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SURVIVAL AND DEVELOPMENT OF *HELICOVERPA ARMIGERA* (HUBNER) ON PUBLIC SECTOR *BT* COTTON HYBRIDS

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ABSTRACT

Laboratory experiment was conducted to find out the survival and development of *Helicoverpa armigera* (Hubner) on public sector *Bt* cotton hybrids (NHH-44 BG II, PKV Hy-2 BG II, PDKV-JKAL-116 BG II, G. COT-10 Hy. BG II and G. COT-08 Hy. BG II). Instarwise observations were documented on leaves, squares, young bolls and mature bolls at 60-80, 90-110, 120-140 and 150-170 days old crop, respectively. The results revealed that the early instars of *H. armigera* exhibited higher larval mortality than the later instars. The surviving larvae revealed adverse effect on many parameters viz., larval and pupal weight, % pupation and adult emergence indicating low growth and survival indices.

Key words: *Helicoverpa armigera*, Bt cotton, hybrids, adult emergence, diet, bioassay, larval weight, pupal weight, pupation, emergence, growth, development

India is a leading cotton (*Gossypium* sp.) grower but its productivity is very low due to the influence of various abiotic and biotic factors. Biotic factors include insect pests, diseases and weeds. Of these, insect pests cause maximum yield loss, as right from germination to the final picking, the crop is subjected to severe damage by 162 species of insect pests (Manjunath, 2004). American bollworm *Helicoverpa armigera* (Hubner) is the major pest in Maharashtra (Bhamare and Wadnerkar, 2018), and cotton producing countries face havoc of such insect pest despite intensive pesticide use. Transgenic cotton technologies were commercialized in 1996 and these have changed the crop protection scenario, and Bt cottons incorporating *Bt*-toxins are now available (Kranthi, 2020). Recently many public sector Bt cotton hybrids are developed in India. In Maharashtra, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani and Dr Panjabrao Deshmukh Krishi Vidyapeeth, Akola have developed NHH-44 BG II and PKV Hy-2 BG II cotton hybrids, respectively. For Bt cotton technology, it is crucial to express cry toxin proteins in adequate quantity in appropriate plant parts (Bhullar and Gill, 2015). Investigations conducted in India indicate that Cry toxin concentration in Bt cotton transmutes with progressing season, as a result efficacy deviates among the hybrids at different plant age and in different plant structures (Rupnar, 2018; Likhitha and Bhamare, 2018; Kranthi et al., 2005). In view of introduction of public sector Bt cotton hybrids for farmers in the open market, the present study assesses the survival and development of *H. armigera* on different plant parts at different growth stages.

MATERIALS AND METHODS

The present study was conducted at the Post Graduate Laboratory, Department of Agricultural Entomology, College of Agriculture, Latur (Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani), Maharashtra during 2019-20. The public sector Bt cotton hybrids (NHH-44 BG II, PKV Hy-2 BG II, PDKV-JKAL-116 BG II, G. COT-10 Hy. BG II, G. COT-08 Hy. BG II and NHH-44 non-*Bt* as control) were cultivated in the Experimental Farm of Department of Agricultural Entomology following the recommended package of practices except plant protection. The initial culture of *H. armigera* was obtained by collecting large sized larvae from the surrounding fields of College of Agriculture, Latur. These were reared with feeding on natural diet (leaves, squares, young bolls and mature bolls of non-Bt cotton) till pupation. The sexes were determined in pupal stages on the basis of distance between genital and anal apertures (viz., less in the case of male and more in the case of female). The freshly emerged adults were released (with proportion of 1:5 female to male) into standard oviposition cage having cotton swab dipped into 10% honey solution and a strip of cotton cloth toweling hung vertically as oviposition substrate. After hatching from eggs on the toweling, the neonate larvae were transferred separately into plastic vials to avoid cannibalism and fed on natural diet till pupation. The different instar larvae obtained were used for further investigations.

The laboratory studies were carried out in completely

Table 1. Mortality (%) of *H. armigera* larvae fed on different plant parts of public sector Bt cotton hybrids

S. No.	Treatments	On leaves (60-80 days old crop)					On squares (90-110 days old crop)					On young bolls (120-140 days old crop)					On mature bolls (150-170 days old crop)				
		I instar	II instar	III instar	IV instar	V instar	I instar	II instar	III instar	IV instar	V instar	I instar	II instar	III instar	IV instar	V instar	I instar	II instar	III instar	IV instar	V instar
T_1	NHH-44 BG II	100.00 (90.00)*	86.67 (68.59)	60.00 (50.77)	50.00 (45.00)	0.00 (0.00)	80.00 (63.43)	70.00 (56.79)	36.66 (37.26)	20.00 (26.57)	0.00 (0.00)	100.00 (90.00)	86.67 (68.59)	56.67 (48.83)	0.00 (0.00)	0.00 (0.00)	100.00 (90.00)	80.00 (63.43)	50.00 (45.00)	0.00 (0.00)	0.00 (0.00)
T_2	PKV Hy-2 BG II	100.00 (90.00)	90.00 (71.57)	70.00 (56.79)	56.67 (48.83)	0.00 (0.00)	100.00 (90.00)	93.33 (75.03)	76.67 (61.12)	60.00 (50.77)	0.00 (0.00)	80.00 (63.43)	66.67 (54.74)	30.00 (33.21)	0.00 (0.00)	0.00 (0.00)	76.67 (61.12)	63.33 (52.73)	30.00 (33.21)	0.00 (0.00)	0.00 (0.00)
T_3	PDKV-JKAL-116 BG II	90.00 (71.57)	76.67 (61.12)	40.00 (39.23)	40.00 (39.23)	0.00 (0.00)	86.67 (68.59)	73.33 (58.91)	40.00 (39.23)	30.00 (33.21)	0.00 (0.00)	90.00 (71.57)	83.33 (65.90)	50.00 (45.00)	0.00 (0.00)	0.00 (0.00)	73.33 (58.91)	53.33 (46.91)	10.00 (18.43)	0.00 (0.00)	0.00 (0.00)
T_4	G. COT-10 Hy. BG II	86.67 (68.59)	70.00 (56.79)	33.33 (35.26)	30.00 (33.21)	0.00 (0.00)	90.00 (71.57)	80.00 (63.43)	50.00 (45.00)	40.00 (39.23)	0.00 (0.00)	76.67 (61.12)	60.00 (50.77)	30.00 (33.21)	0.00 (0.00)	0.00 (0.00)	80.00 (63.43)	66.67 (54.74)	33.33 (35.26)	0.00 (0.00)	0.00 (0.00)
T_5	G. COT-08 Hy. BG-II	76.67 (61.12)	66.67 (54.74)	30.00 (33.21)	20.00 (26.57)	0.00 (0.00)	100.00 (90.00)	86.67 (68.59)	66.67 (54.74)	53.33 (46.91)	0.00 (0.00)	83.33 (65.90)	76.67 (61.12)	40.00 (39.23)	0.00 (0.00)	0.00 (0.00)	83.33 (65.90)	76.67 (61.12)	40.00 (39.23)	0.00 (0.00)	0.00 (0.00)
T_6	NHH-44 (Non- *Bt*)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SE (m) ±	0.19	0.23	0.13	0.13	-	0.13	0.23	0.23	0.13	-	0.19	0.27	0.13	-	-	0.23	0.27	0.13	-	-
	CD p=0.05)	0.58	0.71	0.41	0.41	-	0.41	0.71	0.71	0.41	-	0.58	0.82	0.41	-	-	0.71	0.82	0.41	-	-
	CV %	4.41	6.28	6.06	7.19	-	3.09	6.07	9.07	6.95	-	4.65	7.57	6.84	-	-	5.92	8.31	8.65	-	-

*Figures in parentheses angular transformed values

randomized design (CRD) with three replications using ten larvae per replication, on the field collected plant structures viz., leaves, squares, young bolls and mature bolls of public sector *Bt* cotton hybrids at pre-determined intervals of 60-80, 90-110, 120-140 and 150-170 days old crop, respectively. The plant structures were collected in labeled plastic bags. Collected samples were cleaned and placed individually in a plastic vial. Later laboratory reared different larval instar larvae of *H. armigera* were released on different cotton structures. The plant parts were replaced regularly with fresh *Bt* plant parts (same on which larvae fed) till pupation. The data on mortality of larvae were recorded separately for each instar by feeding them on different plant structures of public sector *Bt* cotton hybrids at pre-determined intervals. Weight of the surviving larvae was recorded after 24, 48 and 72 hr of exposure and weight of pupae was also recorded from each treatment. In addition, other parameters viz., % pupation and adult emergence were documented from the surviving larvae and pupae, respectively. The growth index and survival index were calculated on different treatments using the formulae given by Vennila et al. (2006). The data in respect of survival and development was statistically analyzed by ANOVA with the null hypothesis tested by 'F' test- at p=0.05 (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

The laboratory bioassay revealed that the fifth instar *H. armigera* larvae fed on different plant parts of public sector *Bt* cotton hybrids and NHH-44 non-*Bt* cotton showed no mortality. However, among the different public sector *Bt* cotton hybrids, I, II, III and IV larval instars of *H. armigera* fed on leaves and squares of PKV Hy-2 BG II exhibited maximum % mortality at 60-80 and 90-110 days old crop, respectively. Where, minimum mortality was recorded on leaves of G. COT-08 Hy. BG II at 60-80 days old crop and on squares of NHH-44 BG II at 90-110 days old crop. Maximum mortality was observed when larvae were fed on young and mature bolls of NHH-44 BG II at 120-140 and 150-170 days old crop, respectively; and minimum % mortality of larval instars was on young bolls of G. COT-10 Hy. BG II at 120-140 days old crop and on mature bolls of PDKV-JKAL-116 BG II at 150-170 days old crop (Table 1). Similar trend was observed as regards reduction in larval weight of I, II, III, IV and V instars which survived beyond 24, 48 and 72 hr after exposure; decreasing % pupation and adult emergence, and reduced pupal weight were found to result in low growth and survival indices, when reared on leaves and

Table 2. Effect on larval weight of *H. armigera* fed on different plant parts of public sector Bt cotton hybrids

S. No.	Treatments	Mean larval weight (mg per larva)														
		I instar			II instar			III instar			IV instar			V instar		
		24 hr	48 hr	72 hr	24 hr	48 hr	72 hr	24 hr	48 hr	72 hr	24 hr	48 hr	72 hr	24 hr	48 hr	72 hr
	On leaves (60-80 days old crop)															
T_1	NHH-44 BG II	7.18	19.76	38.40	21.99	29.05	39.16	83.3	87.6	127.86	199.84	230.5	255.2	300.8	306.2	319.5
T_2	PKV Hy-2 BG II	6.94	17.74	35.23	19.41	26.86	36.5	80.53	86.06	114.16	187.3	224.8	250.27	285.36	290.43	309.86
T_3	PDKV-JKAL-116 BG II	7.74	20.33	39.41	23.53	32.23	42.46	87.63	90.26	145	210.2	253.5	279.47	303.16	319.6	323.43
T_4	G. COT-10 Hy. BG II	9.01	22.45	43.42	26.00	38.03	47.86	90.35	106.8	154.33	215.76	278.16	297.77	308.1	330.2	350.1
T_5	G. COT-08 Hy. BG-II	9.74	29.45	58.78	32.83	46.93	53.63	96.16	112.67	162.83	232.73	282.5	321.1	310.33	334.8	358.6
T_6	NHH-44 (Non- *Bt*)	15.33	38.27	76.95	46.56	72.87	86.96	108.7	156.33	192.26	243.63	295.86	379.53	324.83	380.76	416.46
	SE (m) ±	0.26	0.32	0.55	0.54	0.87	0.94	0.84	1.09	2.17	0.87	0.83	1.34	1.53	1.45	1.30
	CD (p=0.05)	0.81	1.00	1.67	1.63	2.65	2.85	2.56	3.32	6.58	2.63	2.52	4.06	4.66	4.39	3.96
	CV %	4.98	2.31	1.97	3.29	3.69	3.19	1.60	1.77	2.51	0.11	0.55	0.78	0.87	0.76	0.65
	Initial weight	4.00	-	-	14.61	-	-	64.61	-	-	179.68	-	-	268.18	-	-
	On squares (90-110 days old crop)															
T_1	NHH-44 BG II	7.9	28.87	54.22	32.29	37.76	58.53	94.6	104.23	160.36	237.53	281.74	317.4	297	320.83	353.7
T_2	PKV Hy-2 BG II	5.47	16.31	36.04	20.74	26.73	35.13	79.51	89.93	113.46	182.33	221.25	244.58	274.7	288.76	305.4
T_3	PDKV-JKAL-116 BG II	7.36	21.85	42.56	27.93	36.00	46.33	88.6	99.63	153.23	213.36	276.13	295.2	294.93	316.5	349.43
T_4	G. COT-10 Hy. BG II	6.25	19.57	39.95	24.36	28.5	39.53	86.86	95.56	143.33	208.06	249.43	277.83	286.7	306.03	320.63
T_5	G. COT-08 Hy. BG-II	6.04	18.51	39.76	22.36	25.56	37.23	81.88	92.46	125.2	197.9	228.13	253.23	281.26	299.43	317.43
T_6	NHH-44 (Non- *Bt*)	10.42	34.56	73.55	28.03	74.5	88.53	102.3	150.2	192.76	251.96	295.7	376.86	320.03	383.06	410.66
	SE (m) ±	0.18	0.38	1.06	0.71	0.87	0.98	1.00	1.23	0.82	1.38	1.66	1.27	1.64	1.25	1.64
	CD (p=0.05)	0.55	1.17	3.23	2.17	2.64	2.98	3.03	3.74	2.51	4.21	5.05	3.88	4.99	3.79	4.98
	CV %	4.38	2.88	3.87	4.78	3.94	3.35	1.95	2.03	0.96	1.11	1.11	0.75	0.97	0.67	0.83
	Initial weight	3.27	-	-	21.27	-	-	75.12	-	-	178.02	-	-	265.91	-	-
	On young bolls (120-140 days old crop)															
T_1	NHH-44 BG II	6.38	18.44	38.01	20.88	31.8	56.53	93.68	107.5	118.43	188.83	226.26	250.76	271.4	299.08	313.33
T_2	PKV Hy-2 BG II	9.94	24.99	44.31	32.23	52.2	69.66	112.02	118.43	156.13	232.33	281.23	298.53	316.16	335.66	360.16
T_3	PDKV-JKAL-116 BG II	7.18	20.71	41.15	28.63	37.4	59.56	98.26	110.53	130.13	201.43	232.86	255.8	286.83	303.6	319.93
T_4	G. COT-10 Hy. BG II	10.56	31.11	59.18	36.13	59.7	73.76	117.33	120.83	162.83	263.96	283.7	323.38	329.56	340.03	368.95
T_5	G. COT-08 Hy. BG-II	8.45	22.66	41.82	30.68	45.86	62.36	102.23	114.53	147.66	212.73	251.93	281.13	301.43	329.6	354.66
T_6	NHH-44 (Non- *Bt*)	12.08	35.61	78.21	44.6	80.5	88.5	121.36	165.63	201.16	276.16	299.46	375.46	337.46	374.03	414.46
	SE (m) ±	0.30	0.70	0.53	0.79	1.20	1.30	1.53	1.46	1.36	1.18	1.40	1.19	1.14	1.22	1.05
	CD (p=0.05)	0.91	2.13	1.61	2.40	3.64	3.96	4.66	4.43	4.13	3.60	4.27	3.63	3.45	3.72	3.20
	CV %	5.73	4.75	1.82	4.26	4.06	3.30	2.47	2.06	1.54	0.89	0.92	0.69	0.64	0.64	0.51
	Initial weight	4.22	-	-	25.08	-	-	81.23	-	-	184.68	-	-	268.68	-	-
	On mature bolls (150-170 days old crop)															
T_1	NHH-44 BG II	5.87	19.46	38.53	25.2	42.6	62.1	94.63	109.43	122.26	189.53	236.53	256.03	271.86	305.5	311.86
T_2	PKV Hy-2 BG II	8.95	25.53	53.38	32.5	52.46	74.73	115.1	119.91	162.2	247.26	283.76	316.2	332.6	339.1	367.86
T_3	PDKV-JKAL-116 BG II	11.09	31.58	58.75	36.9	57.46	88.96	120.36	122.46	175.83	271.1	288.46	337.13	336.83	342.56	385.5
T_4	G. COT-10 Hy. BG II	8.17	22.8	48.83	31.56	48.16	77.33	104.43	114.63	174.96	219.78	273.8	285.9	317.63	337.6	348.06
T_5	G. COT-08 Hy. BG-II	6.88	21.56	44.8	30.46	45.7	72.87	99.8	112.01	133.26	202.86	264.4	259.13	304.9	331.36	338.56
T_6	NHH-44 (Non- *Bt*)	14.11	35.98	72.73	42.16	74.73	94.16	128.5	164.63	203.26	279.16	300.4	375.16	366.56	388.56	435.86
	SE (m) ±	0.27	0.75	0.90	0.91	0.97	1.23	1.02	0.73	1.11	0.79	1.52	1.17	1.19	1.26	1.44
	CD (p=0.05)	0.82	2.29	2.73	2.78	2.97	3.75	3.10	2.23	3.39	2.40	4.61	3.55	3.62	3.82	4.39
	CV %	5.12	5.00	2.95	4.80	3.16	2.73	1.60	1.03	1.23	0.09	0.96	0.66	0.64	0.64	0.68
	Initial weight	3.08	-	-	25.70	-	-	85.67	-	-	191.35	-	-	272.41	-	-

Table 3. Pupation (%) of *H. armigera* larvae fed on different plant parts of public sector Bt cotton hybrids

S. No.	Treatments	On leaves (60-80 days old crop)					On squares (90-110 days old crop)					On young bolls (120-140 days old crop)					On mature bolls (150-170 days old crop)				
		I instar	II instar	III instar	IV instar	V instar	I instar	II instar	III instar	IV instar	V instar	I instar	II instar	III instar	IV instar	V instar	I instar	II instar	III instar	IV instar	V instar
T_1	NHH-44 BG II	00.00 (00.00)*	13.33 (21.41)	40.00 (39.23)	50.00 (45.00)	100.00 (90.00)	20.00 (26.57)	30.00 (33.21)	63.33 (52.73)	80.00 (63.43)	100.00 (90.00)	00.00 (00.00)	10.00 (18.43)	43.33 (41.17)	100.00 (90.00)	100.00 (90.00)	00.00 (00.00)	20.00 (26.57)	50.00 (45.00)	100.00 (90.00)	100.00 (90.00)
T_2	PKV Hy-2 BG II	00.00 (00.00)	10.00 (18.43)	30.00 (33.21)	43.33 (41.17)	100.00 (90.00)	00.00 (00.00)	6.67 (14.97)	23.33 (28.88)	40.00 (39.23)	100.00 (90.00)	20.00 (26.57)	33.33 (35.26)	70.00 (56.79)	100.00 (90.00)	100.00 (90.00)	23.33 (28.88)	36.67 (37.27)	70.00 (56.79)	100.00 (90.00)	100.00 (90.00)
T_3	PDKV-JKAL-116 BG II	10.00 (18.43)	23.33 (28.88)	60.00 (50.77)	60.00 (50.77)	100.00 (90.00)	13.33 (21.41)	26.67 (31.09)	60.00 (50.77)	70.00 (56.79)	100.00 (90.00)	00.00 (00.00)	13.33 (21.41)	50.00 (45.00)	100.00 (90.00)	100.00 (90.00)	26.67 (31.09)	46.67 (43.09)	90.00 (71.57)	100.00 (90.00)	100.00 (90.00)
T_4	G. COT-10 Hy. BG II	13.33 (21.41)	30.00 (33.21)	66.67 (54.74)	70.00 (56.79)	100.00 (90.00)	10.00 (18.43)	20.00 (26.57)	50.00 (45.00)	60.00 (50.77)	100.00 (90.00)	23.33 (28.88)	40.00 (39.23)	70.00 (56.79)	100.00 (90.00)	100.00 (90.00)	20.00 (26.57)	33.33 (35.26)	66.66 (54.73)	100.00 (90.00)	100.00 (90.00)
T_5	G. COT-08 Hy. BG-II	23.33 (28.88)	33.33 (35.26)	70.00 (56.79)	80.00 (63.43)	100.00 (90.00)	00.00 (00.00)	13.33 (21.41)	33.33 (35.26)	46.67 (43.09)	100.00 (90.00)	16.67 (24.10)	30.00 (33.21)	60.00 (50.77)	100.00 (90.00)	100.00 (90.00)	16.67 (24.10)	23.33 (28.88)	60.00 (50.77)	100.00 (90.00)	100.00 (90.00)
T_6	NHH-44 (Non- *Bt*)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)
	SE (m) ±	0.19	0.23	0.13	0.13	-	0.13	0.23	0.23	0.13	-	0.19	0.27	0.13	-	-	0.23	0.27	0.13	-	-
	CD (p=0.05)	0.58	0.71	0.41	0.41	-	0.41	0.71	0.71	0.41	-	0.58	0.82	0.41	-	-	0.71	0.82	0.41	-	-
	CV %	13.63	11.66	3.85	3.50	-	9.86	12.45	7.42	3.56	-	11.76	12.47	3.59	-	-	13.12	10.87	3.23	-	-

* Figures in parentheses angular transformed values

Table 4. Pupal weight of surviving *H. armigera* larvae fed on different plant parts of public sector Bt cotton hybrids

S. No.	Treatments	On leaves (60-80 days old crop)					On squares (90-110 days old crop)					On young bolls (120-140 days old crop)					On mature bolls (150-170 days old crop)				
		I instar	II instar	III instar	IV instar	V instar	I instar	II instar	III instar	IV instar	V istar	I instar	II instar	III instar	IV instar	V instar	I instar	II instar	III instar	IV instar	V instar
T_1	NHH-44 BG II	00.00	152.56	176.23	189.86	303.93	166.6	167.16	184.83	194.26	353.70	00.00	152.23	169.70	277.16	280.66	00.00	162.66	175.80	278.53	305.50
T_2	PKV Hy-2 BG II	00.00	149.33	168.00	170.13	267.10	00.00	146.66	162.13	162.23	305.40	177.73	176.96	197.93	320.26	332.66	194.50	180.26	197.56	329.10	339.10
T_3	PDKV-JKAL-116 BG II	155.30	160.46	185.30	201.66	312.73	152.2	161.30	183.16	188.16	349.43	162.6	158.73	176.06	315.26	319.56	202.93	183.43	204.96	335.03	342.56
T_4	G. COT-10 Hy. BG II	166.26	168.03	194.23	210.43	322.83	151.9	156.46	176.30	176.68	320.63	184.90	185.40	204.20	330.93	341.33	187.66	176.56	191.80	323.10	337.60
T_5	G. COT-08 Hy. BG-II	173.40	174.96	201.63	217.96	328.40	00.00	155.43	166.66	167.13	317.43	164.53	164.06	186.73	323.16	324.03	184.13	166.70	187.63	317.80	331.36
T_6	NHH-44 (Non- *Bt*)	286.39	338.9	339.06	342.43	350.03	278.0	331.35	334.33	335.46	410.66	296.46	336.66	337.16	362.26	363.36	333.10	338.73	336.73	364.03	388.56
	SE (m) ±	0.60	1.65	0.87	0.07	1.44	0.77	1.08	0.96	0.97	1.64	1.18	0.91	0.84	1.04	1.13	0.87	1.03	0.74	1.12	1.26
	CD (p=0.05)	1.83	5.00	2.66	2.39	4.37	2.36	3.30	2.91	2.94	4.98	3.59	2.76	2.56	3.15	3.44	2.65	3.14	2.26	3.41	3.82
	CV %	0.80	1.49	0.72	0.61	0.79	1.08	1.01	0.82	0.82	0.83	1.25	0.80	0.69	0.56	0.60	0.82	0.89	0.59	0.60	0.64

Table 5. Adult emergence (%) from *H. armigera* larvae fed on different plant parts of public sector Bt cotton hybrids

S. No.	Treatments	On leaves (60-80 days old crop)					On squares (90-110 days old crop)					On young bolls (120-140 days old crop)					On mature bolls (150-170 days old crop)				
		I instar	II instar	III instar	IV instar	V instar	I instar	II instar	III instar	IV instar	V instar	I instar	II instar	III instar	IV instar	V instar	I instar	II instar	III instar	IV instar	V instar
T_1	NHH-44 BG II	0.00 (0.00)*	10.00 (18.43)	30.00 (33.21)	46.67 (43.09)	100.00 (90.00)	20.00 (26.57)	30.00 (33.21)	60.00 (50.77)	73.33 (58.91)	100.00 (90.00)	0.00 (0.00)	6.67 (14.97)	26.67 (31.09)	100.00 (90.00)	100.00 (90.00)	0.00 (0.00)	10.00 (18.43)	43.33 (41.17)	100.00 (90.00)	100.00 (90.00)
T_2	PKV Hy-2 BG II	0.00 (0.00)	0.00 (0.00)	23.33 (28.88)	40.00 (39.23)	100.00 (90.00)	0.00 (0.00)	0.00 (0.00)	13.33 (21.41)	33.33 (35.26)	100.00 (90.00)	20.00 (26.57)	26.67 (31.09)	63.33 (52.73)	100.00 (90.00)	100.00 (90.00)	13.33 (21.41)	30.00 (33.21)	70.00 (56.79)	100.00 (90.00)	100.00 (90.00)
T_3	PDKV-JKAL-116 BG II	10.00 (18.43)	20.00 (26.57)	33.33 (35.26)	56.67 (48.83)	100.00 (90.00)	13.33 (21.41)	23.33 (28.88)	50.00 (45.00)	60.00 (50.77)	100.00 (90.00)	0.00 (0.00)	10.00 (18.43)	40.00 (39.23)	100.00 (90.00)	100.00 (90.00)	20.00 (26.57)	40.00 (39.23)	86.67 (68.59)	100.00 (90.00)	100.00 (90.00)
T_4	G. COT-10 Hy. BG II	13.33 (21.41)	30.00 (33.21)	50.00 (45.00)	66.67 (54.74)	100.00 (90.00)	10.00 (18.43)	20.00 (26.57)	43.33 (41.17)	53.33 (46.91)	100.00 (90.00)	23.33 (28.88)	40.00 (39.23)	66.67 (54.73)	100.00 (90.00)	100.00 (90.00)	10.00 (18.43)	26.67 (31.09)	60.00 (50.77)	100.00 (90.00)	100.00 (90.00)
T_5	G. COT-08 Hy. BG-II	20.00 (26.57)	33.33 (35.26)	60.00 (50.77)	73.33 (58.91)	100.00 (90.00)	0.00 (0.00	10.00 (18.43)	20.00 (26.57)	46.67 (43.09)	100.00 (90.00)	10.00 (18.43)	20.00 (26.57)	53.33 (46.91)	100.00 (90.00)	100.00 (90.00)	0.00 (0.00)	20.00 (26.57)	53.33 (46.91)	100.00 (90.00)	100.00 (90.00)
T_6	NHH-44 (Non- *Bt*)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)
	SE (m) ±	0.13	0.13	0.19	0.27	-	0.13	0.13	0.19	0.27	-	0.13	0.19	0.27	-	-	0.13	0.13	0.23	-	-
	CD (p=0.05)	0.41	0.41	0.58	0.82	-	0.41	0.41	0.58	0.82	-	0.41	0.58	0.82	-	-	0.41	0.41	0.71	-	-
	CV %	9.86	7.31	6.74	7.37	-	9.86	7.71	6.97	7.71	-	9.22	8.95	8.08	-	-	9.86	6.23	5.92	-	-

* Figures in parentheses angular transformed values

Table 6. Growth and survival indices of *H. armigera* reared on different plant parts of public sector *Bt* cotton hybrids

Treatments	Growth Index				Survival Index			
	Leaves	Squares	Young bolls	Mature bolls	Leaves	Squares	Young bolls	Mature bolls
NHH-44 BG II	0.75	1.30	0.88	0.94	0.38	0.56	0.46	0.50
PKV Hy-2 BG II	0.64	0.59	1.34	1.37	0.33	0.29	0.62	0.62
PDKV-JKAL-116 BG II	0.99	1.12	1.01	1.77	0.44	0.49	0.50	0.69
G. COT-10 Hy. BG II	1.16	0.94	1.48	1.25	0.52	0.45	0.66	0.59
G. COT-08 Hy. BG-II	1.36	0.72	1.20	1.11	0.58	0.35	0.56	0.54
NHH-44 (Non- *Bt*)	2.38	2.56	2.77	3.03	1.00	1.00	1.00	1.00

squares of PKV Hy-2 BG II. Where, the young bolls and mature bolls of NHH-44 BG II when fed to different larval instars of *H. armigera* demonstrated reduction in same growth and developmental parameters (Tables 2-6).

The bioassay done with different plant parts of public sector *Bt* cotton hybrids conclusively elucidated decrease in mortality rate of *H. armigera* from early stage (leaves and squares) to the later stage (young and mature bolls) of crop. Thus, the expression of Cry toxins significantly declined with the progression of plant age. This view derives support from the earlier findings (Jayaprakash et al., 2013; Baoqian et al., 2011, Arshad et al. 2009, Siebert et al., 2009; Kranthi et al., 2005). The data also revealed higher larval mortality of early instars fed on different plant parts compared to the later instars. However, the surviving late instars showed conflicting effects on the growth and development, such as reduced larval weights, pupation pupal weight and adult emergence. Also, the growth and survival index values became low when reared on leaves and squares compared to young bolls and mature bolls. These results are in accordance with those of earlier workers (Rupnar, 2018; Hallad et al., 2011; Likhitha and Bhamare, 2018, Mahalakshmi and Prasad, 2013; Naik et al., 2012). Among the different public sector *Bt* cotton hybrids superior results were expressed by PKV Hy-2 BG II when *H. armigera* larval instars fed on leaves and squares at 60-80 and 90-110 days old crop, respectively and NHH-44 BG II when fed on young bolls and mature bolls at 120-140 and 150-170 days old crop, respectively.

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