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Pollinator fauna and foraging activity of honey bees in two genotypes of Bt cotton*

Cotton is generally treated as a self pollinated crop but cross-pollination ranging from 5 to 50 percent or more is also reported (Stephens and Finkner, 1953). Cotton pollen is relatively large, heavy, sticky and watery and thus anemophily does not occur. It was reported that the floral nectaries were associated with insect pollination in cotton (Anon., 1879). An array of pollinators plays a vital role in pollination of cotton. It was also reported cotton as a good source of nectar for bees (Anon.,1961). In the short span of seven years (2002 to 2008) Bt cotton has generated economic benefits to the farmers valued at US$5.1 billion, halved insecticide requirements and contributed to the doubling of yield (Clive James, 2009). This has opened an avenue to utilize bees for pollination of Bt cotton. Hence present studies were made to understand the pollinator fauna and activity of honey bees on two Bt cotton hybrids and the results are presented in this paper.

The field experiment was carried out in farmer's field at Govanakoppa village under Bailahongal taluk in Belgum district. Two Bt cotton genotypes namely Bunny BG-I and Bunny BG-II were grown separately in two plots of one acre each during kharif season of 2009 by following the recommended package of practices. No plant protection measures were taken during the entire flowering period in both the Bt cotton genotypes.

Five spots in each Bt cotton genotype were selected randomly in the entire cropped area. Different pollinator species visiting from 1000 to 1200 h and 1400 to 1600 h were recorded for five minutes in these spots. Different species of honey bees visiting flowers were identified and counted in the field itself. Other pollinators visiting Bt cotton flowers were collected using a hand net. The collected pollinators were pinned, labeled and later identified with the help of specialists.

For studying foraging activity of honey bees three spots of 10 m^2 were selected separately in each genotype. Observations on the honey bees visiting the flowers in 10 m^2 area was recorded by counting bees for 5 minutes by walking slowly and diagonally. Such observations were made at 0930 h, 1130 h and 1330 h. Observations were recorded at 7^{th}, 14^{th}, 21^{st}, 28^{th}, 35^{th}, 42^{nd} day after flowering. The data were subjected to ANOVA after $\sqrt{x+0.5}$ transformation.

Eight species of pollinators were found foraging on Bt cotton blossoms (Table 1). Of these, seven species belonged to the order Hymenoptera which formed the dominant group followed by Diptera. Among honey bees, *Apis cerana* Fabricius was the most dominant pollinator (35.21%) followed by *A. florea* Fabricius (31.22%) and by *A. dorsata* Fabricius (24.53%).

The present results are in line with the reports of McGregor *et al.* (1955) and Tanda (1984), who reported that Hymenopterans were more abundant than any other pollinators. Waller (1982) also reported that out of 0.5 per cent of average bee visits, 0.44 were by honey bees and 0.06 per cent by wild bees. Similarly El-Sarrag *et al.,* (1993) noticed that Hymenopterans constituted 56 per cent of total insect visitors on cotton flowers. Mohana Rao *et al.* (1996) reported that pollinating insects that visited flowers of cotton were *A. dorsata, A cerana, A. florea* and solitary bees. The results also endorse the findings of Nachappa (2004) who reported that honeybees constituted 75 per cent of the total visitors of Bt cotton. Similarly Ganapathi (2005) concluded that honeybees and other pollinators constituted 89.10 and 83.77 per cent of the total pollinators.

Foraging activity of *A. dorsat*a on both Bt cotton hybrids (0.22 to 0.29 bees in BG-I and 0.22 to 0.28 bees/ 10 m^2/5 min in BG-II) was seen throughout flowering period without significant variation (Table 2 and 3). Similarly number of bees (0.21 to 0.29 bees in BG-I and 0.21 to 0.32 bees/ 10 m^2/5 min in BG-II) visiting flowers remained same on all the days of observation. These results indicated that *A. dorsata* collected both pollen and nectar throughout the day in a similar pattern during the entire flowering period.

The present results are in line with the reports of Mohana Rao et al. (1996) who reported the activity of *A. dorsata* from 0905 h to 1615 h on cotton. Nachappa (2004) also noticed that *A. dorsata* visited blossoms from 0800 h to 1600 h of the day on Bt cotton.

Foraging activity of *A. cerana* (Table 4 and 5) was seen throughout the day as well as throughout the observation period. However, significantly higher numbers of bees (0.28 and 0.26 bees/10m^2/5min) were observed at 1330 h. Similarly *A. florea* (Table 6 and 7) visited cotton flowers throughout the day with significantly higher number of bees (0.27and 0.24 bees/ 10m^2/5min) at 1330 h in both the Bt cotton hybrids. But the visitation did not differ significantly from 7^{th} to 42^{nd} day after flowering.

Both *A. cerana* and *A. florea* were probably more attracted to nectar secreted by cotton flowers in the afternoon hours. It is known that glands secreting the nectar would be active during mid day period which resulted in increased bee visitation at1330 h.

Uniform visitation by all the species of honey bees during flowering period was obviously due to a longer flowering period with staggered pattern of blossoming in cotton. This pattern of

Table 1. Pollinator fauna in BG-I and BG-II genotypes of Bt cotton

Sl. No.	Pollinator	Systematic position	Relative abundance
1.	*Apis dorsata* Fabricius.	Hymenoptera : Apidae	24.53%
2.	*A. cerana* Fabricius.	Hymenoptera : Apidae	35.21%
3.	*A. florea* Fabricius.	Hymenoptera : Apidae	31.22%
4.	*Xylocopa* sp.	Hymenoptera : Apidae	9.04%
5.	*Pithitis* sp.	Hymenoptera : Anthoporidae	
6.	*Sceliphron* sp.	Hymenoptera : Sphecidae	
7.	*Polistes* sp.	Hymenoptera : Vespidae	
8.	*Eristalins* obliquus	Diptera : Syrphidae	

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Table 2. Foraging activity of *Apis dorsata* in BG-I Bt cotton

SI. No.	Observation time	Bees /10 m² / 5 min						Mean
		7 DAF	14 DAF	21 DAF	28 DAF	35 DAF	42 DAF	
1	0930 h-1000 h	0.19	0.24	0.24	0.24	0.29	0.19	0.22
		(0.83)	(0.86)	(0.86)	(0.86)	(0.88)	(0.83)	(0.85)
2	1130 h-1200 h	0.19	0.14	0.24	0.24	0.24	0.24	0.24
		(0.83)	(0.80)	(0.86)	(0.86)	(0.86)	(0.86)	(0.84)
3	1330 h-1400 h	0.29	0.24	0.19	0.29	0.33	0.33	0.29
		(0.88)	(0.86)	(0.83)	(0.88)	(0.91)	(0.91)	(0.88)
	Mean	0.22	0.21	0.22	0.25	0.29	0.25	
		(0.85)	(0.84)	(0.85)	(0.87)	(0.88)	(0.87)	
			S.Em (±)			CD (0.05)		
	Time (T)		0.015			NS		
	Weeks (W)		0.021			NS		
	T×W		0.036			NS		

Figures in the parentheses are time$\sqrt{(X + 0.5)}$ transformed values

DAF- Days after flowering

Table 3. Foraging activity of *Apis dorsata* in BG-II Bt cotton

SI. No.	Observation time	Bees /10 m² / 5 min						Mean
		7 DAF	14 DAF	21 DAF	28 DAF	35 DAF	42 DAF	
1	0930 h-1000 h	0.19	0.33	0.19	0.19	0.19	0.24	0.22
		(0.83)	(0.91)	(0.83)	(0.83)	(0.83)	(0.86)	(0.85)
2	1130 h-1200 h	0.19	0.29	0.24	0.24	0.19	0.24	0.23
		(0.83)	(0.89)	(0.86)	(0.86)	(0.83)	(0.86)	(0.85)
3	1330 h-1400 h	0.29	0.33	0.29	0.29	0.24	0.24	0.28
		(0.89)	(0.91)	(0.89)	(0.89)	(0.86)	(0.86)	(0.88)
	Mean	0.22	0.32	0.24	0.24	0.21	0.24	
		(0.85)	(0.90)	(0.86)	(0.86)	(0.84)	(0.86)	
			S.Em (±)			CD (0.05)		
	Time (T)		0.01			NS		
	Weeks (W)		0.014			NS		
	T×W		0.025			NS		

Figures in the parentheses are $\sqrt{(X + 0.5)}$ transformed values

DAF- Days after flowering

Table 4. Foraging activity of *Apis cerana* in BG-I Bt cotton

Sl. No.	Observation time	Bees /10 m² / 5 min						Mean
		7 DAF	14 DAF	21 DAF	28 DAF	35 DAF	42 DAF	
1	0930 h-1000 h	0.24	0.19	0.19	0.19	0.14	0.24	0.20
		(0.86)	(0.83)	(0.83)	(0.83)	(0.80)	(0.86)	(0.83)[b]
2	1130 h-1200 h	0.19	0.14	0.19	0.24	0.19	0.24	0.20
		(0.83)	(0.80)	(0.83)	(0.86)	(0.83)	(0.86)	(0.83)[b]
3	1330 h-1400 h	0.27	0.24	0.24	0.28	0.29	0.33	0.28
		(0.88)	(0.86)	(0.86)	(0.88)	(0.89)	(0.91)	(0.88)[a]
	Mean	0.24	0.19	0.21	0.24	0.21	0.27	
		(0.86)	(0.83)	(0.84)	(0.86)	(0.84)	(0.88)	
			S.Em (±)			CD (0.05)		
	Time (T)		0.01			0.04		
	Weeks (W)		0.018			NS		
	T×W		0.03			NS		

Figures in the parentheses are $\sqrt{(X + 0.5)}$ transformed values

DAF- Days after flowering

Table 5. Foraging activity of *Apis cerana* in BG-II Bt cotton

Sl. No.	Observation time	Bees /10 m² / 5 min						
		7 DAF	14 DAF	21 DAF	28 DAF	35 DAF	42 DAF	Mean
1	0930 h-1000 h	0.14	0.19	0.10	0.14	0.10	0.14	0.14
		(0.80)	(0.83)	(0.77)	(0.80)	(0.77)	(0.80)	(0.80)[b]
2	1130 h-1200 h	0.19	0.24	0.14	0.14	0.19	0.19	0.18
		(0.83)	(0.86)	(0.80)	(0.80)	(0.83)	(0.83)	(0.82)[b]
3	1330 h-1400 h	0.24	0.29	0.24	0.19	0.29	0.33	0.26
		(0.86)	(0.89)	(0.86)	(0.83)	(0.89)	(0.91)	(0.87)[a]
	Mean	0.19	0.24	0.16	0.16	0.19	0.22	
		(0.83)	(0.86)	(0.81)	(0.81)	(0.83)	(0.85)	
			S.Em (±)			CD (0.05)		
	Time (T)		0.012			0.04		
	Weeks (W)		0.018			NS		
	T×W		0.03			NS		

Figures in the parentheses are $\sqrt{(X + 0.5)}$ transformed values

DAF- Days after flowering

Table 6. Foraging activity of *Apis florea* in BG-I Bt cotton

SI. No.	Observation time	Bees /10 m² / 5 min						Mean
		7 DAF	14 DAF	21 DAF	28 DAF	35 DAF	42 DAF	
1	0930 h-1000 h	0.10	0.14	0.14	0.14	0.14	0.14	0.13
		(0.77)	(0.80)	(0.80)	(0.80)	(0.80)	(0.80)	(0.80)[b]
2	1130 h-1200 h	0.19	0.19	0.19	0.19	0.19	0.24	0.20
		(0.83)	(0.83)	(0.83)	(0.83)	(0.83)	(0.86)	(0.83)[b]
3	1330 h-1400 h	0.29	0.24	0.24	0.29	0.29	0.29	0.27
		(0.88)	(0.86)	(0.86)	(0.89)	(0.88)	(0.89)	(0.88)[a]
	Mean	0.19	0.19	0.19	0.21	0.21	0.22	
		(0.83)	(0.83)	(0.83)	(0.84)	(0.84)	(0.85)	
			S.Em (±)			CD (0.05)		
	Time (T)		0.013			0.04		
	Weeks (W)		0.019			NS		
	T×W		0.033			NS		

Figures in the parentheses are$\sqrt{(X + 0.5)}$ transformed values

DAF- Days after flowering

Table 7. Foraging activity of *Apis florea* in BG-II Bt cotton

Sl. No.	Observation time	Bees /10 m² / 5 min						
		7 DAF	14 DAF	21 DAF	28 DAF	35 DAF	42 DAF	Mean
1	0930 h-1000 h	0.14	0.10	0.14	0.10	0.14	0.14	0.13
		(0.80)	(0.77)	(0.80)	(0.77)	(0.80)	(0.80)	(0.79)[b]
2	1130 h-1200 h	0.19	0.17	0.19	0.10	0.14	0.19	0.16
		(0.83)	(0.82)	(0.83)	(0.77)	(0.80)	(0.83)	(0.81)[b]
3	1330 h-1400 h	0.29	0.24	0.29	0.14	0.24	0.24	0.24
		(0.89)	(0.86)	(0.89)	(0.80)	(0.86)	(0.86)	(0.86)[a]
	Mean	0.21	0.17	0.21	0.11	0.17	0.19	
		(0.84)	(0.82)	(0.84)	(0.78)	(0.82)	(0.83)	
			S.Em (±)			CD (0.05)		
	Time (T)		0.012			0.035		
	Weeks (W)		0.016			NS		
	T×W		0.027			NS		

Figures in the parentheses are $\sqrt{(X + 0.5)}$ transformed values

DAF- Days after flowering

flowering provides a new flush of flowers daily during entire flowering period for honey bees. These results endorse the reports of Kaziev (1956) who observed bees on cotton with peak activity during mid-day when the amount and concentration of nectar was more. Wafa and Ibrahim (1960) reported similar results. Similarly Tanda (1984) and Mohana Rao *et al.* (1996) reported foraging activity of *A. cerana* from 0930 h to 1545 h in seed production fields of cotton. Ganapathi (2005) also concluded that peak activity of *A. dorsata*, *A. mellifera, A. cerana* and *A. florea* at 1200 h in Bt cotton. The present findings on diversity and activity of honey bees in Bt transgenic cotton are of importance in endorsing sustained activity of pollinators in transgenic ecosystem. Both in BG-I cotton expressing Cry 1A and BG-II having Cry A+ Cry 2Ab genes, the activity of honey bees was not hindered.

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