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RESEARCH PAPER

Status of defender and offender arthropods in *Bt* transgenic cotton

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Abstract: The widescale cultivation Bt cottons in India has altered the landscape of pest management, particularly of sap feeders. To have updated understaning field surveys were carried out during *kharif* 2022-23 and arthropod defenders (spiders, coccinellids and chrysopids) and offenders (sucking pest) in *Bt* cotton at Dharwad and Haveri districts of Karnataka were noted. Their peak activity was found during flowering stage. In the defenders, spiders exhibit a higher abundance compared to chrysopids and coccinellids. Thrips, conversely emerged as predominant offender. In Dharwad district, seasonal mean of spider was 1.23/plant. Chrysopids displayed a seasonal mean of 0.96 individual 1.48 spiders/ plant were recorded, chrysopids exhibited a seasonal mean of 1.33 individuals/plant and coccinellids 1.36/plant. Offenders displayed specific seasonal incidences, with thrips recorded at 14.97/3 leaves, leaf hoppers at 2.67/3 leaves, aphids at 17.05/3leaves, and whiteflies at 1.27/3 leaves. Notably, offender defender ratios differed, with Dharwad district at 7.5 offender per defender and Haveri district at a slightly lower ratio of 6.5 offender per defender was recorded. Overall higher offender and defender population was observed at Haveri district. Thus it's important to maintain wider ratio of defender: offenders through selective practices.

Key words: Cotton, Defender, Offender, Population dynamics, Spider

Introduction

Cotton (*Gossypium* spp.), colloquially known as the 'White gold' of India, holds a pivotal position in the country's agricultural landscape, emerging as a crucial commercial fiber crop. Cultivated over an extensive 12.2 million hectares, cotton not only provides raw materials for various industries but also serves as a significant source of livelihood for approximately 6 million individuals. Furthermore, its economic significance is underscored by its substantial contribution to India's foreign exchange earnings, constituting one-third of the total [Mayee and Rao, 2002].

The cultivation of *Bt* cotton in 2002 marked a transformative period, enhancing yields particularly against lepidopteron pests while simultaneously heightening susceptibility to sucking pests (Tabashnik *et al*., 2010). The realm of sucking pests, including aphids *Aphis gossypii* (Glover), leafhoppers *Amrasca biguttula biguttula* (Ishida), thrips *Thrips tabaci* (Linn), and whitefly *Bemisia tabaci* (Genn.), exerts a profound influence, manifesting diverse damages within *Bt* cotton. Their impact spans from direct yield reduction to the indirect transmission of viral diseases. Significant instances include leafhoppers inducing an 18.78 per cent yield decline, while whitefly vectors facilitate the transmission of cotton leaf curl viral diseases, contributing to substantial yield losses (Harde *et al*., 2018).

Despite the prevalent use of chemical control methods, their application poses multifaceted challenges. The employment of these methods not only harbors health and ecological risks but also fuels insect resistance, disturbing the delicate ecological equilibrium (Dilbar *et al*., 2014).

Traditional chemical pest control methods raise environmental and health concerns and lead to resistance. To address these issues, Integrated Pest Management (IPM) combines cultural, biological, and chemical methods for effective and sustainable pest management. While chemical control is common, there's a need for more attention to biological control methods and their effects on predator populations (Vanden Berg *et al*., 1990).

The knowledge about incidence of pest during the cropping season and its possible dynamics help in designing pest management strategies (Santhosh *et al.*, 2009). So, it is essential to assess the status of defender and offender arthropods in the cotton ecosystem, along with their defender and offender ratio, to understand the role of defenders. This survey was conducted in major cotton-growing areas such as Dharwad and Haveri districts to study the offender defender dynamics in *Bt* transgenic cotton.

Material and methods

Roving farmers field surveys were conducted in Dharwad and Haveri districts [Northern Transitional Zone of Karnataka, Zone-8] (Fig. 1) thrice in the cropping season of *kharif* 2022-23. In Haveri district three taluks (Shiggaon, Haveri, Bydagi) and in Dharwad district three taluks (Dharwad, Annigeri, Kalaghatagi) were considered based on the area under cotton crop. Two villages were selected from each taluk. In each village two fields were surveyed. Ten plants from one acre were selected in zig-zag manner and observed by whole plant bases. The observations were recorded three times during cropping period starting from seedling and flowering stage till boll opening stage. Population of adults and nymphs of thrips, whiteflies, aphids and only nymphs of leafhoppers on three leaves (top, middle and bottom) in ten randomly selected plants

STUDY AREA MAP

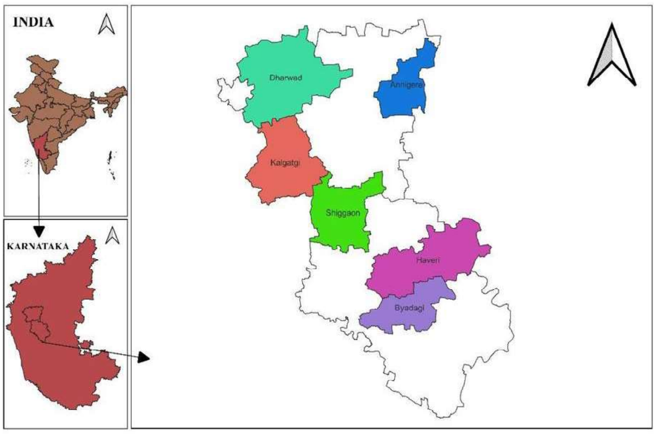

Fig. 1 Locations of sucking pests and predators observations

was observed carefully. Later the population was averaged to present as number per three leaves. Similarly, population of coccinellids (grubs and adults), chrysopids (grubs) and spiders were observed in ten plants selected randomly and presented as number per plant. Furthermore, the data is analysed to derive the offender- defender ratio, it's a measure that quickly assesses the ecological balance. This ratio serves as a valuable tool for assessing the dynamics between pest offenders and beneficial defenders in ecosystems.

Results and discussion

At both Dharwad and Haveri districts the seasonal incidence of offenders and defenders began during seedling stage, except whitefly which was noticed from flowering stage. However, the peak incidence was observed during flowering stage of the crop. Further, the population of offenders and defenders were high in Haveri district compared to Dharwad district (Fig. 2).

Insect predatory spider complex was noticed in all the stages with a peak population during flowering stage of the crop. From table 1 its evident that the average spider population at Dharwad district was 1.23/pl. However, the highest seasonal mean was observed in Haveri district (1.48/pl). During the seedling stage, Kalaghatagi taluk exhibited a higher spider population (0.79/pl) compared to other taluks. Annigeri taluk had the highest spider populations during flowering and boll opening stages with averages of 2.30 and 1.30 spiders/pl, respectively.

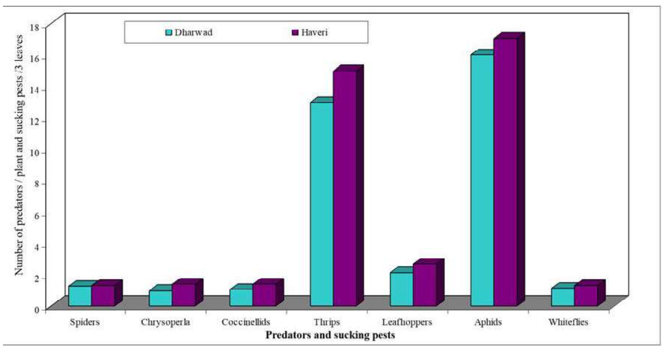

Fig. 2 Predator and sucking pest population in Dharwad and Haveri districts

In contrast, in Haveri district, Byadagi taluk showed a higher spider population (2.53/pl). In sprayed fields, the spider population (Neeralgi-0.52 /pl) experienced a reduction, as reported by Huusela (1998). This aligns with their findings, emphasizing the impact of spray applications on spider populations. Concurrently, a heightened spider population during the flowering stage is consistent with Khuhro *et al*. (2020); El Heneidy *et al*. (1996). Thus, the peak activity of predatory spiders prevails during the vegetative and reproductive growth stages as well, depending on availability of host insects.

The abundance of generalist predator *Chrysoperla carnea* (Stephens) was noticed in all the places as presented in Table 1 and 2. High seasonal mean was noticed at Haveri (1.33/ pl) with Byadagi taluk exhibiting a highest mean of 2.61 individuals/pl at flowring stage. Population in Dharwad district was relatively modest, having maximum during the flowering stage in Kalaghatagi taluk (2.14/pl). Further, the mean ranged from 1.22 to 2.12 individuals/ plant during mid-season. Rosenheim *et al*. (1999); Oliveira *et al.* (2012) have also observed peak population of *C. carnea* during flowering stage due to availability of the prey. This stage co-insides with higher incidence of pests. Thus a prey dependent defender dynamics was posed in cotton ecosystem.

The highest mean seasonal predatory coccinellid (predominantly *Menochilus sexmaculatus* F.) population was recorded at Haveri district (1.36/pl) and comparatively Dharwad district recorded lowest seasonal mean of 1.04/pl. Among all the villages Kondikoppa recorded the highest coccinellid count during the seedling (1.19/pl) and flowering stage (2.03/pl) while Devikoppa recorded the lowest abundance (0.41/pl) at Dharwad district. The highest population count in Haveri district was at Lakmaji koppa (3.23/pl) at flowering stage. The results are in close agreement with the Udikeri *et al*. (2012) who also observed that a strong positive correlation between incidence of predators and aphid on *Bt* cotton similar results were also reported by Sana *et al*. (2011) who reported the highest activity of coccinellid during reproductive stage of the crop.

Among different sap feeders thrips were more persistent throughout the season and crossed ETL (10/leaf) at all the places during flowering stage. In Dharwad and Haveri districts the mean seasonal incidence was 12.93/pl and 14.97/pl, respectively. Thrips populations in Dharwad district varied significantly across different taluks and villages. Devikoppa fields harboured maximum thrips count at the flowering stage (S2) with 27.37/3 leaves, while in Dandikoppa lowest at the boll opening stage (S3) with 6.17/3 leaves. In Haveri district Lakmaji koppa cotton fields sustained highest thrips incidence at the seedling stage (S1) with 14.01 leaves, while Teredahalli recorded the lowest at the boll opening stage (S3) with 9.84/3 leaves. Continuous cultivation of *Bt* cotton without any rotation may have led to enhanced incidence of sucking pests such as thrips. It has been opined so in review done by Peshin *et al*. (2021). These fluctuations highlight the importance of tailored interventions for managing thrips infestations during distinct growth stages (Faircloth *et al*., 2002).

Table 1. Predators and sucking pests in *Bt*-cotton fields at seedling, flowering and boll opening stages in Dharwad district

Taluk	Village	Spiders/plant			*Chrysoperla*/plant			Coccinellids/plant			Thrips/3 leaves			Leaf hoppers/ 3 leaves			Aphids/3 leaves			Whiteflies/3 leaves		
		S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3
Dharwad	Dandikoppa	0.41	1.77	0.92	0.33	0.74	0.71	0.43	1.93	0.92	6.99	20.01	6.17	1.79	2.68	0.24	9.37	24.69	14.34	0.00	2.56	0.00
	Bogur	0.72	1.73	0.81	0.51	1.69	0.94	0.68	1.72	0.97	7.16	22.27	8.35	2.61	3.41	0.81	8.61	26.84	15.19	0.00	3.61	0.00
Mean		0.57	1.75	0.87	0.42	1.22	0.83	0.56	1.83	0.95	7.08	21.14	7.26	2.20	3.05	0.53	8.99	25.77	14.77	0.00	3.09	0.00
Annigeri	Kondikoppa	1.03	2.98	1.85	0.82	1.74	1.17	1.19	2.03	0.87	9.12	25.52	9.43	2.51	3.77	0.82	7.39	21.53	16.15	0.00	4.21	0.00
	Navalli	0.16	1.61	0.74	0.22	0.87	0.72	0.57	1.46	0.68	5.94	19.33	9.12	1.14	3.09	0.36	4.01	24.04	15.91	0.00	2.58	0.00
Mean		0.60	2.30	1.30	0.52	1.31	0.95	0.88	1.75	0.78	7.53	22.43	9.28	1.83	3.43	0.59	5.70	22.79	16.03	0.00	3.40	0.00
Kalaghatagi	Bisaralli	0.41	1.03	0.73	0.29	2.12	0.89	0.66	1.04	0.86	8.63	20.92	9.38	2.37	3.46	0.97	8.87	24.91	14.83	0.00	3.01	0.00
	Devikoppa	1.17	2.47	1.62	0.24	2.15	1.28	0.41	1.21	1.12	7.12	27.37	9.97	2.61	3.91	1.76	8.62	27.17	15.29	0.00	3.86	0.00
Mean		0.79	1.75	1.18	0.27	2.14	1.09	0.54	1.13	0.99	7.88	24.15	9.68	2.49	3.69	1.37	8.75	26.04	15.06	0.00	3.44	0.00
District Mean		0.65	1.93	1.11	0.40	1.55	0.95	0.66	1.57	0.90	7.49	22.57	8.74	2.17	3.39	0.83	7.81	24.86	15.29	0.00	3.31	0.00
Mean of S1,S2, S3			1.23			0.96			1.04			12.93			2.13			15.98			1.10	

S1: Seedling stage, S2: Flowering stage, S3: Boll opening stage

Table 2. Predators and sucking pests population in *Bt*-cotton fields at seedling, flowering and boll opening stages in Haveri district

Taluk	Village	Spiders/ plant			*Chrysoperla*/ plant			Coccinellids/ leaves			Thrips/3 leaves			Leaf hoppers/3 leaves			Aphids/3 leaves			Whiteflies/3		
		S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3
Haveri	Nelogal	0.56	2.67	0.64	0.42	1.42	0.62	0.72	2.13	1.02	10.21	24.31	10.08	2.43	3.92	1.36	7.34	31.06	15.83	0.00	3.26	0.00
	Teredahalli	1.24	2.37	1.13	1.29	2.13	1.43	1.03	2.91	1.31	12.83	25.57	9.84	3.46	4.13	3.99	8.79	33.71	14.62	0.01	4.37	0.00
	Mean	0.90	2.52	0.89	0.86	1.78	1.03	0.88	2.52	1.17	11.52	24.94	9.96	2.95	4.03	2.68	8.07	32.39	15.23	0.01	3.82	0.00
Byadagi	Angaragatti	1.02	2.41	2.09	1.03	2.10	1.28	0.87	2.37	0.85	9.69	25.11	12.56	3.38	4.09	1.26	9.33	33.15	15.42	0.00	5.64	0.00
	Lakmaji koppa	1.23	2.65	2.36	1.08	3.11	1.33	1.07	3.23	1.17	14.01	27.17	12.82	3.17	3.98	3.61	13.15	31.01	16.15	0.00	4.58	0.10
	Mean	1.13	2.53	2.23	1.06	2.61	1.31	0.97	2.80	1.01	11.85	26.14	12.69	3.28	4.04	2.44	11.24	32.08	15.79	0.00	5.11	0.05
Shiggoan	Khursapur	1.07	1.78	1.28	0.82	2.32	0.62	0.73	2.12	0.83	7.23	23.63	11.08	1.91	1.12	1.94	4.16	17.23	15.92	0.00	2.92	0.00
	Neeralgi	0.52	0.96	0.63	0.53	2.11	0.31	0.84	0.93	0.41	5.92	15.40	11.97	1.27	1.93	1.15	5.79	20.18	14.06	0.00	1.98	0.00
	Mean	0.80	1.37	0.96	0.68	2.22	0.47	0.79	1.53	0.62	6.58	19.52	11.53	1.59	1.53	1.55	4.98	18.71	14.99	0.00	2.45	0.00
	District mean	0.94	2.14	1.36	0.86	2.20	0.93	0.88	2.28	0.93	9.98	23.53	11.39	2.60	3.20	2.22	8.09	27.72	15.33	0.00	3.79	0.02
	Mean of S1,S2, S3		1.48			1.33			1.36			14.97			2.67			17.05			1.27	

S1: Seedling stage, S2: Flowering stage, S3: Boll opening stage

Table 3. Defender pest ratio in cotton ecosystem in Dharwad and Haveri districts

	Pest predator complex	*Chrysoperla*: pest	Coccinellid: pest	Spider: pest
Dharwad	1:7.5	1:8.3	1:7.7	1:6.5
Haveri	1:6.5	1:6.7	1:6.6	1:6.1

Leaf hopper populations in Dharwad district exhibited fluctuations, with Devikoppa having the highest count at the flowering stage (S2) with 3.91/3 leaves and Dandikoppa showing the lowest at the boll opening stage (S3) with 0.24/3 leaves. Haveri district displayed varying leaf hopper populations across taluks and villages. Teredahalli recorded the highest count at the seedling stage (S1) with 3.46/3 leaves, while Neeralgi exhibited the lowest at the boll opening stage (S3) with 1.15/ 3 leaves. Overall mean seasonal incidence of 2.67/3 leaves at Haveri district and 2.13/3 leaves at Dharwad district was observed. Balakrishnan *et al*. (2007) could observe similar phenomenon in Tamil Nadu. At present it is serious pest during reproductive phase too, prevailing up to 120 days after sowing and has become one of the limiting factors in economic productivity of the crop.

Another key sap feeder aphid found to be 17.05/3 leaves in Haveri district followed by Dharwad district (15.98/3 leaves). Aphid and whitefly populations displayed distinct trends. At the seedling stage, Dandikoppa recorded maximum aphid population (9.37/3 leaves), while Navalli recorded lowest (4.01/ 3 leaves). During the flowering stage Devikoppa displayed the highest aphid count (27.17/3 leaves), with Kondikoppa having the highest whitefly infestation (4.21/3 leaves). Whitefly population was considerably low but varying significantly among two districts as the data furnished in Table 1 and 2. In contrast, Dandikoppa and Navalli recorded fewer whiteflies, with counts of 2.56 and 2.58/3 leaves, respectively. Interestingly, at the boll opening stage, Kondikoppa continued to lead with the highest aphid population (16.15/3 leaves), while whiteflies were absent at this stage in all locations. Less population of all the offenders during early stages of the crop may be attributed to the seed treatment which significantly reduces the populations of leafhopper, whitefly and thrips up to 35-40 days after sowing (Muhammad and Anjum, 2010). Overall, the fluctuation in population of offenders and defenders depend on the usage trends of various insecticides from different categories which differ among geographical locations. This fluctation is mainly influenced by dealer suggestions, pest and disease severity, peer group influence, effectiveness of specific insecticides, farmer knowledge, insecticide availability and the socioeconomic status of the farmer (Lingappa *et al*., 1993).

Examining the offender-defender ratio in agriculture offers a unique lens to understand the delicate balance between pests and beneficial organisms. This perspective is instrumental in devising sustainable approaches that influence natural predators to maintain a harmonious coexistence, minimizing reliance on external interventions. 7.5 pests were available for one predator at Dharwad district and a lower ratio of 6.5 was recorded at Haveri district (Table 3). Its unique that spiders dominate defender complex of cotton (Fig 3), as these are least

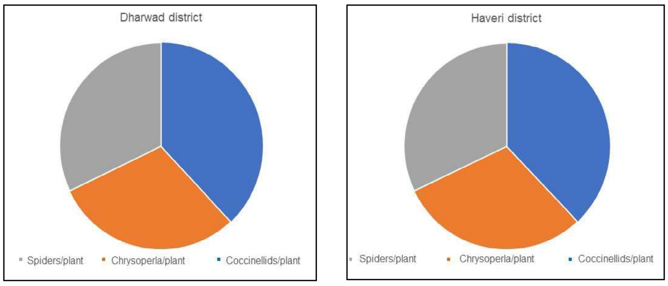

Fig. 3 Defender complex in *Bt* cotton fields

sensitive to insecticides and hence sustained predatory exercise could be there in field. Lee *et al*. (2022) reported a ratio of 1: 40 thrips to predator, which is more than findings of the present study because of considering sucking pest complex. A lower ratio at Haveri district indicates the presence of more defenders per pest which is an indication of good ecosystem and these variations suggest differences in the balance between offenders and defenders, influenced by local factors, cultivation practices and the specific agroecosystem.

These intriguing variations may also be attributed to several factors, including local growing conditions, cultivation practices, and pesticide usage. In Haveri district, the extensive cultivation of *Bt* cotton may have created a habitat for various sucking pests, which in turn serve as prey for defenders. Conversely, the lower defender population observed in Dharwad district might be influenced by the usage of broad-spectrum insecticides. Furthermore, the relatively higher defender incidence in Annigeri (Dharwad district) and Byadagi (Haveri district) could be linked to intercropping practices and reduced usage of broad-spectrum pesticides, both of which are conducive to defender proliferation. It's important to note that these observations also highlighted the significance of growth stages in influencing the dynamics of offender and defender populations. The higher defender population during the flowering stage could be attributed to the availability of pests at this critical stage of crop development, which is in line with previous research of Varsha (2009). This is also in line with prior studies conducted by Pommeresche *et al*. (2013) and Sana *et al*. (2011), who emphasized the importance of intercropping in supporting a greater diversity of defenders and the temporal dynamics of offender and defender densities.

Conclusion

It is evident that average predatory spider population (1.2 to 1.4/pl) in both distrct is appreciable and higher that other two generalist predators. Spiders have high acclimatization and pose less sensitivity to insecticides. However, population shall articulate with prey density.

Notably, offender defender ratios differed, with Dharwad district at 7.5 offenders per defender and Haveri district at a slightly lower ratio of 6.5 offenders per defender, based on growing conditions. Overall higher offender per defender population was observed at Haveri district. The observations may act as guard stone in scheduling bio-intensive IPM practices in cotton.

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