Bio-rational Insecticides against Pink bollworm, *Pectinophora gossypiella* Saunders in Bt cotton

Speaker: **Dr. H. R. DESAI,**
Associate Research Scientist (Entomology)

Concurrent Panel 6A "Bollworms-IPM/IRM"
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in
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NAVSARI AGRICULTURAL UNIVERSITY

MAIN COTTON RESEARCH STATION, NAU, Surat
Gujarat (India)

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Background

- Cotton, the commercial crop for fibre, fuel and edible oil, is playing an important role in Indian economy
- In Gujarat state, cotton was grown in 26.91 lakh ha with production of 120.80 lakh bales and 783 kg/ha productivity during 2013-14 (Anon. 2017).

- In 2014-15, Gujarat occupied second largest area (Approx. 3.0 m ha) after Maharashtra state and cotton cultivation is dominated by the Bt cotton sown as early as April-May in irrigated area and with onset of rain in June-July in rain fed areas of Gujarat

- In 2014-15, there was serious incidence and damage of Pink bollworm, *Pectinophora gossypiella* (Saunders) on Bt cotton hybrids, initiated infestation as early as in flowering stage and inflict subsequent damage to fruiting bodies triggering indiscriminate use of insecticides by the farmers, substantial losses to seed cotton yield and reduced profit margin

- Therefore, there is dire need to recommend effective and economic insecticides for the better control of the pest.

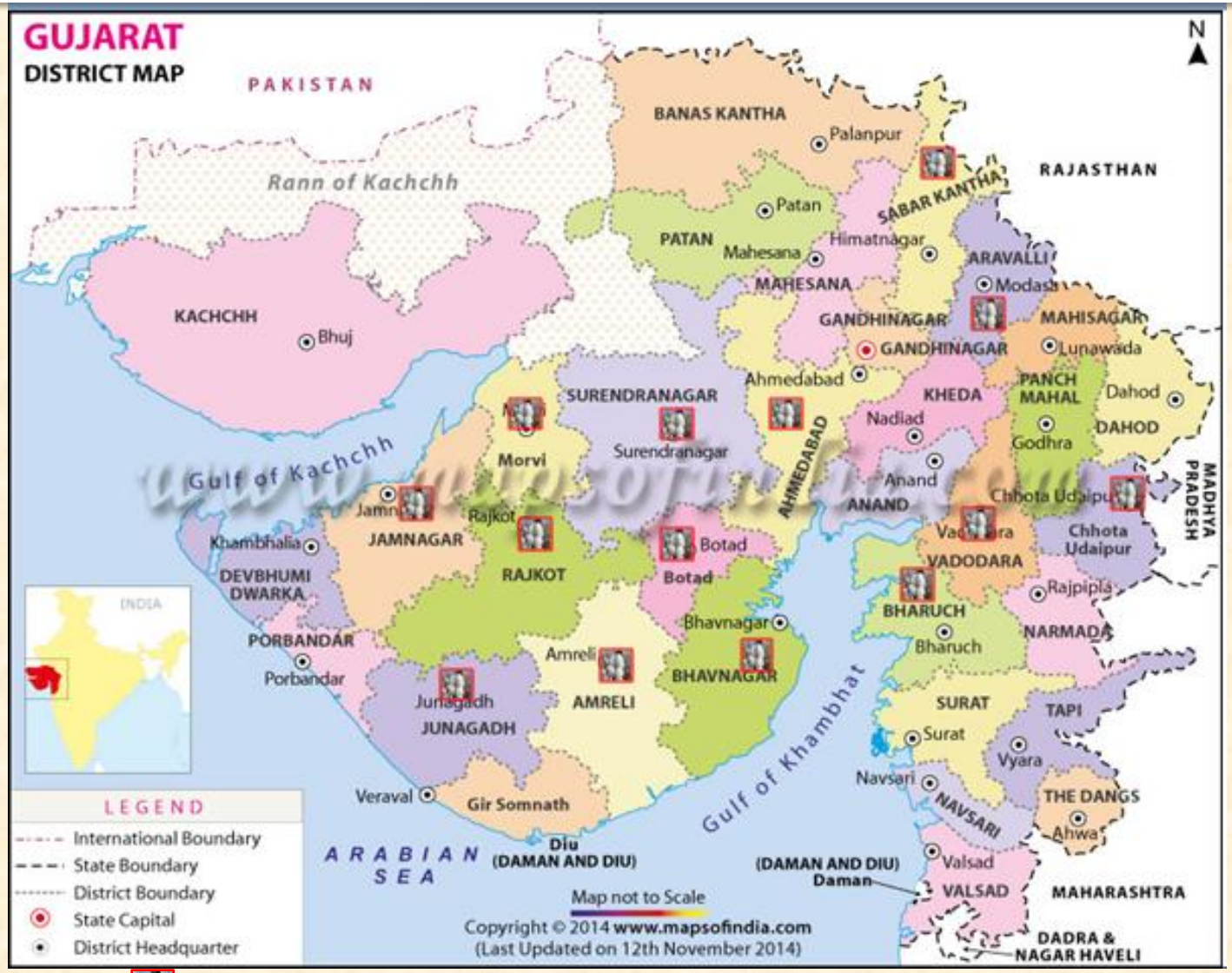
Status of cotton cultivation in India and Gujarat

Year	India			Gujarat		
	Area (Lakh ha)	Production (Lakh bales)	Yield (kg lint /ha)	Area (Lakh ha)	Production (Lakh bales)	Yield (kg lint /ha)
2002-03	76.67	136.00	302.00	16.34	30.50	317.00
2003-04	76.30	179.00	398.82	16.47	50.00	516.09
2004-05	87.86	243.00	470.18	19.06	73.00	651.10
2005-06	86.77	241.00	472.17	19.06	89.00	794.00
2006-07	91.44	280.00	520.56	23.90	103.00	733.00
2007-08	94.14	307.00	554.39	24.22	110.00	772.00
2008-09	94.06	290.00	524.13	23.54	90.00	650.00
2009-10	103.10	305.00	502.91	26.25	98.00	635.00
2010-11	112.35	339.10	513.10	26.33	103.00	686.00
2011-12	121.78	367.00	512.00	29.62	118.80	700.00
2012-13	119.78	370.00	525.00	24.97	89.80	633.00
2013-14	117.27	398.00	577.00	26.91	120.80	783.00
2014-15	126.55	400.00	537.00	30.06	121.80	707.00
2015-16	118.81	352.00	503.00	27.61	97.80	622.00
2016-17	105.00	351.00	568.00	24.00	91.80	673.00

Note: One bale = 170 kg, Anon. 2016

Source: AICCIP – Annual Report (2016-17)

Cotton growing districts in State of Gujarat 2015-16



Major cotton growing districts in Gujarat (>50000 ha)

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Assessment of yield loss due to bollworms (2015-16)

Sr.	Treatment combination	No. of spray		Total Sprays	Av. Seed cotton yield (kg/ha)	Difference in seed cotton yield (kg/ha)	% Avoidable yield loss	Monetary loss (Rs./ha)
		SP	BW					
1	$V_1S_1T_1$	3	2	5	2648.15	194	7.33**	7763
	$V_1S_1T_2$	4	0	4	2454.07			
2	$V_1S_2T_1$	3	2	5	2535.06	138	5.43**	5511
	$V_1S_2T_2$	4	0	4	2397.28			
3	$V_2S_1T_1$	4	1	5	3236.38	**163**	**5.05****	**6532**
	$V_2S_1T_2$	4	0	4	3073.09			
4	$V_2S_2T_1$	4	1	5	3135.56	104	3.32**	4165
	$V_2S_2T_2$	4	0	4	3031.44			
5	$V_3S_1T_1$	4	4	8	2084.94	889	42.63**	35556
	$V_3S_1T_2$	4	0	4	1196.05			
6	$V_3S_2T_1$	4	3	7	1991.44	677	33.98**	27065
	$V_3S_2T_2$	4	0	4	1314.81			

Note: Seed cotton yield price Rs. 40 per Kg during 2015-16 and ** significant at 1% level of significance between protected and unprotected treatment tested through two sample t test

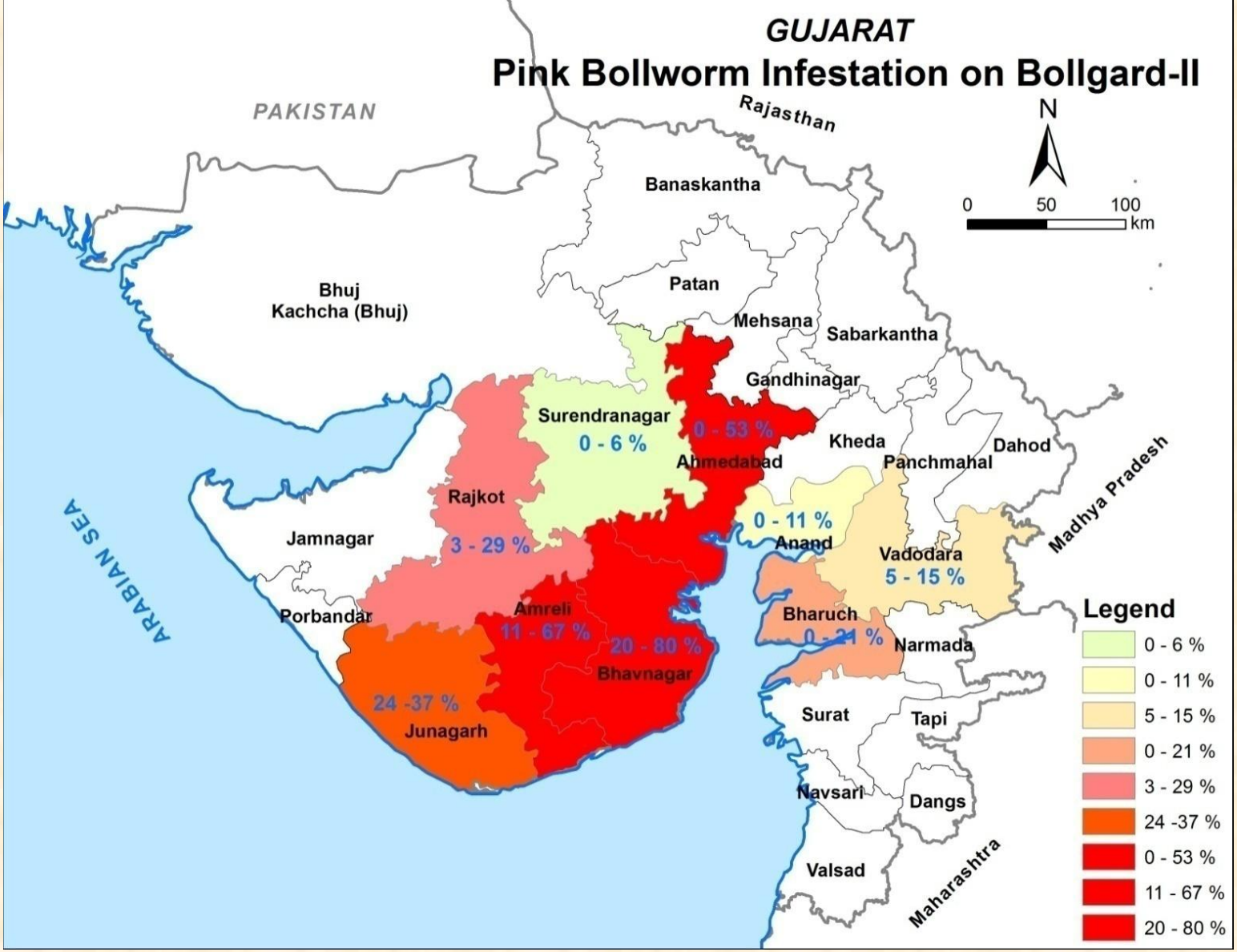
Cotton hybrids		Sowing time		Protection for bollworms	
V_1	RCH 2 BG I	S_1	Early (25^{th} May) sowing	T_1	Protection for bollworms
V_2	RCH 2 BG Π	S_2	Normal (25^{th} June) sowing	T_2	No Protection for bollworms
V_3	RCH 2 non Bt				

Rathod K. R. (2016). Post Graduate Thesis submitted to Navsari Agricultural University (Unpublished)

Survey for assessment of losses due to pink bollworm in cotton growing area of South Gujarat (2015-16)

Sr. No.	Districts	Taluka	Villages	% loss in SCY due to PBW	Monetary loss (Rs/ha)		
					Due to yield loss	Due to additional management cost *	Total
1	Bharuch	Bharuch	Dabhali, Bori, Nikora	4.59	8510	2700	11210
		Amod	Shamlod, Kesod, Kesalu	3.89	8335	2966	11301
		Valia	Daheli, Jabugam, Vandariya, Luna, Tuna	2.15	4245	2780	7025
		Hansot	Katasayan, Kudadara, Valner, Katpora, Dantrai	2.22	5010	3100	8110
		Overall		**3.21**	**6525**	**2886**	**9411**
2	Surat	Olpad	Bhadol, Takarama, Delad	2.92	6142	1911	8053
		Umarpada	Kadvali, Umarda	1.97	3583	2200	5783
		Overall		**2.44**	**4862**	**2055**	**6917**
	*Cost of pheromone traps and lures and spraying of insecticide (s)						

Anonymous (2017). Annual Progress Report of Cotton Entomology submitted and presented in 13th Plant Protection Sub-Committee of Agricultural Research Council for Navsari Agricultural University, Navsari during February, 9-10 2017



Source: State Department of Agriculture, GoG, Gandhinagar (In : one day workshop on Pink bollworm, 09.04.2016 at APMC, Surat during group meeting of AICRP on Cotton

Lab or Field Evolved Resistance in PBW to *Cry1Ac/Cry2Ab* in Gujarat and Other States in India

Author (s)	Salient finding	Source
Dhurua S. and Gujar G. T. (2011)	First evidence of field evolved resistance of PBW to *Cry1Ac* for the strain derived from Amreli, Gujarat having 42 to 47 resistance ratio compared to susceptible strain of Adilabad. The diagnostic dose of 1µg/ml showed only 24 to 31 per cent mortality as against 100 per cent in susceptible populations of Adilabad. They observed no cross-resistance to *Cry2Ab*$_2$ when bioassay with seed powder of KDCHH 441 BG II.	*Pest Manag Sci.*, 67: 898–903.
Ojha, A., Sree, K. S., Bindiya, S., Rashmi, M. S., Ravi, K. C., Suresh, P. J., Mohan, K. S., and Bhatnakar, R. K. (2014).	Analyzed resistance to *Cry1Ac* in field collected PBW from Central India (Maharashtra and Madhya Pradesh) and found reduced binding of labeled Cry 1 Ac protein to receptors localized on the brush border membrane of PBW larval strains with high tolerance to *Cry1Ac*.	*GM Crops & Food: Biotechnology in Agriculture and the Food Chain*, 5(4): 280-286.
Fabrick, J. A., Ponnuraj, J., Singh, A., Tanwar, R., Unnithan, G. C., Yelich, A. J., Li, X., Carriere, Y. and Tabashnik, B. (2014)	Reported alternative splicing and highly variable cadherin transcripts associated with field evolved resistance in PBW in India. DNA sequencing of PBW (from 7 sites including two locations from Gujarat: Anand and Rajkot), they found eight novel severely disrupted cadherin alleles associated with resistance to Cry 1 Ac. Further from these eight alleles, on analysis of cDNA they found a total of 19 transcript isoforms, each containing a premature stop codon, a deletion of at least 99 base pairs or both. Seven of eight disrupted alleles, each produced two or more different transcript isoforms, which implicated alternative splicing of mRNA.	PloS ONE 9(5): e97900. Doi:10.1371/journal.pone.0097900 .
CICR (Nagpur and Coimbatore) 2015	Confirmed the survival of PBW on BG II hybrids (*Cry 1Ac* and *Cry2Ab*) based on bioassay	www.cicr.org.in
Monsanto (2015)	Admitted that PBW are completely susceptible to combination of two proteins expressed in second generation in Bollgard II (Three protein Bt cotton technology in pipe line)	www.monsanto.com
Fabrick, J. A., Unnithan G.C., Yelich A.J., De Gain B., Masson L., Zhang J., Carriere Y. and Tabashnik, B. (2015)	Explained the risk of resistance evolution to pyramided Bt cotton. When toxins are deployed sequentially and refuge are scarce by developed high resistant PBW strains of *Cry1Ac* and *Cry2Ab* through lab selection and created multi-toxin resistant strains with one selection after crossing Cry2Ab resistant strain with *Cry1Ac* resistant strain, which survived on field collected Bt cotton bolls	*Sci. Rep.*, 5, 16554; doi: 10.1038/srep 16554 (2015).
Malthankar, P. A. and Gujar, G. T. (2016).	Studied the inheritance of *Cry2Ab* resistance in the pink bollworm. Selection of PBW for *Cry2Ab* resistance led to the maximal of 37.75 fold resistance vis-à-vis the most susceptible strain and reported the resistance appeared to governed by multiple allele/genes. Fitness costs and inheritance pattern necessitates rigorous monitong of *Cry2Ab* resistance.	*Indian Journal of Experimental Biology*, 54: 586-596

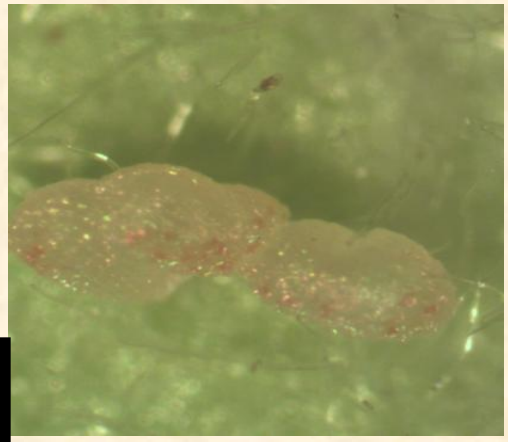
Insecticide use against pink bollworm (2009 -2015)

Kharbade, S. B. and Wayal C. B. (2009)	Lamda-Cyhalothrin 5 EC @ 25 g ai/ha Chlorpyriphos 20 EC @ 500 g ai/ha Quinalphos 25 EC @ 500 g ai/ha	*J. Cot. Res. Dev.* , 23 (1):149-151
Rani, S.B., Prasad, N.V.V.S.D, Rao, P.A. and Rao, S. (2010)	Deltamethrin 1 EC + Triazophos 35 EC @ 360 g ai/ha	*J. Ent. Res.*, 34 (2): 125-129
Rudramani, T., Srinivas Reddy K.M., Ashok Kumar (2011)	Chlorpyriphos + Cypermethrin 44 EC Triazophos + Deltamethrin 35 EC Profenofos + Cypermethrin Indoxacarb 14.5 SC Lamda-cyhalothrin 2.5 EC Thiodicarb 75 SP	*J Farm Sci.*, 1(1): 49-58
Kalyan, R.K., Saini, D.P. and Urmila (2012)	Thiodicarb 75 SP @ 750 g ai/ha Lamda-Cyhalothrin 2.5 EC @ 25 g ai/ha Deltamethrin 2.8 EC @ 15 g ai/ha	*J. Cot. Res. Dev.*, 26 (2):227-229
Rashid M.M., Khattak, M. K., and Abdullah, K. (2012)	Chlorpyriphos +Cypermethrin 44 EC @ 220 g ai/ha	*Pakistan J. Zool.*, 44 (5): 1317-1324
Sabry, A,H., Hassan K.A., and Rahman , A.A. (2014)	Thiamethoxam 25 % WDG @ 40 g ai/ha Chlorantranilliprolle 20 EC @ 50 ml /ha	*Int. J. Sci. Environ. Tech.*, 3 (2): 481-491
Bajya, D.R., Baheti H.S., and Raza S.K. (2015)	Chlorantranilliprolle 9.3 % +Lamda cyhalothrin 4.6 % @ 45-60 g ai/ha	*J. Cot. Res. Dev.* , 29 (1):94-98

Arthropod Pesticide Resistance Database
Pectinophora gossypiella shown resistance to Active Ingradients
(China, Egypt, Mexico, USA, India, South Africa)
DDT
Endosulfan
Methomyl
Chlorfenvinphos
Chlorpyrifos
Leptophos
Quinalphos
Parathion methyl
Carbaryl
Permethrin
fenvalerate
deltamethrin
cypermethrin
spinosad
Source: www.pesticideresistance.org

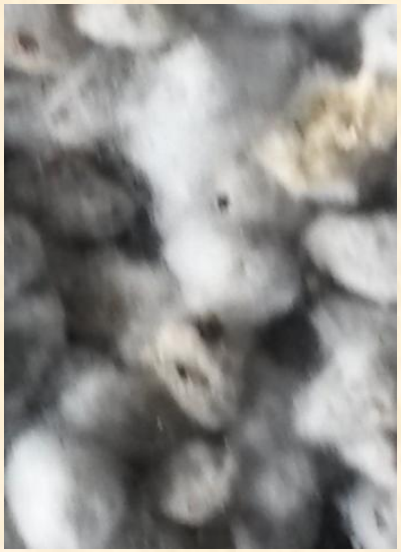
Experimental details :					
(i)	Design	:	RBD		
(ii)	Replications	:	Three (3)		
(iii)	Crop / Variety		G. Cot. Hy. 6 BG II		
(iv)	Spacing		1.20 x 0.45 m		
(v)	Target pest	:	*Pectinophora gossypiella* Saunders		
(vi)	Plot size	:		2015-16	2016-17
			Gross:	6.00 x 6.75 m	7.20 x 4.05 m
			Net:	3.60 x 5.85 m	4.80 x 3.15 m
(vii)	Dose of fertilizer	:	240-40-0 NPK kg/ha		
(viii)	Season & Sowing date	:	*Kharif* 2015-16	*Kharif* 2016-17	
			15/06/2015	30/06/2016	

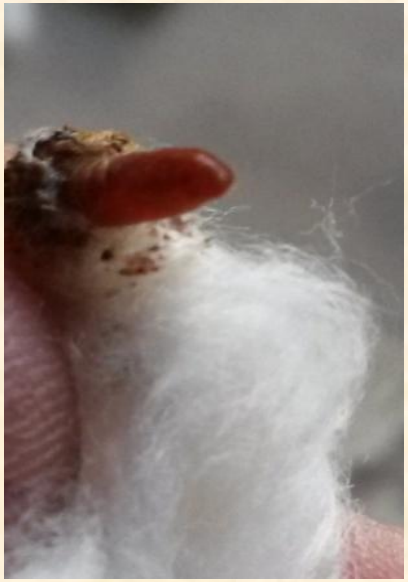
Pink bollworm damage in Bt cotton in early flowering stages in Gujarat



Source: Zinzuvadiya H. D., Desai H. R., Lakum M. B. and Rajkumar B. K. (2017). Biology of pink bollworm, *Pectinophora gossypiella* Saunders (Lepidoptera: Gelechidae) on artificial diet under controlled condition. Trends in Bioscience, 10 (25): 5363-5371

Pink bollworm damage in green bolls (90 DAS onwards) in Gujarat





Multiplication and Spread of PBW from storage and transport

Selection of treatments (MoA and WHO classification)

No	Treatments	WHO Class*	IRAC MoA group	Mode of Action	g *ai*/ha label**	WP
1	Thiodicarb 75 WP	II	1A	Acetyl Cholinesterase (AchE) inhibitors (nerve action)	750	30
2	Chlorpyrifos 20 EC	II	1B		250	30
3	Triazophos 40 EC	Ib	1B		600-800	21
4	Profenophos 50 EC	II	1B		750-1000	15
5	Deltamethrin 2.8 EC	II	3A	Sodium channel modulators (nerve actions)	12.5	-
6	Lambda Cyhalothrin 2.5 EC	II	3A		15-25	21
7	Spinosad 45 SC	III	5	Nicotinic acetylcholine receptor -nAchR allosteric activators (nerve actions)	75-100	10
8	Emamectin benzoate 5 SG	III	6	Chloride channel activators (nerve & muscle action)	9.5-11.0	10
9	Indoxacarb 15.8 EC	II	22A	Voltage -dependent sodium channel blocker (nerve action)	75	14
	***Ib: Highly hazardous**, **II: Moderately hazardous**, **III: Slightly hazardous**					

**As per the Directorate of Plant Protection, Quarantine & Storage Central Insecticide Board & Registration Committee N.H.-IV, Faridabad-121 001, major uses of pesticides (Registered under the Insecticides Act, 1968) up to 30.06.2016 for cotton crop

Details of Treatments

No.	Treatments	Conc.	Dose (ml or g /10 lit water)
1	Emamectin benzoate 5 SG	0.0025 %	5 g
2	Chlorpyriphos 20 EC	0.04 %	20 ml
3	Indoxacarb 15.8 EC	0.0079%	5 ml
4	Triazophos 40 EC	0.08%	20 ml
5	Spinosad 45 SC	0.014%	3 ml
6	Profenophos 50 EC	0.1 %	20 ml
7	Thiodicarb 75 WP	0.15%	20 g
8	Lambda Cyhalothrin 2.5 EC	0.0025%	10 ml
9	Deltamethrin 2.8 EC	0.0028%	10 ml
10	Control	-	-

Spray details	2015-16	2016-17	Farmers field
1st spray	75 DAS		26.08.16
2nd Spray	15 Days After First Spray		28.09.16

Observations recorded

- ✓ Rosette Flower due to Pink Bollworm Infestation (80, 90 and 105 DAS)
- ✓ Green boll damage / 10 Green bolls sampled (5, 10 and 15 Days after Each spray)
- ✓ No. of larvae / 10 green bolls (5, 10 and 15 Days after Each spray)
- ✓ Open boll and locule damage by pink bollworm (at harvest)
- ✓ Seed cotton yield (at pickings)
- ✓ Estimation of Economics based on prevalent prices

Rosette flower

Damage in flower

Green boll damage

PBW larvae

Locule & seed damage

Table 1: Damage to flowers (Rosette flower) by PBW (Pooled 2015-16 & 2016-17)

Sr. No.	Treatments	Dose (g a.i./ha)	Rosette flowers (%)				
			Before	80 DAS	90 DAS	105 DAS	Pooled
T1	Emamectin benzoate 5 SG	12.5	21.51 (13.55)	9.77 (3.45)	11.53 (4.00)	7.54 (2.57)	**9.61 (3.34)**
T2	Chlorpyriphos 20 EC	200	21.77 (13.85)	16.27 (8.00)	16.21 (8.13)	15.55 (7.38)	16.01 (7.84)
T3	Indoxacarb 15.8 EC	39.5	22.50 (14.73)	9.88 (3.55)	11.41 (3.93)	3.74 (1.26)	**8.34 (2.91)**
T4	Triazophos 40 EC	400	22.74 (15.11)	14.31 (6.29)	15.27 (7.39)	17.17 (8.73)	15.58 (7.47)
T5	Spinosad 45 SC	67.5	23.31 (15.78)	12.85 (4.99)	7.75 (2.71)	6.95 (2.19)	**9.18 (3.30)**
T6	Profenophos 50 EC	500	23.07 (15.42)	8.77 (3.47)	9.91 (3.54)	13.09 (5.28)	10.59 (4.10)
T7	Thiodicarb 75 WP	375	25.06 (18.10)	13.56 (5.67)	16.33 (8.09)	14.36 (6.25)	14.75 (6.67)
T8	Lambda cyhalothrin 2.5 EC	12.5	21.10 (13.22)	15.08 (7.33)	16.17 (8.08)	14.82 (6.67)	15.36 (7.36)
T9	Deltamethrin 2.8 EC	14	24.29 (17.06)	13.10 (5.21)	14.35 (6.54)	14.44 (6.37)	13.96 (6.04)
T10	Control	-	24.43 (17.36)	23.95 (16.58)	24.56 (17.47)	18.70 (10.34)	22.40 (14.80)
	S. Em. ±		1.02	1.56	1.46	1.49	0.93
	CD at 5%		NS	4.44	4.16	4.24	2.57
	S.Em. ± (Y x T)		1.47	2.33	2.04	2.34	2.24
	CD at 5% (Y x T)		NS	NS	NS	NS	NS
	CV %		11.09	29.36	24.63	32.16	28.62

Note: 1. Figures in parentheses are original values; those outside are Arcsine transformed values; DAS- Days After Spray

Table 2: Damage to green bolls by PBW (Pooled of 2015-16 & 2016-17)

Sr. No.	Treatments	Dose (g *a.i.*/ha)	#Green boll damage (%) by PBW				
			Before spray	5 DAS	10 DAS	15 DAS	Pooled
T1	Emamectin benzoate 5 SG	12.5	20.15 (12.06)	12.62 (5.00)	11.04 (3.93)	9.22 (2.60)	**10.96 (3.84)**
T2	Chlorpyriphos 20 EC	200	20.51 (12.37)	19.24 (10.95)	18.90 (10.89)	17.18 (8.98)	18.44 (10.27)
T3	Indoxacarb 15.8 EC	39.5	20.51 (12.61)	11.74 (4.37)	9.59 (3.00)	7.76 (1.87)	**9.70 (3.08)**
T4	Triazophos 40 EC	400	20.41 (12.35)	18.92 (10.78)	18.02 (9.76)	15.32 (7.25)	17.42 (9.26)
T5	Spinosad 45 SC	67.5	19.68 (11.53)	13.33 (5.61)	12.05 (4.57)	8.81 (2.48)	**11.39 (4.22)**
T6	Profenophos 50 EC	500	20.11 (11.91)	19.25 (11.00)	17.74 (9.80)	17.02 (8.75)	18.00 (9.85)
T7	Thiodicarb 75 WP	375	18.73 (10.63)	16.06 (8.00)	15.28 (7.31)	13.09 (5.22)	14.81 (6.84)
T8	Lambda cyhalothrin 2.5 EC	12.5	21.02 (13.14)	19.77 (11.52)	19.33 (11.37)	16.75 (8.39)	18.62 (10.43)
T9	Deltamethrin 2.8 EC	14	21.53 (13.60)	16.33 (8.13)	14.00 (5.92)	14.61 (6.51)	14.98 (6.85)
T10	Control	-	20.43 (12.40)	24.60 (17.41)	25.65 (18.87)	25.52 (18.68)	25.26 (18.32)
	S. Em. ±		0.84	0.95	0.87	0.80	0.51
	CD at 5%		NS	2.74	2.53	2.33	1.42
	S.Em. ± (Y x T)		1.22	0.85	0.87	0.80	0.84
	CD at 5% (Y x T)		NS	2.39	2.45	2.25	2.32
	CV %		10.43	8.53	9.31	9.49	9.09

Figures in parentheses are original values; those outside are Arcsine transformed values
#Pooled data of total four sprays of both the years

Table 3: Number of PBW larvae / 10 green bolls (Pooled of 2015-16 & 2016-17)

Sr. No.	Treatments	Dose (g a.i./ha)	No. of larva (e)/10 green bolls				
			Before spray	5 DAS	10 DAS	15 DAS	Pooled
T1	Emamectin benzoate 5 SG	12.5	1.86 (3.00)	1.20 (1.00)	1.10 (0.75)	1.05 (0.67)	**1.12 (0.81)**
T2	Chlorpyriphos 20 EC	200	1.77 (2.67)	1.80 (2.75)	1.67 (2.33)	1.71 (2.50)	1.73 (2.53)
T3	Indoxacarb 15.8 EC	39.5	1.67 (2.34)	1.18 (1.00)	1.01 (0.58)	1.10 (0.75)	**1.10 (0.78)**
T4	Triazophos 40 EC	400	1.91 (3.17)	1.86 (3.00)	1.66 (2.33)	1.72 (2.50)	1.75 (2.61)
T5	Spinosad 45 SC	67.5	1.76 (2.67)	1.32 (1.33)	1.14 (0.92)	1.25 (1.08)	**1.24 (1.11)**
T6	Profenophos 50 EC	500	1.81 (2.83)	1.66 (2.33)	1.46 (1.67)	1.54 (1.92)	1.55 (1.97)
T7	Thiodicarb 75 WP	375	1.73 (2.50)	1.49 (1.75)	1.40 (1.50)	1.40 (1.50)	1.43 (1.58)
T8	Lambda cyhalothrin 2.5 EC	12.5	1.72 (2.50)	1.74 (2.58)	1.70 (2.42)	1.59 (2.08)	1.68 (2.36)
T9	Deltamethrin 2.8 EC	14	1.73 (2.50)	1.64 (2.25)	1.43 (1.58)	1.55 (2.00)	1.54 (1.94)
T10	Control	-	1.84 (3.00)	1.96 (3.50)	2.18 (4.33)	2.15 (4.17)	2.10 (4.00)
	S. Em. ±		0.09	0.10	0.09	0.07	0.05
	CD at 5%		NS	0.29	0.26	0.19	0.14
	S.Em. ± (Y x T)		0.13	0.12	0.14	0.13	0.13
	CD at 5% (Y x T)		NS	0.33	0.39	NS	0.36
	CV %		13.10	12.90	16.13	14.99	14.66

Figures in parentheses are original values; those outside are (square root plus 0.5) transformed values; DAS- Days After Spray
#Pooled data of total four sprays of both the years

Table 4: Damage to open boll and locules at harvest by PBW (Pooled of 2015-16 & 2016-17)

Sr. No.	Treatments	Dose (g a.i./ha)	% OBD	% LD	Seed cotton yield (kg/ha)
T1	Emamectin benzoate 5 SG	12.5	**11.66 (4.12)**	**8.08 (2.02)**	2330.83
T2	Chlorpyriphos 20 EC	200	23.73 (16.22)	18.26 (9.92)	1828.00
T3	Indoxacarb 15.8 EC	39.5	**10.67 (3.50)**	**6.71 (1.44)**	2394.00
T4	Triazophos 40 EC	400	21.20 (13.23)	16.86 (8.45)	1677.67
T5	Spinosad 45 SC	67.5	**13.75 (5.70)**	**9.02 (2.58)**	2239.67
T6	Profenophos 50 EC	500	20.06 (11.86)	16.20 (7.83)	1899.33
T7	Thiodicarb 75 WP	375	19.75 (11.52)	14.99 (6.81)	2077.33
T8	Lambda cyhalothrin 2.5 EC	12.5	24.20 (16.98)	19.00 (10.66)	1778.50
T9	Deltamethrin 2.8 EC	14	22.05 (14.34)	17.48 (9.11)	1907.17
T10	Control	-	29.83 (24.79)	24.28 (16.97)	1095.33
	S. Em. ±		0.66	0.43	100.80
	CD at 5%		1.87	1.22	287.32
	S.Em. ± (Y x T)		0.97	0.62	151.99
	CD at 5% (Y x T)		NS	NS	NS
	CV %		8.54	7.30	13.69

Figures in parentheses are original values; those outside are Arcsine transformed values

Table 5 : Economics of PBW Management in BG II hybrid at Surat (Pooled of 2015-16 & 2016-17)

Sr. No.	Treatments	Conc.	Quantity/ ha	Treatments cost (Rs./ha)	Mean Seed Cotton Yield (kg/ha)	Yield increase over control (kg/ha)	Benefit over control (Rs./ha)	Net profit (Rs./ha)	CBR
T_1	Emamectin benzoate 5 SG	0.0025%	250	5168	**2330**	1235	55575	**50407**	1:9.75
T_2	Chlorpyriphos 20 EC	0.04%	1000	1688	1828	733	32985	31297	1:18.54
T_3	Indoxacarb 15.8 EC	0.0079%	250	2668	**2394**	1299	58455	**55787**	1:20.91
T_4	Triazophos 40 EC	0.08%	1000	2048	1677	582	26190	24142	1:11.79
T_5	Spinosad 45 SC	0.014%	150	6108	**2239**	1144	51480	**45372**	1:7.43
T_6	Profenophos 50 EC	0.1%	1000	2248	1899	804	36180	33932	1:15.09
T_7	Thiodicarb 75 WP	0.15%	1000	6288	2077	982	44190	37902	1:6.03
T_8	Lambda Cyhalothrin 2.5 EC	0.0025%	500	1888	1778	683	30735	28847	1:15.28
T_9	Deltamethrin 2.8 EC	0.0028%	500	1678	1907	812	36540	34862	1:20.78
T_{10}	Control	-	-	-	1095	0	0	-	-

Note: 1. Labour wages: Rs. 178/day, 2. Price of produce: Rs. 45/kg , 3. Spray volume: 500-750 l/ha

- **Maximize protection by targeting hatching eggs (neaonates ingesting chemicals from the egg case at hatching) and early instar stages (larvae feeding on plant material) as well as some contact activity**

- **Robust residual activity : translaminar absorption (Emamectin benzoate and Spinosad), rapid absorption into crop enhances rain fastness which prevent photo– degradation**

- **Highly selective to beneficial insects (**Emamectin benzoate was found safer to coccinellids beetles; Hole and Bharud, 2011; Govindan *et* al., 2013) **and pollinators (non toxic to foraging bees)**

- **Excellent environmental profile (Short half life)**

- **Further, in practice, alteration of compounds from different MoAs groups provide a sustainable and effective approach to IRM. Hence, all three products (belonging to different groups having nerve actions) to be used in alteration for management of pink bollworm.**

Conclusion & Recommendation

Looking to the effectiveness of three products as described above and near green chemistries, Cotton farmers of South Gujarat cultivating *Bt* cotton of Agro-climatic zone II are advised to manage pink bollworm by two sprayings of any one of the following insecticide, first spray at 75 days after sowing and second after 15 days of the first spray (with alteration of product) for effective control of pink bollworm in hotspot area.

1. **Indoxacarb 15.8 EC @ 0.0079% (5 ml/10 lit. of water) or**
2. **Emamectin benzoate 5 SG @ 0.0025% (5 g/10 lit. of water) or**
3. **Spinosad 45 SC @ 0.014% (3 ml/10 lit. of water)**

AS PER CIB GUIDELINES:

Year	Crop	Pest/ Disease	Pesticide with formulation	Doses			Waiting Period (days)*
				Quantity of formulation	Conc.	Dilution in water	
2017	Cotton	Pink boll worm	Indoxacarb 15.8 EC	39.5 ml	0.0079%	500 L	14
			Emamectin benzoate 5 SG	12.5 g	0.0025%	500 L	10
			Spinosad 45 SC	67.5 ml	0.014%	500 L	10

*As per the Directorate of Plant Protection, Quarantine & Storage Central Insecticide Board & Registration Committee N.H.-IV, Faridabad-121 001, major uses of pesticides (Registered under the Insecticides Act, 1968) up to 30.06.2016 for cotton crop

Bio-rational Insecticides against Pink Bollworm, *Pectinophora gossypiella* Saunders in *Bt* cotton

***Desai, H. R**., Patel, R. D., Bhanderi, G. R. and Solanki, B. G.

Main Cotton Research Station, Navsari Agricultural University, Surat, Gujarat, India

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ABSTRACT

After introduction of *Bt* cotton hybrids during 2002 and its wide spread cultivation (>85% area) in Gujarat state has showed change in dynamics of the pests. The pink bollworm, once a serious problem for non Bt cotton especially in later stage of the crop has now become a major problem in Bt cotton hybrids appearing from flowering stage of the crop and inflicting damage if unattended. With a view to manage from the initial stage of the crop, field experiments were carried out at Main Cotton Research Station, Navsari Agricultural University, Surat for two seasons during *kharif* 2015-16 & 2016-17 in RBD with ten treatments and three replications. The first application of Indoxacarb 15.8 EC @ 0.0079%, Emamectin benzoate 5 SC @ 0.0025% or Spinosad 45 SC @ 0.014% at 75 DAS (days after sowing) and second application at 15 days after first spray was found economical and effective in managing pink bollworm in *Bt* cotton. Mean damage to flower was 2.91, 3.30 and 3.34% in treatments of Indoxacarb 15.8 EC, Spinosad 45 SC and Emamectin benzoate 5 SC, respectively as against 14.80 % rosette flowers in untreated control. Average pink bollworm population was 0.78, 0.81 and 1.11 larvae/10 green bolls with 3.08, 3.84 and 4.22 per cent damage to green bolls in the treatments of Indoxacarb 15.8 EC, Emamectin benzoate 5 SC and Spinosad 45 SC as against 4.00 larvae /10 green bolls and 18.32 % damage to green bolls in untreated control. Mean damage to open boll and locules was 3.50 and 1.44, 4.12 and 2.02 and 5.70 and 2.58% in corresponding treatments as against 24.79 and 16.97% in untreated control. The seed cotton yield was 2394, 2330 and 2240 kg/ha in respective treatments as against 1095 kg/ha in untreated control.

NAVSARI AGRICULTURAL UNIVERSITY

MAIN COTTON RESEARCH STATION, NAU, Surat
Gujarat (India)

SURAT MAIN COTTON RESEARCH STATION