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Comparative Efficacy of Insecticides Against *Bemacia Tabaci* and *Thrips Tabaci* on Cotton Crop

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Abstract: Cotton is known as ‘‘The King of Fibers’’ and the natural fiber of the world. This current research was carried out to check the toxicity of endosulfan and imidacloprid against sucking insects like thrips and whitefly. The research was performed in district Sheikhupura in 2023. For thrips and white fly, the data were recorded before 24 hours of spray, and then data were collected at 24, 48 and 72 hours and after that with a two-week duration until October. 25 plants were selected and from every plant 1 leaf from lower, middle and upper leaves were chosen, at different heights. In August spraying was performed when the economic threshold level (ETL) was reached. Results exhibited that the best toxicity was recorded in imidacloprid compared to endosulfan against whitefly and thrip population control. Hence, it was concluded that whitefly and thrips caused a huge amount of crop loss in cotton so, managed it timely by spraying the insecticides with suitable time intervals for better yield of cotton.

Keywords: Cotton, Whitefly, Thrips, Yield and Populations

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1. Introduction

Cotton is known as ‘‘The King of Fibers’’ and natural fiber of the world. Different types of cotton are grown in the world, in which *Gossypium hirsutum* L. is mostly snow in many regions of the earth and meets 90% demand of the whole world. The current cotton trade is about 40 billion US dollars in value, but at the end of 2030, its value is expected 60 billion dollars (Poggemann *et al*., 2023; Hammiche *et al*., 2024; Levine *et al*., 2024). For the economy of Pakistan cotton plays an important role (Backbone of Pakistan's economy), contributing 60% of the total foreign exchange for the export of raw and products of cotton (Ali *et al*., 2019; Naveed *et al*., 2023; Nafees *et al*., 2024). Due to the cultivation of cotton about 1.5 million of Pakistan's population earn their income (Sattar *et al*., 2020; Nadeem *et al*., 2023; Zuberi *et al*., 2024).

A total of 110 ginning industries are present in the Vehari and twenty-two factories are working currently in the District Vehari. During the current year, the cotton production in the Vehari District are 112,678 bales which less than the previous year (188,485 bales). Current season the cotton area has decreased almost 40 percent from last year. The crop yields of cotton are lost due to various factors from the last few years which include the viability of seeds, insect pests and pathogens. These factors not only reduce the yield but also affect quality and market price (Brewer *et al*., 2016; Ermanis *et al*., 2021; dos Santos Cordeiro *et al*., 2024). Cotton plants remain under stress due to different pathogen attacks throughout the crop duration (Fones *et al*., 2022; Madani *et al*., 2023; Govindan *et al*., 2024). These pathogens are bacteria, fungi, nematodes and viruses which reduce the crop yield (Javed *et al*., 2022; Etesami *et al*., 2023; Gowtham *et al*., 2024). In the world loss due to insect pests vary in different countries, like in China it annuls range of 15-20% of economic loss and may be up to 50% (Chen *et al*., 2020; Wu *et al*., 2020; Lu *et al*., 2022). In India, the disease attacks cotton leaf areas around 80-90 percent and cotton yield loss of about 25 % (Khairnar and Goje, 2020; Naik *et al*., 2021; Kamble and Tikadar, 2024). In Pakistan, the cotton yield loss due to insect pathogens ranges from 20-40% (Karar *et al*., 2020; Saleem *et al*., 2023; Wahid and Mahmmod, 2024).

Since 1947, cotton lint production has increased 11.2 times and seed cotton per acre 4.4 times but there is also a gap between advanced countries with higher production per acre (Zaman *et al*., 2021; Gudeta *et al*., 2023; Nazeer *et al*., 2023). Many factors involved in the loss of yield include the alternaria leaf spot (Fagodiya *et al*., 2022), bacterial blight (Jiang *et al*., 2020), boll rot (Nagrale *et al*., 2020), fusarium wilt (Yuan *et al*., 2020), leaf curl virus (Prasad *et al*., 2020) and verticillium wilt of cotton (Chohan *et al.*, 2020). *Cotton leaf curl disease* (CLCuD) is a major disease in cotton crop, first reported in Pakistan in 1967 near Multan district (Afzal *et al.*, 2023). The disease is caused by a virus that is transmitted by whitefly (Majid *et al*., 2020; Mubarik *et al*., 2021). Symptoms of this disease include leaf curling, leaf enation, stunted growth, veins thickness, and dark color of the leaf (Qazi *et al.*, 2007; Ahmad *et al.*, 2010; Nasim *et al*., 2022). The quality of fiber is affected due to this disease, and ginning out turn (GOT), yield per plant, and seed weight also reduces (Abdelbary *et al.*, 2021; Monga and Sain 2021). Infection of CLCuD at the seedling stage is highly destructive causing enormous yield losses (Sarwar *et al.*, 2023). In cotton, fusarium wilt is also an important disease that caused significant losses (12%) in Pakistan (Agha *et al*., 2022; Asif *et al.*, 2023).

Red cotton bug is a serious problem in Pakistan and India due to attack on lint staining because it not only damages the cotton and mature seeds but also transmits the fungus (Karar *et al*., 2021; Jiang and Yan, 2023). It is polyphagous in nature that it feed on multiples crop and now again the major pest in cotton crop (Shah *et al*., 2016; Nagrare *et al*., 2022).

Control of insect pests through chemical-based insecticides and pesticides is very common all over the world. No doubt it's the fastest and most assured method of insect pest management but it has several side effects that are more than the benefits of its use. Demerits of the chemical base insecticides include resistance activation in insect pests and ultimately increase in the application dose of the chemical. Overdose of pesticides results in soil and air pollution with the passage of time. Also, the edible plant parts get poisonous with the passage of time. All these changes are expected to have a bad effect on humans ultimately and damaging the natural ecosystem which is a major issue at this time. Global warming, climate change, and other related aspects are due to such kind of bad management practices. The biological control method is not so effective alone due to lot of reasons including unfavorable environmental conditions, unwise pesticide spray applications, and a less sufficient system for the massive production of biological control. Maintenance of abiotic factors like humidity, temperature and light etc. is also the best way to control pest population management only in an enclosure medium. Naturally, this factor can be helpful but not artificially in field conditions.

For the management of pests in cotton crop mostly farmers rely on the pesticides which is effective and easily tool. In Pakistan in cotton crops nearly 80% pesticides are sprayed which total cost more than ten billion rupees (Nauen and Bretschneider, 2002). On the other hand, chemical control techniques are the rapid method of insect pest control. Crop safety improved with greater use of artificial chemicals and pesticides in *Gossypium hirsutum* crop and consequently enhanced production of *Gossypium hirsutum*. Currently, agricultural output relies on the use of chemicals; certainly, it is a well-recognized and widespread technique for the management of insect pests so it's essential to the Agriculture system. Synthetic chemicals have helped agriculturalists to manage the common pests simply and effectually which prove dangerous in the decline of crop yield (Rehman *et al*. 2016).

2. Materials and Methods

2.1 Study site

The research was performed in district Vehari in 2023. A field experiment was conducted to check the effect of insecticide (Endosulfan and imidacloprid) against cotton thrips and white fly.

2.2 Sowing of cotton

The cotton crop was sown and grown in randomized complete blocks. The plot size was 5m×3m.

2.3 Spraying process

Spraying was performed in day time with temperatures ranging from 30-35C at 5.7 km per hour wind. The suitable conditions were chosen to reduce the chances of spray glide and loss. Endosulfan and imidacloprid were applied at the recommended dose in cotton.

2.4 Collection of data

For thrips and white fly, the data were recorded before 24 hours of spray, and then data were collected at 24, 48 and 72 hours and after that with a two-week duration until October when applying the insecticide arbitrarily in each plot which will be taken in z-scheme. 25 plants were selected and from every plant 1 leaf from lower, middle and upper leaves were chosen, at different heights. In August spraying was performed when the economic threshold level (ETL) was reached.

3. Data analysis

Data were analyzed by using Statistics 10.0 software. A randomized complete block under a two-way factorial arrangement design was used with three replications. The means of treatment were separated by using the Tukey HSD test. The probability value was 0.05.

4. Results and Discussion

Results of thrips populations in the upper, middle and lower leaves of cotton plants before and after the spray of endosulfan showed that the maximum thrips population was recorded before the spray of insecticides at the upper leaf of the cotton plant (07.33 per leaf) which was non-significantly different from the lower leaf of the plant (07.33 per leaf) and significantly varied from all other treatment where applied the insecticides. Non-significant difference was observed between the upper leaves after the 24-hour application (5.33 per leaf), and the middle and lower plant leaves at the same time intervals which was statistically varied from other treatments and time intervals. After 48-hour application, the populations of thrips also finds non-significant different at all three-leaf plant part (3.67 per leaf) which significantly varied from before and after remaining time intervals. The lowest populations were recorded at the lower leaf portion after 72 hours (1.67 per leaf) which was significantly different from before and after the remaining time intervals shown in (Figure No. 1).

The highest white fly population was recorded before the spray of insecticides at the upper leaf of the cotton plant (09.33 per leaf) which was non-significantly different from the middle leaf of the plant (08.33 per leaf) and significantly varied from all other treatments where applied the insecticides. Non-significant difference was observed between the lower leaves after the 24-hour application (5.67 per leaf) and the middle plant leaf (5.33 per leaf) at the same time intervals which was statistically varied from other treatments and time intervals. After 48-hour application, the populations of white fly also found non-significant differences at all three-leaf plant parts (4.33, 4.00 per leaf) respectively which significantly varied from before and after the remaining time intervals. The lowest populations were recorded at the upper leaf portion after 72 hours (1.67 per leaf) which was significantly different from before and after the remaining time intervals shown in (Figure No. 2).

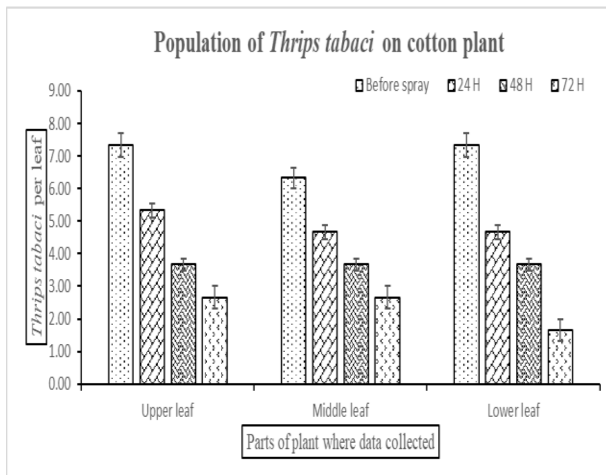

Figure 1. Mean populations of *Thrips tabaci* before and after spray of endosulfan in cotton plant different leaf areas

Results of thrips populations in the upper, middle, and lower leaves of cotton plants before and after the spray of imidacloprid showed that the maximum thrips population was recorded before the spray of insecticides at the upper leaf of the cotton plant (07.67 per leaf) which was non-significantly different from the lower leaf of the plant (06.00 per leaf) and significantly varied from all other treatment where applied the insecticides.

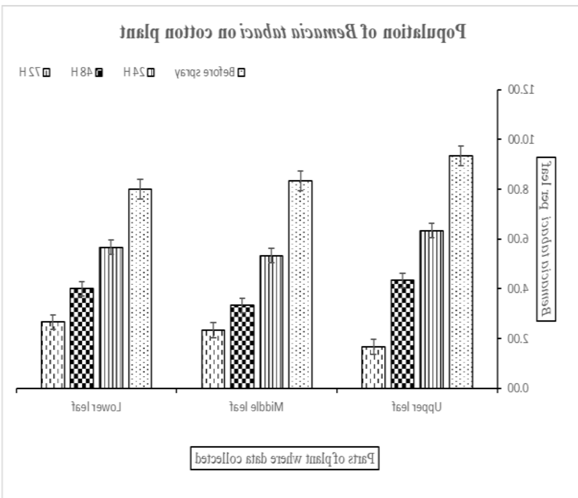

Figure 2. Mean populations of *Bemacia tabaci* before and after spray of endosulfan in cotton plant different leaf areas

Non-significant difference was observed between the upper leaves after the 24-hour application (5.67 per leaf), and the middle and lower plant leaf at the same time intervals which was statistically varied from other treatments and time intervals. After 48-hour application, the populations of thrips also finds significant different at all three-leaf plant part (4.67, 4.00 and 2.67 per leaf) which significantly varied from before and after remaining time intervals. The lowest populations were recorded at the lower leaf portion after 72 hours (0.67 per leaf) which was significantly different from before and after the remaining time intervals shown in (Figure No. 3).

The highest whitefly population was recorded before the spray of insecticides at the lower leaf of the cotton plant (06.00 per leaf) which was non-significantly different from the upper and middle leaf of the plant (05.33 per leaf) and significantly varied from all other treatments where applied the insecticides. Non-significant difference was observed between the upper leaves after the 24-hour application (3.67 per leaf), and the middle and lower plants leaf at the same time intervals which was statistically varied from other treatments and time intervals. After 48-hour application, the populations of whitefly also found non-significant differences at all three-leaf plant part (2.67 per leaf) which significantly varied from before and after remaining time intervals. The lowest populations were recorded at the middle leaf portion after 72 hours (0.67 per leaf) which was significantly different from before and after the remaining time intervals shown in (Figure No. 4).

Our results are in line with Aslam *et al*. (2004) who evaluated the 7 pesticides against *Amrasca bigutulla bigutulla*, *B. tabaci* and *T. tabaci* on cotton. The more efficient pesticide against *Amrasca bigutulla bigutulla*, up to 7 days was Acetamiprid, Imidacloprid while Carbosulfan was unsuccessful in managing *Amrasca bigutulla bigutulla*. For *B. tabaci* the more effectual pesticide was Acetamiprid, Thiamethoxam, while Acetamiprid, Imidacloprid, Methamidophos proved greatly effective for *Thrips tabaci*. Results also matched with Bharpoda *et al*. (2014) who executed the 9 synthetic pesticides in competition to sucking insect pests viz. leaf hopper, aphid, thrips: and whitefly, in cotton range RCH-2 Bt. Data indicated that the imidacloprid showed the best result against the whitefly and aphid followed by thiamethoxam and diafenthiuron. Maximum production of cotton crop was harvesting in imidacloprid sprayed field (30.80 q per ha) followed by clothianidin (27.34 q per ha), difenthiuron (26.94 q ha), thiamethoxam (26.01 q per ha) and acetamiprid (25.68 q per ha). Patel *et al*. (2014) also estimated the efficiency of cyantraniliprole, endosulfan and indoxacarb use against the *Gossypium hirsutum* aphid, whitefly and thrips. The 2 highest treatments of cyantraniliprole 10 percent OD prove largely efficient in controlling the population of *A. gossypii*, *T. tabaci*and *B. tabaci* in the year related to indexacarb and endosulfan. The *Gossypium hirsutum* production was measured considerably larger with cyantraniliprole 10% OD and 105 with an enhancement of 50.80 and 52.81%with control. Considering it, the cyantraniliprole 10% OD is suggested for efficient management of sucking pests in *Gossypium hirsutum.*

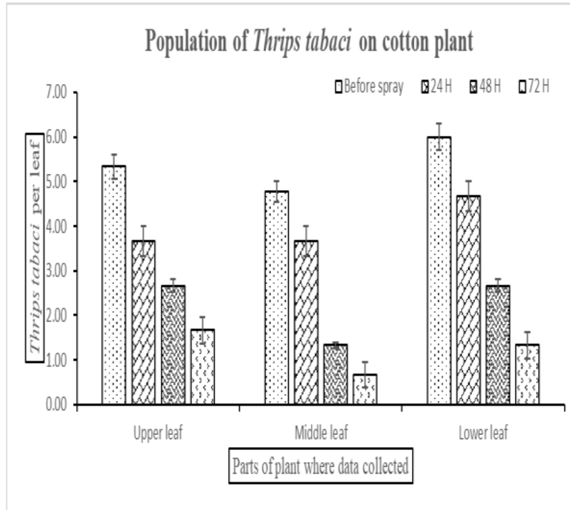

Figure 3. Mean populations of *Thrips tabaci* before and after spray of imidacloprid in cotton plant different leaf areas

Data also correlated with Asif *et al*. (2016) who find out the relative effectiveness of some insecticides for managing sucking pests of *Gossypium hirsutum* (whitefly, thrips and jassid). Imidacloprid then nitenpyram were found efficient for the decrease of thrips and white fly. Nitenpyram has the greatest % of reduction (73.80%) against jassid but was not different from imidacloprid (63.49%). Therefore, these 2 insecticides prove efficient for sucking pests and increased seed cotton production about the other ones. Nazir *et al*. (2017) also determined that the insects including aphids, jassids, whiteflies, thrips, red cotton bugs and dusky cotton bugs, were a challenge to transgenic (BT) *Gossypium hirsutum* crop globally. So, this experiment finds the field efficiency of 6 marketable insecticides such as Blaster 72.5%WP, Jozer 202SL, Confidor 20%SL, Bugatti 50%SC, Senator 41.6%EC and Pouch 35%SC against sucking pests and also finds their effect on ants, coccinellid beetles, green lacewings and parasitoid wasps. Confidor was found to be most efficient against all insect pests. And Confidor, Jozer, Bugatti, Blaster and Senator exhibited a great effect on beneficial insects causing a 90% decrease in their population, and pouch has less effect on environmentally friendly insects and therefore proved to be good. This experiment proves that Jozer and Confidor are suggested to be included in the IPM strategy on crops i.e. Bt *Gossypium hirsutum.*

Data are matched with Halder *et al*. (2018) who estimated the efficiency of some insecticides like Flonicamid (50% WG), Buprofezin (25% SC), Spirotetramat (240 SC), Sulfoxaflor (24% SC), Spiromesifen (22.9% SC), Dinotefuran (20% SG), Clothianidin (50% WDG) along with some chemicals, Imidacloprid (0.5 ml/l) and Thiamethoxam (0.3 gm/l) against Jassid infesting *Gossypium hirsutum* variety Surabhi. 9 insecticides with untreated control, overall, 10 treatments repeated 3 times taken in it.

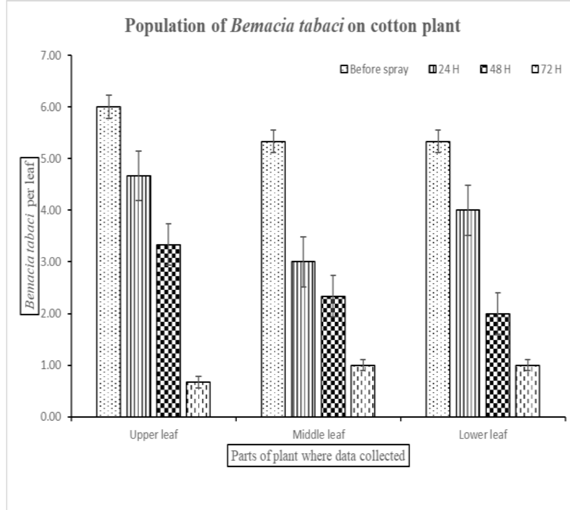

Figure 4. Mean populations of *Bemacia tabaci* before and after spray of imidacloprid in cotton plant different leaf areas.

All the treatments gave the highest reduction to the jassid population and greater population in the untreated control. From all these the most efficient insecticides was Buprofezin (25% SC) 80.16% then Imidacloprid (17.8% SL) 78.77% and less efficient was Sulfoxaflor (24% SC) 69.45%. Suvash and Nihal (2020) also conducted experiments to check the effectiveness of new chemistry insecticides against the thrips and whitefly at Kalyani, Nadia, West Bengal during 2016-18. Results revealed that highest mortality of whitefly and thrips was recorded in the field where apply the combine application of acetamiprid plus diafenthiuron

Data also matched with Habib-ur-Rehman *et al*. (2020) who carried out the experiment under lab. condition to toxicity of synthetic insecticides with different concentration against whitefly. Data exhibited that maximum mortality was recorded in buprofezin (82.13 %) followed by endosulfon (77.46 %) and acetamiprid (69.52%). Wawdhane *et al*. (2020) also find Effectiveness of different pesticides against the sucking complex of cotton at Nagpur during 2016-17. Data indicated that best results was observed in imidacloprid against the nymph stage of whitefly, aphid, jassid and thrip followed by spiromesifen. Parmar (2023) also determined the toxicity of various insecticides against the sucking complex of cotton at Navsari Agricultural University, Surat during 2021. Results showed that the best performance was recorded in the imidacloprid followed by thiamethoxam.

4. Conclusion

The study examined the efficacy of endosulfan and imidacloprid against thrips and whitefly infestations on cotton crops. Results indicated that imidacloprid demonstrated superior toxicity compared to endosulfan in controlling both whitefly and thrips populations. Thrips populations were notably reduced across all plant leaf areas following imidacloprid application, with the lowest populations recorded after 72 hours. Similarly, whitefly populations showed significant reduction, especially after 48 hours post-application of imidacloprid. These findings align with previous studies, confirming the efficacy of imidacloprid in managing sucking insect pests on cotton crops. Given the substantial economic losses caused by whitefly and thrips infestations in cotton, timely management through suitable insecticide application intervals is crucial for optimizing cotton yield.

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References

Abdelbary, A.M., H.M. Hamoud, W.M. Yehiya, A.M. Abdelmoghny, M.R. Eman, E.A. Samia, M.H. Orabi, S.M. Mariz, M.S. Srour, E.D. Sawsan and S.S. Attia. 2021. Giza 97" a new Egyptian long staple cotton variety. Egypt J. Agric. Res. 99: 284-295.

Afzal, M., S. Saeed, H. Riaz, M. Ishtiaq and M.H. Rahman. 2023. A critical review of whitefly (*Bemisia tabaci* gennadius) cryptic species associated with the cotton leaf curl disease. J. Innov. Sci. 9: 24-43.

Agha, S.I., N. Jahan, S. Azeem, S. Parveen, B. Tabassum, A. Raheem, H. Ullah and K. Anwar. 2022. Research article characterization of broad-spectrum biocontrol efficacy of *Bacillus velezensis* against *Fusarium oxysporum* in *Triticum aestivum* L. Not. Bot. Horti. Agrobot. Cluj Napoca. 50: 12590-12590.

Ahmad, S., A. Noor-ul-Islam, F. Mehmood, K. Ashraf and M. Hanif. 2010. Screening of cotton germplasm against cotton leaf curl virus. Pak. J. Bot. 42: 3327-3342.

Ali, M.A., J. Farooq, A. Batool, A. Zahoor, F. Azeem, A. Mahmood and K. Jabran. 2019. "Cotton production in Pakistan." J. Cotton Res. 2: 249-276.

Asif, M.U., R. Muhammad, W. Akber, M. Tofique, 2016. Relative Efficacy of Some Insecticides against the Sucking Insect Pest Complex of Cotton. Q. Int. Sci. J. 53(2).

Asif, R., M.H. Siddique, S. Hayat, I. Rasul, H. Nadeem, M. Faisal and S. Muzammil. 2023. Efficacy of *Saccharothrix algeriensis* NRRL B-24137 to suppress *Fusarium oxysporum* f. sp. vasinfectum induced wilt disease in cotton. Peer J. 11: e14754.

Aslam, M., M. Razzaq, S. Rana and M. Faheem. 2004. Comparative efficacy of different insecticides against sucking pests of cotton. J. Res. Sci., 15: 53-58.

Bharpoda, T.M., N.B. Patel, R.K. Thumar, N.A. Bhatt, L.V. Ghetiya, H.C. Patel and P.K. Borad, 2014. Evaluation of insecticides against sucking insect pests infesting bt cotton BG- II. Int. Q. J. of Life Sci., 9(3): 977-980.

Brewer, M.J., D.J. Anderson and M.N. Parajulee. 2016. Cotton water-deficit stress, age, and cultivars as moderating factors of cotton fleahopper abundance and yield loss. Crop Prot. 86: 56-61.

Chen, P., Q. Xiao, J. Zhang, C. Xie and B. Wang. 2020. Occurrence prediction of cotton pests and diseases by bidirectional long short-term memory networks with climate and atmosphere circulation. Comput. Electron. Agric. 176: 105612.

Chohan, S., R. Perveen, M. Abid, M.N. Tahir and M. Sajid. 2020. Cotton diseases and their management. Cotton Production and Uses: Agronomy, Crop Protection, and Postharvest Technologies. pp. 239-270.

dos Santos Cordeiro, C.F., J.P.A. Raphael and F.R. Echer. 2024. Boll distribution in the cotton canopy is affected by nitrogen management and cover crops in a sandy soil under water scarcity. Field Crops Res. 306: 109209.

Ermanis, A., S. Gobbo, J.L. Snider, Y. Cohen, V. Liakos, L. Lacerda, C.D. Perry, M. Aaron Bruce, G. Virk and G. Vellidis. 2021. Defining physiological contributions to yield loss in response to irrigation in cotton. J. Agron. Crop Sci. 207: 186-196.

Etesami, H., B.R. Jeong and B.R. Glick. 2023. Biocontrol of plant diseases by Bacillus Spp. Physiol. Mol. Plant Pathol. 102048.

Fagodiya, R.K., A. Trivedi and B.L. Fagodia. 2022. Impact of weather parameters on Alternaria leaf spot of soybean incited by *Alternaria alternata*. Sci. Rep. 12: 6131.

Fones, H.N., D.P. Bebber, T.M. Chaloner, W.T. Kay, G. Steinberg and S.J. Gurr. 2020. Threats to global food security from emerging fungal and oomycete crop pathogens. Nat. Food. 1: 332-342.

Govindan, G., S. KR, V. Alphonse and S. Somasundram. 2024. Role of germin-like proteins (glps) in biotic and abiotic stress responses in major crops: A review on plant defense mechanisms and stress tolerance. Plant Mol. Biol. Rep. 1-19.

Gowtham, H.G., P. Hema, M. Murali, N. Shilpa, K. Nataraj, G.L. Basavaraj, S.B. Singh, M. Aiyaz, A.C. Udayashankar and K.N. Amruthesh. 2024. Fungal Endophytes as Mitigators against Biotic and Abiotic Stresses in Crop Plants. J. Fungi. 10: 116.

Gudeta, B., E.G. Kedisso, D. Gurmessa, D. Tesfaye, S. Damtew, W. Taye, A. Gebre-Egziabher, M. Balcha, T. Daba, A.

Workie and K. Maredia. 2023. Adaptability of genetically engineered Bt cotton varieties in different growing regions of Ethiopia. Advan. Agric. 1-16.

Habib-ur-Rehman, Q. A., Zia, S., Umar, M. Y., & Habib, B. 2020. COMPARATIVE EFFICACY OF THREE INSECTICIDES AGAINST COTTON WHITEFLY (Bemesia tabaci) UNDER CONTROLLED ENVIRONMENT. J. Glob. Innov. Agric. Soc. Sci., 8 (1):11-14.

Halder, P., M.K. Datta and S. Basak, 2018.Evaluation of some Novel Mode of Insecticides against Cotton Jassid (Amrasca biguttula biguttula Ishida) in New Alluvial Zone of West Bengal, India. Int. J. Curr. Microbiol. App. Sci. 7: 33-37.

Hammiche, D., R. Bellache and A. Boukerrou. 2024. Effect of interfacial bonding characteristics on dynamic mechanical analysis of cotton fiber reinforced composites. in interfacial bonding characteristics in natural fiber reinforced polymer composites: fiber-matrix interface in biocomposites. Singapore: Springer Nature Singapore. pp. 141-153.

Javed, T., R. Shabbir, A. Tahir, S. Ahmar, F. Mora-Poblete, M. Razzaq and A. Naseer. 2022. Etiology, epidemiology, and management of maize diseases. In cereal diseases: Nanobiotechnological approaches for diagnosis and management. Singapore: Springer Nature Singapore. 53-82.

Jiang, L. and H. Yan. 2023. Cloning, expression, purification and biochemical characterization of the recombinant chitinase enzyme encoded by CTS2 in the budding yeast. Protein Expr. Purif. 208: 106294.

Jiang, N., J. Yan, Y. Liang, Y. Shi, Z. He, Y. Wu, Q. Zeng, X. Liu and J. Peng. 2020. Resistance genes and their interactions with bacterial blight/leaf streak pathogens (*Xanthomonas oryzae*) in rice (*Oryza sativa* L.)-an updated review. Rice. 13: 1-12.

Kamble, R. and K.S. Tikadar. 2024. Cotton cultivating marginalised farmers' climate change perceptions, impacts and adaptation strategies in Vidarbha region, central India. Sustain. Agri. Food Enviro. Res. 12: xxx-xxx.

Karar, H., M.A. Bashir, K.A. Khan, H.A. Ghramh, S. Atta, M.J. Ansari, Z. Ahmad and F.R. Khan. 2020. The impact of adjacent habitats on population dynamics of red cotton bugs and lint quality. PLoS One. 15: e0242787.

Karar, H., M.A. Bashir, M. Haider, N. Haider, M. Hassan, M. Hashem and S. Alamri. 2021. Ecological impact on development of hemipterous bug (*Dysdercus koenigii*) (Hemiptera: Pyrrhocoridae) and boll rot disease of cotton (*Gossypium hirsutum*) grown in the diversified field. Saudi J. Biol. Sci. 28: 3957-3964.

Khairnar, K. and N. Goje. 2020. Image processing-based approach for diseases detection and diagnosis on cotton plant leaf. In Techno-Societal 2018: Proceedings of the 2nd International Conference on Advanced Technologies for Societal Applications-Volume 1. Springer International Publishing. pp. 55-65.

Levine, M.N., A.A. Joyce, F.J. Heijting, S.M. King and P. Meehan. 2024. Cotton thread production, communities of practice, and value in Postclassic Oaxaca, Mexico. In realizing value in Mesoamerica: The dynamics of desire and demand in ancient economies. Cham: Springer International Publishing. pp. 247-276.

Lu, Y., K.A. Wyckhuys, L. Yang, B. Liu, J. Zeng, Y. Jiang, N. Desneux, W. Zhang and K. Wu. 2022. Bt cotton area contraction drives regional pest resurgence, crop loss, and pesticide use. Plant Biotechnol. J. 20: 390-398.

Madani, M. 2023. Top ten plant parasitic nematodes of economic importance in arid and semi arid area, threatening green house and field crops. J. Agric. Mari. Sci. 28: 136-146.

Majid, M.U., Z. Sher, B. Rashid, Q. Ali, M.B. Sarwar, S. Hassan and T. Husnain. 2020. Role of leaf epicuticular wax load and composition against whitefly population and cotton leaf curl virus in different cotton varieties. Cytol. Genet. 54: 472-486.

Monga, D. and S.K. Sain. 2021. Incidence and severity of cotton leaf curl virus disease on different BG II hybrids and its effect on the yield and quality of cotton crop. J. Environ. Biol. 42: 90-98.

Mubarik, M.S., X. Wang, S.H. Khan, A. Ahmad, Z. Khan, M.W. Amjid, M.K. Razzaq, Z. Ali and M.T. Azhar. 2021. Engineering broad-spectrum resistance to cotton leaf curl disease by CRISPR-Cas9 based multiplex editing in plants. GM Crops Food. 12: 647-658.

Nadeem, A., H.M. Tahir, A.A. Khan, Z. Hassan and A.M. Khan. 2023. Species composition and population dynamics of some arthropod pests in cotton fields of irrigated and semi-arid regions of Punjab, Pakistan. Saudi J. Biol. Sci. 30: 103521.

Nafees, A.A., A. Allana, M.M. Kadir, J. Potts, C. Minelli, S. Semple, S. De Matteis, P. Burney and P. Cullinan. 2024. A cluster randomised controlled trial to reduce respiratory effects of cotton dust exposure among textile workers: The MultiTex RCT study. Eur. Respir. J. 63: 2301028.

Nagrale, D.T., S.P. Gawande, N. Gokte-Narkhedkar and V.N. Waghmare. 2020. Association of phytopathogenic *Pantoea dispersa* inner boll rot of cotton (*Gossypium hirsutum* L.) in Maharashtra state, India. Eur. J. Plant Pathol. 158: 251-260.

Nagrare, V.S., B.B. Fand, R. Kumar, V. Naik, K. Bhure, B. Naikwadi, N. Gokte-Narkhedkar and V.N. Waghmare. 2022. Arthropod pests and their natural enemies associated with cotton in India: A Review. Indian J. Entomol. 713-725.

Naik, V.C.B., S. KB, S. Kranthi, V.S. Nagrare, S. Kumbhare, N. Gokte-Narkhedkar and V.N. Waghmare. 2021. Pink bollworm, *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae) survival on transgenic cotton in India. Egypt. J. Biol. Pest Control. 31: 1-7.

Nasim, A., M.A.R. Rashid, K. Hussain, I.M. Al-Shahwan and M.A. Al-Saleh. 2022. Interaction estimation of pathogenicity determinant protein βC1 encoded by cotton leaf curl Multan Betasatellite with *Nicotiana benthamiana* nuclear transport factor 2. Peer J. 10: e14281.

Nauen R, Bretschneider T. New modes of action of insecticides. Pestic. Outlook. 2002; 13:241-245

Naveed, M., H.S. He, S. Zong, H. Du, Z. Satti, H. Sun and S. Chang. 2023. Cotton cultivated area detection and yield monitoring combining remote sensing with field data in lower Indus River basin, Pakistan. Environ. Monit. Assess. 195: 401.

Nazeer, W., Z.U. Zia, M. Qadir, S. Ahmad and M.R. Shahid. 2023. Sustainable cotton production in Punjab: Failure and its mitigating strategies. In sustainable agriculture in the era of the OMICs revolution. Cham: Springer International Publishing. pp. 483-500.

Nazir, T., M.D. Gogi, M.Z. Majeed, W. Hassan, A. Hanan and M.J. Arif, 2017. Field evaluation of selective systemic formulations against sucking insect pest complex and their natural enemies on a transgenic bt cotton. Pakistan J. Zool. 49: 1789-1796.

Parmar, P. R. (2023). Efficacy of Seed Treatment Chemicals Against Sucking Pests of Bt Cotton. *International Journal of Agriculture Sciences*, *ISSN*, 0975-3710.

Patel, R.D., T.M. Bharpoda, N.B. Patel and P.K. Board, 2014. Bio-efficacy of cyantraniliprole 10% od- an anthranilic diamide insecticide against sucking pests of cotton. Int. Q. J. of Life Sci. 9: 89-92.

Poggemann, L., B. King, J. Meyer and A. Dittler. 2023. Morphology of particulate structures on a fiber array before and at clogging point of an aerosol filtration process. Separations. 10: 462.

Prasad, A., N. Sharma, G. Hari-Gowthem, M. Muthamilarasan and M. Prasad. 2020. Tomato yellow leaf curl virus: impact, challenges, and management. Trends Plant Sci. 25: 897-911.

Qazi, J., I. Amin, S. Mansoor, M.J. Iqbal and R.W. Briddon. 2007. Contribution of the satellite encoded gene βC1 to cotton leaf curl disease symptoms. Virus Res. 128: 135-139.

Rehman, A., L. Jingdong, A.A. Chandio, I. Hussain, S.A. Wagan and Q. Memon, 2016. Economic perspectives of cotton crop in Pakistan. Journal of the Saudi Society of Agricultural Sciences 18(3), 269-274.

Saleem, M.A., M.M.A. Baig, M.Q. Ahmad, Z.U. Zia, M. Asif and M. Nauman. 2023. Micro-climatic effect on cotton yield, quality, Bt toxin & GT Gene. Int. J. Innov. Approa. Agric. Res. 7: 40-52.

Sarwar, M., M.F. Saleem, B. Ali, M. Sagir, M.B. Tahir, M. Wahid, M. Shahid, T.M. Mwamba, B.A. Khan, H. Maqsood and H. Maqsood. 2023. Manipulation of plant growth stimulants on plant morphology, phenology, and disease incident of *Gossypium hirsutum* L. under various thermal regimes. Arab. J. Geosci. 16: 170.

Sattar, S., B. Nawaz and M. İshaq. 2020. Inheritance pattern and association of qualitative and quantitative traits in cotton for sustainable breeding Goal. Int. J. Agric. Innov. Res. 4: 308-317.

Shah, Z.U., A. Ali, I. Haq and F. Hafeez. 2016. Seasonal history of dusky cotton bug (*Oxycarenus hyalinipennis* Costa). J. Entomol. Zool. Stud. 4: 228-233.

SUVASH, C., & NIHAL, R. (2020). Bio-efficacy of some newer insecticides against whitefly, *Bemisia tabaci* (Gennadius) and thrips, *Scirtothrips dorsalis* (Hood) infesting bt cotton. An International Quarterly Journal of Life Science. 15(1): 055-059,

Wahid, M.A. and Z. Mahmood. 2024. Estimation of heterosis in cotton genotypes for yield performance at Multan location PR China. 01 January 2024, PREPRINT (Version 2) available at Research Square [https://doi.org/10.21203/rs.3.rs-3758519/v2].

Wawdhane, P. A., Nandanwar, V. N., Mahankuda, B., Ingle, A. S., & Chaple, K. I. (2020). Bio-efficacy of insecticides and bio pesticides against major sucking pests of Bt-cotton. J. Entomol. Zoo Stud, 8, 829-833.

Wu, Y., J. Li, H. Liu, G. Qiao and X. Huang. 2020. Investigating the impact of climate warming on phenology of aphid pests in China using long-term historical data. Insects. 11: 167.

Yuan, J., T. Wen, H. Zhang, M. Zhao, C.R. Penton, L.S. Thomashow and Q. Shen. 2020. Predicting disease occurrence with high accuracy based on soil macroecological patterns of Fusarium wilt. Int. Soc. Micro. Ecol. J. 14: 2936-2950.

Zaman, I., M. Ali, K. Shahzad, M.S. Tahir, A. Matloob, W. Ahmad, S. Alamri, M.R. Khurshid, M.M. Qureshi, A. Wasaya and R. Datta. 2021. Effect of plant spacings on growth, physiology, yield and fiber quality attributes of cotton genotypes under nitrogen fertilization. Agron. 11: 2589.

Zuberi, M., M. Spies and J.Ø. Nielsen. 2024. Is there a future for smallholder farmers in bioeconomy? The case of 'improved'seeds in South Punjab, Pakistan. For. Policy Econ. 158: 103100.