J Agric. Res., 2024, Vol. 62(2):103-110
www.jar.com.pk
Agriculture Department
Government of Punjab

ISSN: 2076-7897 (Online) / ISSN: 0368-1157 (Print)
DOI: https://doi.org/10.58475/2024.62.2.2046

Crossref

ENTOMOLOGY

OPPORTUNITIES AND CHALLENGES FOR SUSTAINABLE COTTON WHITEFLY MANAGEMENT IN PUNJAB PAKISTAN: A REVIEW

Nicola D Cannon*[1] and Shahid Jiskani[2]

[1]Professor of Agriculture, [2]Researcher, Royal Agricultural University, Cirencester, Gloucestershire, GL7 6JS United Kingdom.

*Corresponding author's email: Nicola.Cannon@rau.ac.uk

Article received on: 01/05/2023
Accepted for publication: 18/07/2024

ABSTRACT

Whiteflies (*Bemisia tabaci*) in cotton (*Gossypium hirsutum* L) cause wide spread yield loss through the transmission of a range of viruses. Whitefly are becoming difficult to control and manage partially as a result of changing weather patterns in Pakistan, synthetic pesticides are commonly used in attempts to combat this pest, but recommended rates are often exceeded to try and improve control resulting in resistance issues and health complications for the farmers applying the pesticides. There are integrated, non-chemical control options for whiteflies including crop rotation design, bi-cropping, trap cropping, irrigation management, mulching, varietal resistance and biological control which can help reduce the pest burden when used appropriately. Growing Bt cotton can help to reduce challenges in whitefly control.

KEYWORDS: *Bemisia tabaci*; sucking insects; control; crop-rotation resistance; Pakistan

INTRODUCTION

Cotton (*Gossypium hirsutum L*) growing generates 0.8% share of gross domestic product (GDP) (Bashir *et al.* 2024) is the third largest crop grown in Pakistan making it the fourth largest cotton growing country in the world. However, Pakistan's cotton yields have stagnated during the past two decades and increasingly farmers struggle to be globally competitive (Rana, 2021). The southern part of Punjab has a favorable weather for cotton production (Shafiq-ur-Rehman *et al.,* 2021; Yasin *et al.,* 2020) as the predominate weather for the region is hot and dry in the summer and cold and dry in winter with a temperature range of 7°C to 48°C (Ahmed *et al.,* 2022). Soils are predominately alkaline loams with low available nitrogen, phosphorus and potassium (Ahmed *et al.,* 2022). Cotton is grown for fibres which are utilized by the textile industry whilst also producing seeds for oil and animal feed sector (Ozyigit *et al.,* 2007). Cotton-wheat rotation are among Pakistan's most common cropping system (Ahmed *et al.,* 2022). Generally, farmers in Pakistan do not have access to the appropriate machinery for direct drilling wheat and as the stubble after cotton is often slightly compacted, the cotton stems must be removed to create a seed bed for the following wheat crop (Ahmed *et al.,* 2022) which in the long term may lower soil organic matter levels.

Whiteflies (*Bemisia tabaci*), amongst other pests cause damage to cotton crops resulting in a global loss of billions of USD (Hasan *et al.,* 2019). *B. tabaci* are still one of the most challenging pests among the 1556 species of whiteflies in vegetable and ornamental crops globally (Sani *et al.,* 2021). They feed on many crops from a wide range of crop families (Kunjwal *et al.,* 2018; Sani *et al.,* 2020) and their feeding can lead to the plant becoming infected with a wide range of viruses, including the cotton leaf curlvirus (CLCV) which causes slow or even halts early crop growth (Parkash *et al.,* 2021) and decreasing photosynthesis rate as well as excreting honeydew during feeding (Polston and Capobianco, 2013; Gao *et al.,* 2017). CLCV is widespread throughout the world, with epidemics in Africa, Asia and South America, leading to around 1500 kg/ha yield loss in South America alone (Mahas *et al.,* 2022). The symptoms of the disease include internodal shortening; rolling and cupping of leaves; reddening veins; wilting; smaller flower and boll size and even sterility in cotton plants (Conner *et al.,* 2022). Whiteflies, are characterized by the six stages in their life cycle: egg, four instars and adult (Sani *et al.,* 2020) (Figure 1). The incubation of the eggs which can be deposited on either the upper or lower leaves of plants, can take 5 to 9 days, depending on the host species and the influence of

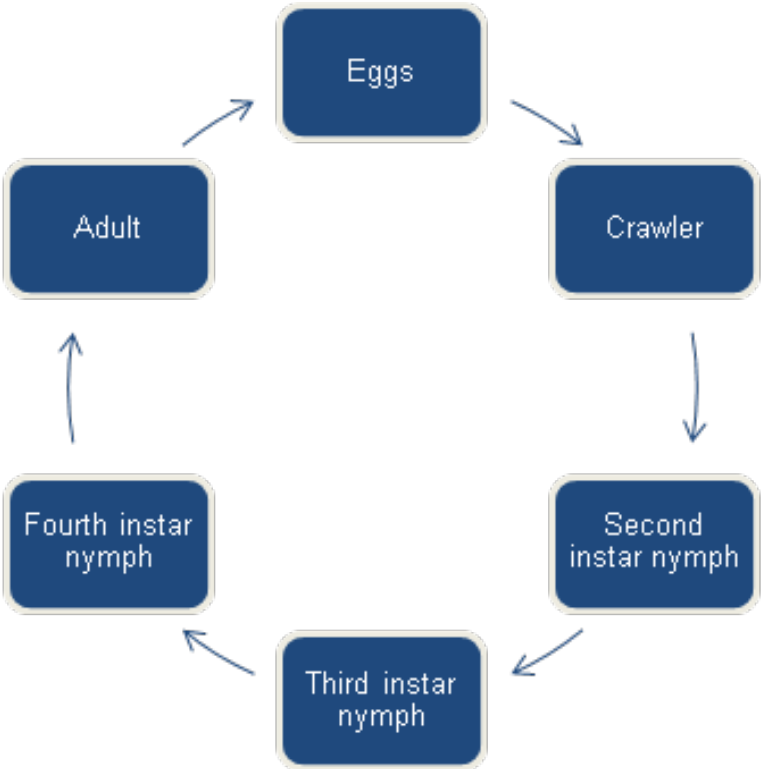


Figure 1: Whitefly lifecycle in Pakistan

temperature and humidity (Gangwar and Charu, 2018; Solanki and Jha, 2018). After hatching the whitefly crawlers start feeding on the leaf with their proboscis in a probing action (Fekrat & Shishehbor, 2007).

The historical problem of whitefly control

Whiteflies were first identified in Greece in 1889 by Gennadius, who named them *Aleyrodestabaci* in tobacco plants (Sani *et al.,* 2020), and it was reported as a vector for the pathogen transmission in tobacco leaf curl virus and African cassava mosaic virus (Facquet and Fargette, 1990). There were reports of whiteflies in 1928 in the Brazilian region of Bahia State (the instances where the species spread pathogens was then discovered in the tropical Americas in 1946 in arrow leaf sida (*Sidarhombifolia*). In the 1950's, the mechanism of transmission of Euphobia mosaic virus was reported, and the 1960s and 70s saw more diseases transmitted by whiteflies in tropical Americas and the Caribbean basin until in the 80s, the pest became a sizable threat to cotton and other crops (Brown and Bird, 1992). In the decade that followed, the level of whitefly infestation was very high globally causing large economic losses in crop damage (Brown and Bird, 1992). Initially, research interests and efforts were limited to a local or regional level until the pest and related diseases became more prevalent across the globe (Brown and Bird, 1992). Both the species of whiteflies and the virus spread by them have since been studied extensively, with major breakthroughs during the last few decades of 20th Century (Brown and Bird, 1992). Controlling whiteflies is consistently a challenge due to the ability to become resistant to pesticides. Whiteflies also benefit from the wide range of crops that can serve as host plants to this pest, as well as increased human activity and trade aiding their distribution worldwide. There have been instances where irregular rainfall patterns (see table 1) in the world might have contributed to spikes in whiteflies infestation (Kumar *et al.,* 2002). Under the context of increased occurrences of extreme weather patterns, including those observed in Pakistan in June 2022, there will be greater climatic challenges influencing the ideal sowing time for optimal whitefly control in cotton. Cotton has benefited from technological advances over the years, specifically new cultivars through genetic modification to resist pests. Since 1996, cotton plant have been genetically modified for protection against bollworms by using the toxin (δ-endotoxins (Cry proteins)) producing gene from *Bacillus thuringiensis* bacterium in the soil, hence the name Bt (Rana, 2021). The commercialization of Bt-Cotton started in the United States in 1996 and since then two other generations of Bt-Cotton have been commercialized (Rana, 2021). These varieties have since been used in many cotton growing areas in the world (Zhao *et al.,* 2022) including Pakistan where it was introduced in 2002 (Rana, 2021).

Table 1: Extreme weather events in Pakistan

Weather factor	Details	Source
Temperature	The average annual temperature has risen from 24.6°C in 1980 to 25.5°C leading up to 2023	WorldData.info
Precipitation	2010 had flooding anomalies greater than 2 and 2022 experienced had flooding anomalies greater than 4	Ashfaq *et al*. 2023
Precipitation	There is an increasing precipitation trend in September and June	Adnan, Ullah & Shouting 2016
Precipitation	In May 2023, 900mm of rain fell making it the wettest May since 1962	WorldData.info
Precipitation	The provinces of Sindh and Balochistan experienced a 75% increase in intensity of rainfall over 5 days due to 1.2°C global warming.	Otto *et al.* (2023)
Precipitation	In February 2023, just 5mm of rain fell making it the driest February for 22 years	WorldData.info
Drought	There was the longest drought ever recorded in Pakistan from 2000-02	Adnan, Ullah & Shouting 2016

Bt-cotton does not target whiteflies specifically and therefore the mechanism with which Bt-Cotton is able to resist whiteflies has not been extensively studied (Zhao *et al.,* 2022). The adoption of Bt-cotton around the world led to a decline in the use of pesticides in cotton, due to decrease in numbers of targeted bollworm (Abubakar *et al.,* 2022), but there have been reports of nontarget pest outbreaks (Lu *et al.,* 2012). In the absence of Bt-Cotton, extensive use of high rates of insecticide to control whiteflies has led to resistance (Roditakis *et al.,* 2009), especially in the Q-biotype (Yuan *et al.,* 2012). Pakistan has been at a disadvantage in terms of whitefly control as the high rates of insecticide use have led to resistance in whiteflies, coupled with many host plants for this pest within the country. Whitefly resistance has not been such a challenge in many other countries as Bt-Cotton has suppressed this issue.

Current methods of whiteflies control:

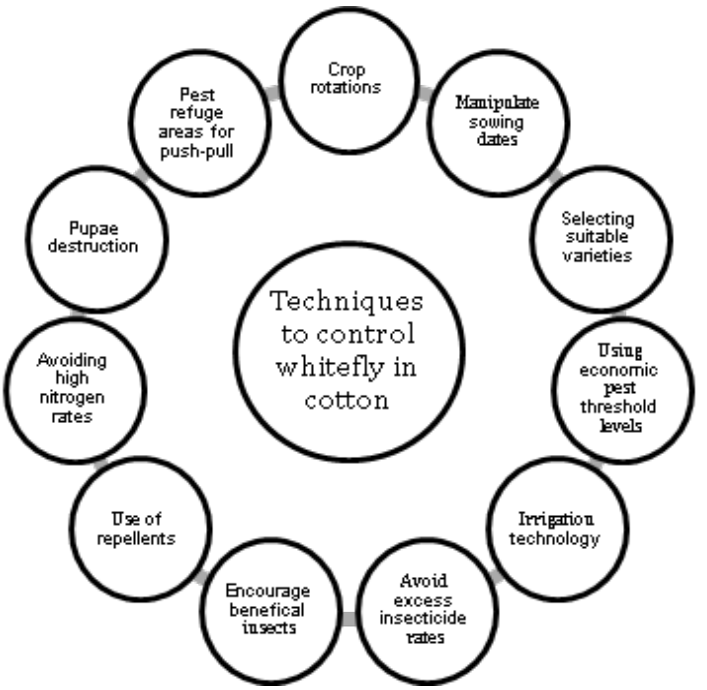
Whiteflies are usually controlled by synthetic insecticides and the cultivation of cotton uses 6% of all the pesticides and 16% of all the insecticides in the world, the most for any crop globally (Shafiq-ur-Rehman *et al.,* 2021). In Pakistan, cotton crops often receive as much as twice the recommended amount of insecticide used in conventional cotton cultivation elsewhere (Khan *et al.,* 2011; Yasin *et al.,* 2021). The large amount of pesticide usage represents a significant portion of the input cost (around 33%) (Farooqi, 2010) and therefore lower the financial returns from a given yield, whilst also being a threat to the health of farmers, consumers and population in the surrounding region due to pollution (Sani *et al.,* 2020). There have been reports of thousand casualties in Pakistan that have been linked to pesticide poisoning every year (Shafiq-ur-Rehman *et al.,* 2021), in addition to the health problems including neurological disorders and leukemia (Hashmi *et al.,* 2011). The overuse of pesticide also means that resistance in pests develop faster which cause further pest challenges. There are physical and cultural control methods that can reduce the numbers of whiteflies with varying degrees of effectiveness. Most of the available research, however, uses different host plants and different environments, and therefore there are uncertainties in whether the methods work well in the wheat-cotton rotation in Punjab, Pakistan. In some circumstances it has been found that reducing the nitrogen supplied to the cotton plants can reduce whitefly numbers (Bi *et al.,* 2001), however, this may have implications on final yield. The use of drip or sprinkler irrigation can lower the density of whiteflies and therefore the transmission of viruses they spread (Abd-Rabou & Simmons, 2012), however, changing irrigation pattern can impact crop yield by reducing the crop water availability for growth and resulting plant stress. Diversifying the crop rotation and intercropping cotton with other plant species can help control whiteflies. Uses of tall-growing grasses or cereals from the Gramineae family which are non-host plants for whiteflies have been shown to increase predatory insects which then helps reduce whitefly numbers (Bao-jie *et al.,* 2021). Intercropping or bi-cropping with other species such as sunflowers, buckwheat and soybean with cotton has been shown to reduce whitefly density (Yan *et al.,* 2019). The principle is the “push-pull” strategies to deter and attract pests, by exploiting the pests’ preferences when it comes to the plant species, cultivars or growth stage of the crop (Cook *et al.,* 2007). Push-pull can be done by the establishment of the same species as the main crop earlier or later and then adding

Table 2: The opportunities and challenges of introducing bi-cropping systems

Opportunities arising from bi-cropping	Challenges of bi-cropping
Different plant species to attract insect predators	Challenges when using mechanized harvesting, spraying and planting systems
Improved land use efficiency	Potential increased intraspecific plant competition
Reduced weed growth	More complex cropping system management required
Spreads cropping risk	

Source: Cannon et al., (2019)

Figure 2: A range of management techniques which are required for successful whitefly management.



insect pheromones or other chemicals that can attract the insects. These other plants are of varying economic benefits from harvestable crops to catch crops, and therefore might not be suitable for the Punjab regions. The uses of mulches have also shown some effectiveness in a range of crops by using combinations of organic mulch such as cocoa hull, barks, wheat straw (Sani *et al.,* 2020) and compost and synthetic mulches (Simmons and Abd-Rabou, 2008) physical barriers such as rubber chips and plastic sheets can decrease whiteflies infestation in crops including tomato and snap bean (Abubakar *et al.,* 2022) by reflecting sunlight, which is reported to have a repelling effect on whiteflies (Summers *et al.,* 2005; Nasruddin *et al.,* 2020). But mulches and the other cultural or physical methods listed might be difficult to execute, because they usually involve coordination between different farmers, shifts in agricultural systems and synthetic mulches may leave undesirable residues in the soil. There are traditional methods that many farmers are already using to repel sucking pests including whiteflies such as spraying of liquids including buttermilk (Kumar *et al.,* 2002), cow urine and other botanical extracts or solids manures such as cow dung (Abukabar *et al.,* 2022). Buttermilk's usefulness comes from its ability to spread and sticks to the wings of whiteflies due to the casein protein present in it (Abukabar *et al.,* 2022). Spraying buttermilk on okra crops have resulted in a 60% reduction in whitefly populations (Karthikeyan *et al.,* 2006), and when combined with detergents on black gram have reduced whiteflies population (Taggar and Singh, 2020). Cow urine, on the other hand, contains herbal aqueous extracts that drive whiteflies away, and unlike pesticides, does not target

the natural enemies of whiteflies (Patel *et al.,* 2017). Other extracts including garlic and milkweed extracts have helped control whitefly (Barati *et al.,* 2013). These methods, however, are not backed up by scientific evidence, with inconsistent results and varying constraints by environmental factors (Isman, 2017). ***Current and future options for more sustainable control methods:*** All the physical and cultural methods mentioned so far are useful for integrated approaches as they involve the use of a wide range of methods to reduce environmental pressures (Kanakala and Ghanim, 2019). Biological control involves the use of one organism to aid the control of crop pests (Daniel and Wyss. 2010). There have been as many as 150 species identified as natural enemies of whiteflies, but research into the different species as possible ways to control whiteflies is limited (Gerling *et al.,* 2001). Predator species such as *Coccinellidae* species(ladybird beetle) and *Chrysoperla carnea (*Stevens) green lacewing) have demonstrated high level of whiteflies reduction in greenhouse conditions on tomato crops (Rehman, 2020), but further research is required to test their abilities to control whiteflies in cotton in field conditions. The development of resistance management plan for Bt-Cotton relies on the resistance to Cry proteins being recessive to avoid resistance alleles occurring at high frequencies when random mating between individuals for producing moths to mate with any resistant survivors (Knight *et al.,* 2021). Additionally, plans can then be developed to avoid early or late planting of crops to limit exposure of whitefly using structured refuge areas to dilute resistance at the end of the season by killing pests with resistance alleles by trap crops and cultivation (Abubakar *et al.,* 2022). These same principles can be applied to non Bt-Cotton in Pakistan through the use of refuges, planting window, pupae destruction, late season spraying in an integrated approach to control pests to avoid disruptive chemical insecticide (Knight *et al.,* 2021). Changes to the cotton plant variety with the introduction of Bollgard 3, which produces both Cry1Ac and Cry2Ab2 in addition to the Vip3A protein and changes to the alleles in pests have since induced adaptations to the scheme, but the ultimately the plan has been highly effective where Bt-Cotton is grown (Knight *et al.,* 2021). RNA interference (RNAi) offer promise for white fly control through molecular mechanisms involved in the regulating gene expression in eukaryotic cells. The small double-stranded RNA (dsRNA) enables a sequence specific suppression expression of a target gene (Ribeiro *et al.,* 2022) and often used against coleopteran and lepidopteran pests. An example of how this could be used in white fly control is by silencing expression genes that control of transport the juvenile hormones (JHs) which are important for insect development (Fu *et al.,* 2016) but so far this is not commonly used for whitefly control in cotton. Control tactics also need to involve cooperation between scientists from local universities and state department to determine economic threshold level for the application of insecticide when threshold numbers of whitefly adults and nymphs have reached per leaf (Dhilln *et al*., 2016; Kumar *et al*., 2002). Programmes involving improved surveillance and monitoring schemes, enhanced spray technologies and techniques to farmers training programs have substantially helped the control of whitefly population in Punjab, India. Such programs can help farmers appreciate the wide range of management techniques that can be used simultaneously to help in avoiding severe pest attack and to prevent pesticide resistance (Figure 1).

CONCLUSION

Adoption of IPM and molecular techniques like RNAi interference and transgenic plants which contain toxins against whitefly are becoming more important in whitefly management however, seed prices and restricted access to seed limit this option for farmers in Pakistan. The seeds of Bt-Cotton are difficult to obtain due to the fear of infringing Monsanto's IPRs, leaving farmers to get seeds from less reliable sources. However, farmers need to adopt a wide range of non-chemical techniques to avoid resistance and create an appropriate growing environment for cotton in Pakistan

REFERENCES

Abd-Rabou, S. and A. M. Simmons 2012. Effect of three irrigation methods on incidences of *Bemisia tabaci* (Hemiptera: Aleyrodidae) and some whitefly-transmitted viruses in four vegetable crops. Trends Entomology. 8:21–26.

Abubakar, M., K. Bhupendra, C. Krishnappa R. Ankush and D. Yadav, 2022. Whitefly (*Bemisia tabaci*) management (WFM) strategies for sustainable agriculture: a review. Agriculture.12(9).

Adnan, S., K. Ullah and G. Shouting 2016. Investigations into precipitation and drought climatologist in South Central Asia with special focus on Pakistan over the period 1951-2010. Journal of Climate. 29(16): 6019-6035.

Ahmed, A., I. H. Hussain, I. A. Nasrullah, A. Khalil, A. Basharat, Hamid and M. Imtiaz 2022. Impact of planting techniques on the productivity of the cotton-wheat rotation in Punjab, Pakistan. International Journal of Agriculture and Biology. 28(1):40-48.

Ashfaq, M., N. Johnson, F. Kucharski, N.S. Dffenbaugh, M. Adnan Abid, M.F.Horan, D. Singh,

S. Mahajan, S. Ghosh, A. Ganguly, K. Evans and S. Islam. 2023. The influence of natural variability on extreme monsoons in Pakistan. Climate and Atmospheric Science 6, 148.

Barati, R., G. Golmohammadi, H. Ghajarie, M. Zarabi and R. Mansouri. 2013. Efficiency of some herbal pesticides on reproductive parameters of silver leaf whitefly, *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae). Archives Phytopathology Plant Protection. 47: 212–221.

Bao-jie, C., D. Zhang and H. Dong. 2021. Control of cotton pests and diseases by intercropping: a review. Journal of Integrative Agriculture. 20(12):3089-3100.

Bashir, S., A. Yaqoob, R. Bashir, S. Bukhari, N. Shahid, S. Azam, A. Bakhsh, T. Husnain, A. A. Shahid and A. Q. Rao. 2024. Barley chitinase genes expression revamp resistance against whitefly (BemisiaTabaci) in transgenic cotton (*Gossypium hirsutum* L.). Journal of Cotton Research. 7 (9).

Bi, J.L., G. Ballmer, L. R. Hendrix, T. J. Henneberry and N. C. Toscano. 2001. Effect of cotton nitrogen fertilization on Besisiaargentifolii densities and honeydew production. Entomologia Experimentalis et Applicata. 99(1).

Brown, J. K. and J. Bird. 1992. Whitefly-transmitted Germiniviruses and Associated Disorders in the Americas and the Caribbean Basin. Plant Diseases. 76(3):220-225.

Cannon, N.D., D. M. Kamalongo and J. S. Conway. 2019. The effect of bi-cropping wheat (*Triticum aestivum*) and beans (Vicia faba) on forage yield and weed competition. Biological Agriculture and Horticulture. 36(1):1-15.

Cook, S. M., Z. R. Khan and J. A. Pickett. 2007. The Use of Push-Pull Strategies in Integrated Pest Management. Annual Review of Entomology. 52(1):375–400.

Conner, K. N., E. Sikora, J. Koebernick and M. Zaccaron. 2022. Interdisciplinary team addresses Cotton leafroll dwarf virus in Alabama. Journal of Extension. 60(2).

Daniel, C. and E. Wyss. 2010. Field applications of Beauveriabassiana to control the European cherry fruit fly Rhogoletiscerasi. Journal of Applied Entomology.134:9–10.

Dhillon, B. S. and R. S. Sidhu. 2016. Successful management of whitefly incidence in cotton through joint efforts of farm experts and farmers. Prog. Fmg – Mont. J. Punjab Agric. Univ., 52:5–7.

Facquet, C. and D. Fargette, 1990. African cassava mosaic virus; Etiology, epidemiology, and control. Plant Disease 74:404-411.

Farooqi, Z. 2010. Comparative performance of Bt cotton: economic and environmental aspects. Master's Thesis. Department of Environmental and Resource Economics, University of Agriculture, Faisalabad, Pakistan.

Fu, K.Y., Q. Li, L. T. Zhou, Q. W. Meng, F. G. Lü, W. C. Guo and G. Q. Li. 2016 Knockdown of juvenile hormone acid methyl transferase severely affects the performance of Leptinotarsa decemlineata (Say) larvae and adults. Pest Management Science. 72:1231–1241.

Fekrat, L. and P. Shishehbor. 2007. Some biological features of cotton whitefly, Bemisiatabaci (Homoptera: Aleyrodidae) on various host plants. Pak. J. Biol. Sci. 10:3180–3184.

Gangwar, R.K. and G. Charu. 2018. Lifecycle, distribution, nature of damage and economic importance of whitefly, Bemisiatabaci (Gennadius). Acta Scientific Agriculture. 2:36–39.

Gao, T., Z. Wang, Y. Huang, N. O. Keyhani and Z. Huang. 2017. Lack of resistance development in Bemisiatabaci to Isariafumosorosea after multiple generations of selection. Scientific Reports. 7: 1–11.

Gerling, D., O. Alomar and J. Arnò. 2001. Biological control of Bemisiatabaci using predators and parasitoids. Crop Protection. 20: 779–799.

GoP, 2018. Economic Survey of Pakistan. Ministry of Finance, Planning and Development Department, Islamabad. Pakistan.

Hashmi, J.A., Y. Zafar, M. Arshad, S. Mansoor and S. Asad, 2011. Engineering cotton (*Gossypium hirsutum* L.) for resistance to cotton leaf curl disease using viral truncated AC1 DNA sequences Virus Genes. 42: 286-296

Isman, M.B. 2017. Bridging the gap: Moving botanical insecticides from the laboratory to the farm. Ind. Crops Protection. 110: 10–14.

Kanakala, S., and M. Ghanim, 2019. Global genetic diversity and geographical distribution of Bemisiatabaci and its bacterial endosymbionts. PLOS ONE. 14(3): e0213946.

Karthikeyan, C., D. Veeraragavathatham, Karpagam, and A.A. Firdouse. 2006. Cow Based Indigenous technologies in dry farming. Indian Journal of Traditional Knowledge. 5: 47–50.

Khan, M., N. Akram, M. I. Husnain, I. H. Padda and S. A. Qureshi. 2011. Poverty environment nexus: use of pesticide in cotton zone of Punjab,

Pakistan Journal of Sustainable Development 4(3):163–173.

Knight, K.M., G.P. Head and D.J. Rogers. 2021. Successful development and implementation of a practical proactive resistance management plan for Bt cotton in Australia. Pest Management Science.77(10): 4262–4273.

Kumar, A., R. Bhansali and P. C. Mali. 2002. Response of biocontrol agents in relation to acquired resistance against leaf curl virus in chilli. In Proceedings of Asian Congress of Mycology Plant Pathology, Mysore, India, 1–4 October 2002; University of Mysore: Mysore, India; Indian Society of Mycology and Plant Pathology: Udaipur, India; Pp. 167.

Kunjwal, N. and R. M. Srivastava, 2018. Insect pests of vegetables. In Pests and Their Management; Springer Nature Singapore Pte Ltd.: Uttarakhand, India. Pp. 163–221.

Lu, Y., K. Wu, Y. Jiang, Y. Guo and N. Desneux. 2012. Widespread adoption of Bt cotton and insecticide decrease promotes biocontrol services. Nature. 487: 362–365.

Mahas, J. W., F. B. Hamilton, P. M. Roberts, C. H. Ray, G. L. Miller, M. Sharman, K. Conner, S. Bag, E. K. Blythe, M. D. Toews and A. L. Jacobson. 2022. Investigating the effects of planting date and Aphis gossypii management on reducing the final incidence of cotton leafroll dwarf virus. Crop Protection.158.

Nasruddin, A., N. Agus, A. Saubil, J. Jumardi, B. Rasyid, A. Siriniang, A.D. Nasruddin, F. Firdaus and A. E. Said, 2020. Effects of mulch type, plant cultivar, and insecticide use on sweet potato whitefly population in chili pepper. Scientifica,1–7.

Otto, F. E. L., M. Zachariah, F. Saeed, A. Siddiqi, S. Kamil, H. Mushtaq, T. Arulalan, T. AchutaRao, S. T. Chaithra, C. Barnes, S. Philip, S. Kew, R. Vautard, G. Koren, I. Pinto, G. Piotr Wolski, M. Vahlberg, R. Singh, J. Arrighi, M. van Aalst, L. Thalheimer, E. Raju, S. Li, W. Yang, L.J. Harrington and B. Clarke. 2023. Climate change increased extreme monsoon rainfall, flooding highly vulnerable communities in Pakistan. Environmental Research Climate 2, 025001.

Ozigit, I.I., M.V. Kahraman and O. Ercan. 2007. Relation between explants age, total phenols and regeneration response in tissue cultured cotton (*Gossypium hirsutum* L.) African Journal of Biotechnology. 6: 3-8.

Parkash, V., D.B. Sharma, J. Snider, S. Bag, P. Roberts, A. Tabassum, D. West, S. Khanal, N. Suassuna and P. Chee. 2021. Effect of cotton leafroll dwarf virus on physiological processes and yield of individual cotton plants. Frontiers in Plant Science 12.

Patel, N.B., D.M. Korat and R.R. Acharya. 2017. Impact evaluation of cow-urine and vermiwash on insect pests of brinjal. International Journal of Tropical Agriculture. 35: 591–595.

Polston, J.E. and H. Capobianco. 2013.Transmitting plant viruses using whiteflies. Journal of Vis. Exp. 81: 1–10.

Ram, K., D. Kumar, D. Kalkal and Ravikant. 2022. Influence of meteorological factors and natural enemies on activity of whitefly and mealybug in Bt cotton. Journal of Cotton Research and Development. 36(2): 237–243.

Ribeiro T.P., D.D.N. Vasquez, L.L.P. Macedo, I.T. Lourenço-Tessutti, D.C. Valença, O.B. Oliveira-Neto, B. Paes-de-Melo, P.L. Rodrigues-Silva, A.A.P. Firmino, M.F. Basso, C.B.J. Lins, M.R. Neves, S.M. Moura, B.M.D. Tripode, J.E. Miranda, M.C.M. Silva and M.F. Grossi-de-Sa. 2022. Stabilized Double-Stranded RNA Strategy Improves Cotton Resistance to CBW (*Anthonomus grandis*). International Journal of Molecular Science. 23(22):13713.

Rehman, H. 2020. Use of Chrysoperlacarnea larvae **to** control whitefly (Aleyrodidea: Hemiptera) on tomato plant in greenhouse. Pure Applied Biology. 9: 2128–2137

Roditakis, E., M. Grispou, E. Morou, J.B. Kristoffersen, N. Roditakis, R. Nauen, J. Vontas and A. Tsagkarakou, 2009. Current status of insecticide resistance in Q biotype *Bemisia tabaci* populations from Crete. Pest Management Science. 65(3): 313–322.

Sani, I., S. I. Ismail, S. Abdullah, J. Jalinas, S. Jamian and N. Saad. 2020. A Review of the Biology and Control of Whitefly, *Bemisia tabaci* (*Hemiptera: Aleyrodidae*), with Special reference to biological control using entomopathogenic fungi. Insects. 11(9): 619.

Shafiq-ur-Rehman Z., A. Ijaz, H. Gulfam R. Ayesha, T. Farooq, N. Naima, A. Salman and M. Salik. 2021. Pesticide usage and its application patterns among cotton growers of the southern Punjab, Pakistan. Pakistan Journal of Agricultural Sciences. 58(2): 739–742.

Simmons, A.M. and S. Abd-Rabou. 2008. Population of the sweet potato whitefly in response to different rates of three sulfur-containing

fertilizers on ten vegetable crops. International Journal of Vegetable Science. 5: 7–70.

Solanki, R.D. and S. Jha, 2018. Population dynamics and biology of whitefly (*Bemisia tabaci Gennadius*) on sunflower (*Helianthus annuus* L.). Journal of Pharmacognosy and Phytochemistry. 7, 3055–3058.

Summers, C.G.; J. P. Mitchell and J. J. Stapleton. 2005. Management of aphid-borne viruses and *Bemisia argentifolii* (*Homoptera: Aleyrodidae*) in zucchini squash by using UV reflective plastic and wheat straw mulches. Environmental Entomology. 33: 1447–1457.

Taggar, G.K. and R. Singh. 2020. Evaluation of some nonconventional insecticides against whitefly *Bemisia tabaci* in black gram. Indian Journal of Entomology. 82: 294–297.

Vijay Kumar, J. S. Kular, Rishi Kumar, S. S. Sidhu and P.K. Chhuneja, 2021. Integrated whitefly [*Bemisia tabaci* (Gennadius)] management in Bt-cotton in North India: an agroecosystem-wide community-based approach. Current Science. 119(4): 618–624.

Yan, S., J. Yu, J.P. Michaud, L. Guo, B. Zeng, Q. Zhang and X. Liu. 2020. Intercrops can mitigate pollen-mediated gene flow from transgenic cotton while simultaneously reducing pest densities. Science of The Total Environment 711.

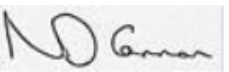
YanHui, L., W. KongMing, J. YuYing, G. YuYuan and N. Desneux. 2012. Widespread adoption of Bt cotton and insecticide decrease promotes biocontrol services. Nature. 487(7407): 362–365.

Yasin, M. A., K. Bakhsh, R. Ali and H.I. Hussain, 2021. Impact of better cotton initiative on health cost and pesticide exposure of women cotton pickers in Punjab, Pakistan. Environmental Science & Pollution Research. 28(2): 2074–2081.

Yuan, L., S. Wang, J. Zhou, Y. Du, Y. Zhang and J. Wang. 2012. Status of insecticide resistance and associated mutations in Q-biotype of whitefly, Bemisiatabaci, from Eastern China of Crop Protection. 31(1): 67–71.

Zhao, D., X. Ni, Z. Zhang, H. Niu, R. Qiu and H. Guo, 2022. Bt protein hasten entomopathogenic fungi-induced death of nontarget pest whitefly by suppressing protective symbionts.Science of the Total Environment.853.

CONTRIBUTION OF AUTHORS

Sr. No.	Author's name	Contribution	Signature
1.	Nicola D Cannon	Wrote-up the manuscript	
2.	Shahid Jiskani	Reviewed the manuscript