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Population Dynamics of Sucking Insect Pest and Predator, *Chrysoperla carnea* in Transgenic *Bt* Cotton and Non *Bt* Cotton Varieties

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QAS planned the research project, wrote, revised and edited the manuscript. MS participated in the critical review and provide guidance during writing research manuscript. RS conceived and supervised the overall study and made critical revision. NH provide guidance during execution of experiment. RM made critical revisions to the manuscript and helped to analyze the data.

Key words
Transgenic, Population fluctuation, Natural enemies

ABSTRACT

Transgenic *Bt* cotton, initially introduced to combat bollworm infestations, inadvertently resulted in increased populations of sucking pests such as *Thrips tabaci*, *Bemisia tabaci*, and *Amerasica devastans* in *Bt* cotton fields. The heavy reliance on indiscriminate pesticide application to control these pests has detrimental effects on natural fauna. This study aimed to explore the efficacy of natural enemies as an alternative to pesticides for managing sucking pests in different varieties of *Bt* cotton. Field experiments were conducted on various *Bt* cotton varieties, including Super NIAB-602, Super NIAB-992, Super NIAB-3701, Super NIAB-886, Super NIAB-142, NIABt-102, IR-443, NIA-Bt-100, IR-1513, IR-NIBGE-1524, and the non-transgenic *Bt* variety Sadori. Population densities of *A. devastans*, *T. tabaci*, *B. tabaci*, and the predator *Chrysoperla carnea* were recorded on the upper, middle, and lower leaves of twenty plants in each group. Results revealed that Super NIAB-142 exhibited the highest population of *A. devastans* (10.00±0.57), followed by NIABt (8.00±0.57). Likewise, Super NIAB-602 demonstrated the highest population of *T. tabaci* (7.66±0.33), with IR-1513 ranking second (6.66±0.88). For *B. tabaci*, Super NIAB-142 displayed the highest population (10.00±0.57), closely followed by Super NIAB-602 (8.00±1.15). Conversely, Sadori exhibited the lowest populations of *A. devastans*, *T. tabaci*, and *B. tabaci*, with values of 0.33±0.33, 1.00±0.57, and 1.0±0.57, respectively. Additionally, Super NIAB-142 showcased significantly higher populations of *C. carnea* eggs, larvae, and adults (0.54±0.0, 0.44±0.01, and 0.38±0.05), followed by Super NIAB-602. In contrast, Sadori displayed the lowest populations of *C. carnea* eggs, larvae, and adults (0.07±0.01, 0.16±0.01, and 0.06±0.06). These findings underscore the potential of utilizing natural enemies, particularly *C. carnea*, as a viable method for managing sucking pests in transgenic *Bt* cotton, thereby reducing the excessive dependence on pesticides.

EINRODUCTION

Cotton is a commercially important fiber and cash crop cultivated in tropical and warm temperate regions worldwide. It is grown annually and has various valuable products derived from its seeds, such as oil, lint, hulls, and animal feed (Ozyigit *et al*., 2007). In Pakistan, cotton was grown on 3.009 million hectares in 2016-17, resulting in an average production of 14.101 million bales. In the Sindh province alone, cotton was cultivated on 0.660 million hectares, yielding an average of 4.500 million bales (Daily Ali et al., 2019). Cotton production is affected by various factors, and insect pests pose a major threat, causing significant yield reduction. Among the insect pests, the bollworm complex and sucking complex are the two major types damaging cotton crops. Economically damaging bollworms include spotted bollworm (*Earias vitella*), American bollworm (*Helicoverpa armigera*), and pink bollworm (*Pectinophora gossypiella*). To modernize agriculture and manage insect pests, the introduction of insecticidal crop cultivars with transgenic traits has played a significant role globally. Introducing new resistance genes into economically important crops can help develop insect resistance and integrate pest management strategies (Gatehouse and Gatehouse, 1998). *Bt* cotton, which is genetically modified to resist bollworm infestations, was introduced. However, gradually, sucking insects such as whiteflies (*Bemisia tabaci*), thrips (*Thrips tabaci*), and jassids (*Amerasica devastans*) became serious problems for transgenic cotton. Losses in *Bt* cotton ecosystems due to sucking pests have been reported to reach up to 8.37% (Banerjee, 2002). Cotton growers indiscriminately use

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pesticides to combat these sucking insect pests. Globally, there is a growing concern to implement alternative methods of crop protection that reduce the use of agrochemicals. Integrated pest management systems rely on continuous field monitoring, physical and biological control, and the performance of natural enemies in cotton ecosystems (Konradsen, 2007; Eddleston *et al*., 2002). Natural enemies, including *Coccinella septempunctata* Linnaeus, *Chrysoperla carnea* Stephen, *Menochilus sexmaculatus* Fabricius, *Trichogramma brasiliensis* (Ashmead), *Trichogramma achaeae* Nagraja, spiders, and *Chelomus blackburni* Cameron, play a significant role in managing sucking insect pests in cotton crops (Dhaka and Pareek, 2007). *C. carnea*, in particular, has contributed greatly to the biological control of sucking insect pests, helping to keep their populations below economically damaging levels (Hoy and Nguyen, 2000). The population development of predators depends on the availability of prey, and beneficial insect populations thrive in field conditions where their food sources are abundant (Solangi *et al*., 2005). Predators like coccinellids (Coleoptera: Coccinellidae) are highly efficient in managing small and soft-bodied insects, and more than 400 species of these predators have been documented worldwide (Michaud, 2001). The incidence of insect pests greatly reduces the yield and value of cotton crops. The upsurge in the occurrence of these insect pests is primarily dependent on relative humidity, rainfall, and temperature (Aheer *et al*., 1994). Considering the losses caused by various sucking insect pests in cotton crops, this study focuses on the population dynamics of these pests and the predator *Chrysoperla carnea.*

MATERIALS AND METHODS

Studies on the seasonal occurrence of sucking pests and the predator *C. carnea* in transgenic cotton varieties, along with a non-transgenic variety, were conducted during the Kharif season of 2020 at the Nuclear Institute of Agriculture (NIA) Experimental Farm. The cotton varieties used in the experiment included Super NAIB-602, Super NIAB-992, Super NIAB-3701, IR-443, NIABt-100, IRNIBGE-1524, IR-1513, NIABt-102, Super NIAB-142, Super NIAB-886, and the non-*Bt* cotton variety Sadori. Agronomic practices recommended for cultivation were followed in the experimental plots, and no plant protection measures were applied. The experiment was set up using a randomized complete block design (RCBD), with three replications, and the selected plot size was 15x3 m. Observations on the population densities of sucking insect pests such as jassids (*A. devastans*), thrips (*T. tabaci)*, Whiteflies (*B. tabaci*), and the field population of the predator *C. carnea* were recorded from three leaves of five randomly selected plants at weekly intervals, starting 30 days after the cotton crop germinated. These three leaves were chosen from the top, middle, and bottom canopy of the plants.

Statistical analysis

Statistical analysis of the data was conducted using Statistix® version 8.1. The analysis involved the use of ANOVA (analysis of variance) to determine significant differences between the treatments. Additionally, the least significant difference (LSD) test, as described by Steel *et al.* (1997), was used to compare means and identify statistically significant variations among the treatment groups.

RESULTS

Studies on population dynamics of the predator *Chrysoperla carnea* and sucking insect pests in transgenic *Bt* cotton and non-*Bt* cotton concluded that lower numbers of sucking pests were recorded in the cotton variety Sadori compared to other *Bt* cotton varieties.

Sucking insect pests

Jassids (Amerasica devastans)

The population of *A. devastans* was higher throughout the cropping season, as shown in Figure 1A. The maximum population of *A. devastans* (10.0 ± 0.6a per 5 leaves) was observed in Super NIAB-142, followed by NIABt-100 (8.0 ± 0.6ab per 5 leaves). The population of *A. devastans* on other varieties decreased in the following order: Super NIAB-886 (2.6 ± 0.3g per 5 leaves), Super NIAB-602 (3.0 ± 0.6fg per 5 leaves), Super NIAB-992 (3.3 ± 0.8efg per 5 leaves), IR-443 (3.6 ± 0.3efg per 5 leaves), Super NIAB-3701 (5.0 ± 1.1def per 5 leaves), IR-NIBEG-1524 (5.3 ± 0.3cde per 5 leaves), NIA*Bt*-102 (7.0 ± 1.1bcd per 5 leaves), IR-1513 (7.3 ± 0.6bc per 5 leaves). The lowest population of *A. devastans* (0.3 ± 0.3h per 5 leaves) was observed in the non-*Bt* cotton variety Sadori.

Thrips (Thrips tabaci)

The results regarding the *T. tabaci* in transgenic *Bt* cotton and non-*Bt* cotton throughout the cropping season are shown in Figure 1B. The maximum population of *T. tabaci* (7.6 ± 0.3a per 5 leaves) was observed in the Super NIAB-602 variety, followed by IR-1513 (6.6 ± 0.8ab per 5 leaves). Similarly, the population of *T. tabaci* decreased in the following order in other varieties: Super NIAB-886 (2.0 ± 0.5gh per 5 leaves), Super NIAB-3701 (3.0 ± 0.5fg per 5 leaves), NIABt-102 (3.3 ± 0.6efg per 5 leaves), Super NIAB-142 (4.0 ± 0.6def per 5 leaves), Super NIAB-992 (5.0 ± 0.6bcde per 5 leaves), IR-443 (5.6 ± 0.3bcd per 5 leaves), NIABt-100 (6.0 ± 1.1abc per 5 leaves), and IRNIBGE-1524 (4.6 ± 0.3cdef per 5 leaves). However, the lowest population of *T. tabaci* (1.0 ± 0.6h per 5 leaves) was observed in the non-*Bt* cotton variety Sadori.

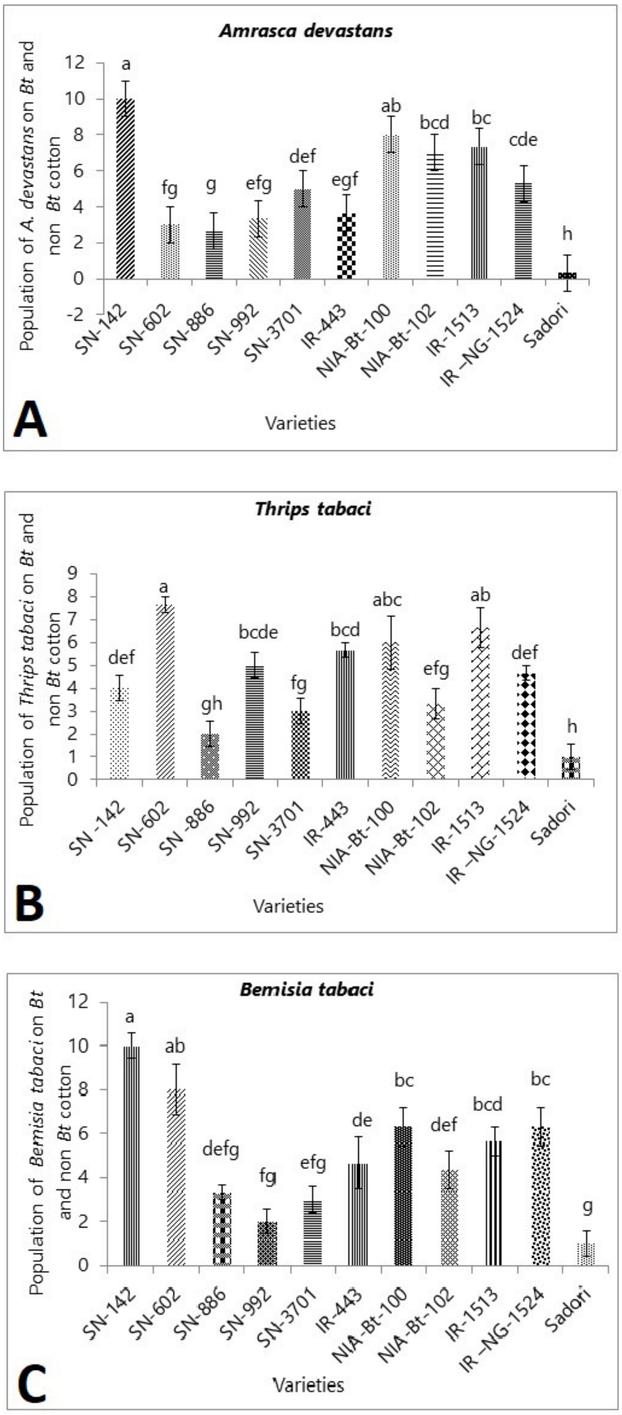

Fig. 1. Average population density of *Amrasca devastanus* (A), *Thrips tabaci* (B) and *Bemisia tabaci* (C) on transgenic *Bt* and non*Bt* varities.

White flies, Bemisia tabaci (*Gennad*)

The population of *Bemisia tabaci* was comparatively higher than that of jassids throughout the entire cropping season, as shown in Figure 1C. The maximum population of *B. tabaci* (10.0 ± 0.6a per 5 leaves) was observed in the transgenic *Bt* cotton variety Super NIAB-142, followed by Super NIAB-602 (8.0 ± 1.1ab per 5 leaves). However, the population of *B. tabaci* decreased in the following order in other transgenic *Bt* cotton varieties: Super NIAB-992 (2.0±0.6g per 5 leaves), Super NIAB-3701 (3.0 ± 0.6fg per 5 leaves), Super NIAB-886 (3.3 ± 0.3defg per 5 leaves), NIABt-102 (4.33 ± 0.88cdef per 5 leaves), IR-443 (4.66±1.20de per 5 leaves), IR-1513 (5.6 ± 0.6bcd per 5 leaves), IR-NIBGE-1524 (6.3 ± 0.8bc per 5 leaves), and NIABt-100 (6.3 ± 0.8bc per 5 leaves). The lowest population of *B. tabaci* (1.0 ± 0.6g per 5 leaves) was recorded in the non-Bt cotton variety Sadori.

Chrysoperla carnea *(Stephen)*

C. carnea *eggs*

The population of *C. carnea* eggs was observed throughout the entire cropping season, as shown in Figure 2A. The highest population of *C. carnea* eggs (0.57 ± 0.03a per 5 leaves) was noticed in the transgenic *Bt* cotton variety Super NIAB-142, followed by Super NIAB-602 (0.41 ± 0.01b per 5 leaves). In descending order, the population of *C. carnea* eggs in other transgenic *Bt* cotton varieties was as follows: Super NIAB-992 (0.25 ± 0.02d per 5 leaves), Super NIAB-886 (0.35 ± 0.01c per 5 leaves), IR-443 (0.17 ± 0.1ef per 5 leaves), NIABt-100 (0.19 ± 0.1e per 5 leaves), IR-1513 (0.12 ± 0.03fg per 5 leaves), IR-NIBGE-1524 (0.10 ± 0.03fg per 5 leaves), NIABt-102 (0.13 ± 0.02ef per 5 leaves), and Super NIAB-3701 (0.21 ± 0.01de per 5 leaves). However, the population of *C. carnea* eggs was found to be the lowest (0.07 ± 0.01 h per 5 leaves) in the non *Bt* cotton variety Sadori.

C. carnea *larvae*

The population trend of *Chrysoperla carnea* larvae was observed throughout the entire cropping season in both transgenic *Bt* cotton varieties and non-Bt cotton variety, as documented in Figure 2B. The highest number of *C. carnea* larvae (0.44 ± 0.01a per 5 leaves) was noticed in the transgenic *Bt* cotton variety Super NIAB-142, followed by Super NIAB-602 with a population of (0.38 ± 0.01b per 5 leaves). On the other hand, the population of *C. carnea* larvae decreased in the following order in other transgenic *Bt* cotton varieties: Super NIAB-886 (0.29 ± 0.01efg per 5 leaves), Super NIAB-992 (0.29 ± 0.02def per 5 leaves), NIA*Bt*-100 (0.36 ± 0.1bcd per 5 leaves), IR-443 (0.22 ± 0.01hi per 5 leaves), IR-NIBGE-1524 (0.21 ± 0.03fgh per 5 leaves), Super NIAB-3701 (0.31 ± 0.01cde per 5 leaves), NIA*Bt*-102 (0.36 ± 0.01bc per 5 leaves), and IR-1513

(0.21 ± 0.01ghi per 5 leaves). Likewise, the lowest number of *C. carnea* larvae (0.16 ± 0.01i per 5 leaves) was noticed in the non-*Bt* cotton variety Sadori.

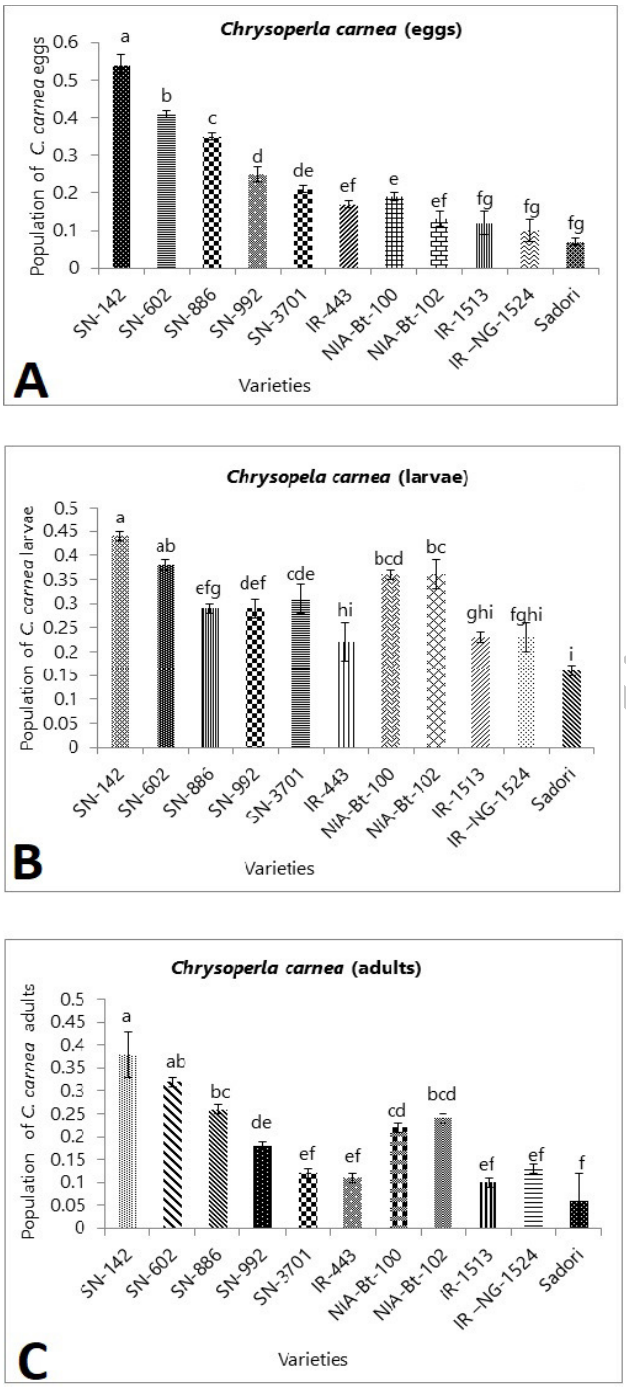

Fig. 2. Average population density of *Chrysoperla carnea* eggs (A), larvae (B) and adults (C) on transgenic *Bt* and non *Bt* varities.

C. carnea *adults*

The adult population of the predator *C. carnea* was observed throughout the entire cropping season, as demonstrated in Figure 2C. The maximum population of *C. carnea* (0.38 ± 0.05a per 5 leaves) was observed in the transgenic *Bt* cotton variety Super NIAB-142, followed by Super NIAB-602 with a recorded population of (0.32 ± 0.01ab per 5 leaves). The population trend decreased in the following order in other transgenic *Bt* cotton varieties: Super NIAB-886 (0.26 ± 0.01bc per 5 leaves), NIABt-102 (0.24 ± 0.01bcd per 5 leaves), IR-NIBGE-1524 (0.13 ± 0.01ef per 5 leaves), IR-1513 (0.10 ± 0.01ef per 5 leaves), Super NIAB-992 (0.18 ± 0.01de per 5 leaves), Super NIAB-3701 (0.12 ± 0.01ef per 5 leaves), NIA*Bt*-100 (0.22 ± 0.01cd per 5 leaves), and IR-443 (0.11 ± 0.01ef per 5 leaves). However, the least population *C. carnea* adults (0.06 ± 0.00f per 5 leaves) was noticed in the non-*Bt* cotton variety Sadori.

DISCUSSION

Sucking insect pests such as jassids, thrips, and whiteflies have become a serious problem in transgenic *Bt* cotton ecosystems compared to non-*Bt* cotton. The highest population of *A. devastans* was observed in the transgenic *Bt* variety Super NIAB-142, followed by NIA*Bt*-100. However, the jassid population reduced compared to other transgenic *Bt* cotton varieties, namely SuperNIAB-602, IR-443, SuperNIAB-992, IR-NIBGE-1524, SuperNIAB-886, SuperNIAB-3701, NIA*Bt*-102, and IR-1513. The lowest population of jassids was recorded in the non-*Bt* variety Sadori. According to Ashfaque *et al.* (2010) the maximum population *A. devastans* was 2.00 per leaf in the transgenic *Bt* genotype CP-1401, while the minimum population of 1.19 per leaf was observed in the non-transgenic genotype CIM-496. Similar findings on the population fluctuation of Jassids in transgenic *Bt* cotton were reported by Rekha *et al.* (2008). The highest population of thrips was observed in SuperNIAB-602, followed by IR-1513, while the population decreased on other varieties such as SuperNIAB-886, SuperNIAB-3701, NIA*Bt*-102, SuperNIAB-IR-NIBGE-1524, SuperNIAB-992, IR-443, and NIABt-100. The lowest population of thrips was found in the non-*Bt* cotton variety Sadori. The higher population of thrips on transgenic *Bt* cotton compared to traditional cultivars, as reported by Men *et al.* (2005) and Naveen *et al.* (2007), supports our findings. Similar results on the population fluctuation of *T. tabaci* on *Bt* cotton and non-*Bt* cotton were also examined by Godhani (2006), who reported a maximum thrips population of 23.66 per 3 leaves in the *Bt* cotton system. Regarding whiteflies *(B. tabaci*), their population in transgenic *Bt* cotton was comparatively higher than that of Jassids over the entire cropping season.

The highest populations of *B. tabaci* were observed in Super NIAB-142, followed by Super NIAB-602. The population of B. *tabaci* decreased in SuperNIAB-992, Super NIAB-3701, SuperNIAB-886, NIA*Bt*102, IR-443, IR-1513, IR-NIBGE-1524, and NIA*Bt*-100 (6.33 ± 0.88bc per 5 leaves). The least population *of B. tabaci* was found in the non-*Bt* cotton variety Sadori. Similar results on a higher incidence of *B. tabaci* in transgenic *Bt* cotton hybrids, Super NIAB-886, NIAB-992, NIAB-3701, NIA*Bt*-100, IR-443, NIA*Bt* 102, and IR- NIBGE-1524, were reported by Jeyakumar *et al*. (2008). *C. carnea* plays a vital role in reducing the population of these insect pests in the transgenic *Bt* cotton ecosystem. However, the results revealed that the population of *C. carnea* eggs, larvae, and adults were higher in the transgenic *Bt* cotton variety Super NIAB-142, followed by SuperNIAB-602. The population of C. carnea decreased in other transgenic *Bt* cotton varieties, including SuperNIAB-886, SuperNIAB-3701

CONCLUSION

The study concluded that transgenic *Bt* cotton varieties harboured a higher population of sucking insects, including *Thrips tabaci*, *Amrasica devastanus*, and *Bemisia tabaci*, compared to the non-transgenic *Bt* cotton variety Sadori. Additionally, transgenic *Bt* cotton varieties exhibited increased activity of the generalist predator *Chrysoperla carnea* in comparison to the non-transgenic *Bt* cotton variety Sadori.

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Ethical statement

We ensure that all research is conducted in accordance with ethical principles. Neither human was the subject in this research nor such kind of animal, which required any administrative approval.

Statement of conflict of interest

The authors have declared no conflict of interest.

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