationship between farmers' socio-economic attributes and their level of awareness.

Table 4 indicated that the farmers' age, educational level, and cotton production were statistically significantly related to their awareness level (P = 0.000). In contrast, land size, area under cotton cultivation, and annual income did not show a statistically significant association with awareness. For age, education, and cotton production, the null hypothesis was rejected, whereas for land size, area under cotton, and income, the alternative hypothesis was rejected. These results suggested that older farmers, those with higher educational levels, and those producing more cotton were more likely to have greater awareness of the various cotton diseases.

Table 3. Ranking of cotton diseases based on their perceived damage to the cotton crop by farmers.

Diseases of cotton	Mean	SD	Weighted Score	Rank order
CLCuV	4.294	0.516	1641	1
Verticillium wilt	3.844	0.840	1509	2
Root rot	3.832	0.984	1505	3
Collar rot	3.416	0.922	1483	4
Para wilt	3.328	0.936	1460	5
Boll rot	3.022	1.220	1438	6
Bacterial leaf blight	2.864	1.083	1382	7
Twig blight	2.473	1.372	1364	8

1=Strongly disagree, 2=Disagree, 3=undecided, 4=Agree, 5=Strongly Agree.

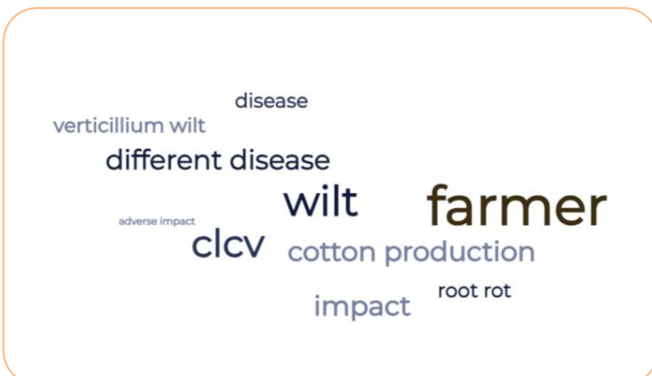

Figure 4. Word cloud showing farmers' perceptions of cotton diseases.

Table 4. Relationship between demographic attributes and level of awareness.

Demographic attributes	χ^2	P
Age	252.52	0.000
Education	58.18	0.000
Land size	122.36	0.576
Area under cotton (in acres)	65.892	0.344
Income	3.294	0.510
Production of cotton (in Kg)	118.605	0.000

Dependent variable: awareness about the diseases; Independent variable: socio-economic attributes.

Factors Contributing to Inadequate Disease Control and Their Relationships

To test the underlying hypothesis, a chi-square test was conducted, considering different factors influencing disease control as independent variables and disease control as the dependent variable. It was hypothesized that these factors had varying effects on the inadequate management of cotton diseases. The chi-square test results, presented in Table 5, were used to evaluate these relationships.

Table 5 showed that various factors, as perceived by the farmers, contributed to the ineffective control of cotton diseases. The high cost and poor quality of pesticides were identified as the primary reasons for inadequate disease management. During discussions, respondents expressed dissatisfaction with the quality of available pesticides. Farmers agreed that:

"…we were advised to use fungicides against the diseases along with expensive crop supplements, but the results were often unsatisfactory. Ultimately, we had to apply excessive amounts of fungicides, which further increased our production costs."

When interviewed, an agricultural expert explained:

"…our cotton varieties were not resistant to the fungal pathogens; therefore, the only viable option was to manage the diseases through fungicides and crop supplements. However, spraying techniques remained a challenge, as farmers rarely adopted the recommended methods and nozzles, which could have ensured effective disease control."

The cultivation and availability of uncertified cotton varieties also contributed to ineffective disease management. Farmers reported that numerous cotton varieties were available locally, making it difficult to identify the appropriate ones. They often relied on dealers' advice, which led to the use of poor-quality seeds with low germination rates and high susceptibility to diseases. The sowing of susceptible varieties significantly contributed to inadequate disease control ($\bar{X}$ = 4.13). Other major contributing factors included erratic rainfall ($\bar{X}$ = 4.07), temperature fluctuations ($\bar{X}$ = 4.07), and the use of inappropriate spraying techniques ($\bar{X}$ = 3.84). Farmers voiced serious concerns regarding climate change and its impact on cotton production. One respondent stated:

"…the climate is beyond our control, and cotton is a highly sensitive crop. Every year, our cotton suffers from rising temperatures and unpredictable rainfall."

Another respondent added:

"…last year, my crop initially showed promise, but production declined sharply due to a sudden increase in temperature. I observed extensive flower shedding and prolonged vegetative growth."

During the discussion, it became evident that climate change was a key factor in reducing cotton yields. It adversely affected both vegetative and reproductive growth, increased susceptibility to insect pests, and promoted disease outbreaks. Improper spraying techniques further worsened the situation. Farmers reported using traditional spraying methods, which led to pathogen resistance, particularly in whiteflies, a major vector of fungal infections. One farmer explained:

"…our spray men were untrained and typically used a single nozzle for all types of sprays. This practice contributed to increasing resistance and the ineffective control of pathogens in cotton crops."

Statistical analysis indicated that the availability of uncertified cotton varieties in the local market (P = 0.01), rising temperatures (P = 0.000), and inappropriate spraying techniques (P = 0.000) were significantly associated with poor disease control. These results implied that the cultivation of uncertified varieties, higher temperatures, and improper spraying practices collectively hindered farmers' ability to manage cotton diseases effectively.

Table 5. Factors behind inadequate control of diseases.

Factors	Mean ± SD	χ^2	P
High-cost and substandard pesticides	4.68±.463	1.907	0.167
Availability of un-certified varieties in the market	4.63±.734	14.375	0.001
Sowing of susceptible varieties	4.13±.339	3.400	0.183
Erratic rains	4.07±.481	6.051	0.821
Temperature	4.07±.526	39.808	0.000
Use of inappropriate spraying techniques	3.84±.702	91.534	0.000

1.0-2.4 (Low), 2.5-3.4 (Medium) 3.5-5.0 (High).

Discussion

The results of this study indicate a noticeable shift among farmers from cotton to sugarcane cultivation in Rahim Yar Khan. The mean area under sugarcane was higher than that under cotton, reflecting changes driven by multiple factors, including challenges and opportunities faced by farmers. As reported by Asif (2022), intensive pesticide use in cotton cultivation has significantly increased production costs, prompting farmers to explore alternative crops. Similarly, Shahzad et al. (2021) observed that shifting from cotton to sugarcane improved farmers' livelihoods by increasing net profits. Sugarcane is easier to cultivate and less prone to disease than cotton. Cotton, in contrast, is affected by a range of diseases; for instance, 83% of pesticides were applied to cotton, which is 54% higher than the quantities used for sugarcane and rice (Qamar-ul-Haq et al., 2008). Key diseases affecting cotton include boll rot, leaf spot, CLCuV, and bacterial blight (Zanwar et al., 2015). In the present study, CLCuV emerged as the dominant disease, with most farmers being aware of its impact on cotton crops. These findings align with Zahid et al. (2018), who reported universal awareness of CLCuV among cotton growers. Additional studies by Velásquez et al. (2018) and Sandipan et al. (2016) confirm that CLCuV significantly reduces cotton yield, with leaf wilting, a major symptom, being influenced by weather conditions and the cultivation of non-resistant varieties.

Our study further revealed that the prevalence of uncertified cotton varieties, rising temperatures, and the use of inappropriate spraying techniques were significantly associated with inadequate disease control. These factors limited farmers' ability to manage cotton diseases effectively. Malik and Ahsan (2016) similarly highlighted that climate change-related temperature increases and water shortages pose critical challenges for cotton production. Environmental factors affecting disease occurrence and yield reduction have also been reported by Dhage and Garg (2021) and Ashraf et al. (2024). Raza and Ahmad (2017) demonstrated that climate change during the flowering and fruit development stages negatively affects cotton crops, while Majeed et al. (2021) showed adverse effects on biological processes. According to Xiao et al. (2019), moderate temperatures followed by rainfall enhance disease susceptibility, particularly in autumn. Moreover, Amjad Bashir et al. (2022) reported correlations between temperature, humidity, rainfall, and whitefly populations, which serve as vectors for fungal diseases, contributing to yield loss (Abubakar et al., 2022).

Another critical factor limiting effective disease management was the use of unapproved cotton varieties. Nazli et al. (2010) noted that the adoption of unapproved varieties began in 2005 to achieve higher yields; however, this practice has negatively affected cotton production (Mehmood, 2021). Raania and Zafar (2009) recommended banning unapproved varieties, though Pakistan's cottonseed sector remains underdeveloped due to multiple constraints (Rana et al., 2013). Forrester (2009) also identified the absence of a professional seed industry as a key factor in declining cotton production. Our study underscores the significant role of unapproved seeds in disease prevalence and highlights the lack of empirical research on their impacts in Pakistan.

The use of unapproved varieties and improper spraying techniques contributed to higher disease susceptibility. Farmers often applied excessive pesticides to control infections. Khan and Damalas (2015) reported that farmers applied 6-16 sprays per crop, while more educated farmers applied fewer. Awareness of pesticide toxicity discouraged overuse. Our findings indicate that age, education, and farm size were significantly associated with farmers' disease awareness, echoing results by Ashraf et al. (2015), which showed that increased education is linked to higher awareness.

Improper spraying techniques, which are neither environmentally safe nor effective, were widespread. Mubushar et al. (2019) reported poor adherence to recommended spraying practices. Approximately 93% of farmers lacked knowledge of pesticide modes of action and chemical composition (Bakhtawer and Afsheen, 2021), often relying on traditional nozzles (Patel et al., 2016). Indiscriminate pesticide use has also been reported by Mehmood et al. (2021), and studies have linked this behavior to a lack of education and training regarding safe pesticide use (AL-Zaidi et al., 2019; Khuhro et al., 2020; Bakhtawer and Afsheen, 2021).

Conclusion

Diseases are a major factor limiting cotton production, with excessive pesticide use increasing production costs and crop susceptibility. Farmers are generally aware of cotton diseases, particularly CLCuV, which is widely recognized. Ineffective disease control is driven by the cultivation of unapproved varieties, high temperatures, and improper spraying techniques. Age, education, and farm size influence farmers' disease awareness and management practices. A lack of education and training likely contributes to the use of unapproved varieties and improper spraying. This study addresses a research gap by examining the use and impact of unapproved cotton varieties and provides insights into farmers' awareness, guiding strategies for disease management, extension support, and environmentally safe practices to improve cotton production.

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Authors' Contributions

SA designed the study, wrote the manuscript, collected and analyzed the data, and assisted with disease scoring. HAAR prepared the materials, collected data, AA, collected and analysed data, MMK analysed qualitative data, proofread the manuscript, AA, prepared the questionnaire, MS analysed the data, language editing and all authors reviewed and approved the final version.

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Conflict of Interest

The authors declare no conflict of interest.

Sustainable Development Goals Targeted

SDG 2: Zero Hunger

SDG 12: Responsible Consumption and Production

SDG 13: Climate Action

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