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Validation of existing IPM module of cotton under high density planting system

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Abstract
The present field experiment was carried out to validate the existing IPM module of cotton under high density planting system (HDPS) using ARBC-64 (compact non-*Bt* variety) and Bindaas BG II (commercial *Bt* hybrid) at MARS, Dharwad, Karnataka, India during *kharif* 2016-17. Both genotypes were sown under HDPS (45 × 15 cm) and regular (normal) spacing (90 × 60 cm). IPM module comprised seed treatment with imidacloprid 600 FS, okra as a trap crop, installation of pheromone traps and need based application of selective insecticides. Results revealed that, irrespective of the genotypes, non-significant difference was observed with respect to pests population among HDPS and normal spaced crops. Further, HDPS blocks registered higher seed cotton yield of 26.12 and 23.95 q/ha as compared to 20.35 and 21.20 q/ha under normal spaced crop with a net profit of ₹ 90,485/- and ₹ 67,508/- per hectare under HDPS as compared to ₹ 68,215/- and ₹ 66,976/- per hectare, respectively.

Keywords: IPM, HDPS, normal spacing, sucking pests, bollworms

1. Introduction
Cotton is an important commercial crop and designated as king of fiber crops. Being long duration and succulent in nature, the crop is infested by number of insect pests and inflicts greater loss to crop. In India, about 162 insect pest species have been recorded which causes yield loss to extent of ₹ 2,87,000 million annually [7]. The sucking pests occur at all the stages of crop growth and responsible for indirect yield losses. A reduction of 22.85 percent in seed cotton yield due to sucking pests has been reported [14]. In addition bollworms especially, American bollworm, *Helicoverpa armigera* (Hubner) and pink bollworm, *Pectinophora gossypiella* (Saunders), causes considerable damage to the crop in India [5].
To combat the ravages caused by these pests, intensive usage of insecticides in cotton is a common practice. Cotton consumes about 48 per cent of pesticides used in India and 22.5 per cent of the world [13]. Under the inevitable circumstances, huge amount of pesticide usage for the control of insect pests in cotton has become a psycho-socio-economic problem to the cotton growers. In addition, sole reliance on pesticide usage created agro-ecological problems *viz.*, pests resurgence and resistance, destruction of natural fauna, health hazards and environmental pollution [6].
Therefore, ecofriendly pest management approaches have become a promising option to overcome production constraints. The IPM technologies for cotton have been developed, validated and implemented by cotton growers throughout the country are location specific, economically and ecologically viable [11, 9]. Despite yield and economic advantages of HDPS cotton, especially in rainfed and marginal soils, the adoption of closure spacing and high plant density create congenial condition for buildup of pests population [10, 4, 8, 15, 3]. Under these circumstances, the required quantity of applied pesticides may not reach the targeted pests. Hence, IPM approaches would be viable option which affords protection against all the pests of cotton grown under HDPS. In this context, existing adoptable IPM practices under HDPS cotton has been validated.

2. Materials and Methods
The present field experiment was carried out at Main Agricultural Research Station, Dharwad, Karnataka during *kharif* 2016-17 involving ARBC-64 (compact non-*Bt* variety) and Bindaas BG II (commercial *Bt* hybrid). The both genotypes were sown under HDPS (45 × 15 cm) as well as regular (normal) spacing (90 × 60 cm) following all recommended package of practices. The IPM module integrated with seed treatment with imidacloprid 600 FS @ 10 mL

per kg, okra *Abelmoschus esculentus* (L.) Moench as trap crop, installation of pheromone traps, spraying with selective insecticides *viz.*, nimbecidine 300 PPM @ 5 mL L^{-1}, fipronil 5 SC @ 1 mL L^{-1}, dinotefuran 20 SG @ 0.3 g L^{-1} and profenophos 50 EC @ 2.0 mL L^{-1} to contain sucking pests, based on economic threshold level (ETL). At later stage of crop lamda cyhalothrin 5 EC @ 0.5 mL L^{-1} was sprayed to contain the infestation of PBWs. Whereas in ARBC-64 (non-*Bt* variety), an additional intervention of Spinosad 45 SC @ 0.1 mL L^{-1} was taken to manage the bollworms. Sequential details of module imposition are given in Table 1.

Observations on incidence of pests were recorded on 10 randomly selected plants in each block at weekly interval avoiding border rows. The incidence of sucking pests *viz.*, thrips, aphids, and leafhoppers were recorded from top, middle and bottom leaves on three randomly selected leaves. The population of mirid bug was recorded from the square formation stage on 25 squares in each block. The observations on flower bud maggot infestation were initiated from bud formation stage. Percent flower bud damage worked out based on total number number of damaged and non-damaged flower buds. The incidence of *Helicoverpa armigera* (Hubner) larvae was made on whole plant basis from square formation stage. The larvae of PBW were observed by dissecting 25 green bolls from each treatment and expressed as number of PBW larvae per 25 green bolls. During the observation on PBW larval counts, the number of damaged bolls due to PBW were also counted and expressed as per cent green boll damage. At the time of picking, 100 fully opened bolls were collected and based on total number of locules and damaged locules observed, percent locule damage was calculated. The population of predator's *viz.*, spiders, coccinellids (grubs and adults) and *Chrysoperla* spp. (grubs) were recorded on whole plant basis from randomly selected plants and averaged to predator population per plant.

Before harvesting of seed cotton, the number of good opened bolls (GOBs) and bad opened bolls (BOBs) were recorded from 10 randomly selected plants in each treatment. The data has been averaged to per plant and presented as GOBs and BOBs per plant. Seed cotton yield was recorded block wise separately and later extrapolated to q ha^{-1} for each blocks. Finally, cost economics (net profit and B:C ratio) of each HDPS and regular spaced block was worked by considering the cost of protection, cost of production, total cost of cultivation and value of the seed cotton yield of the respective module.

The observations of experiment were subjected to statistical analysis as seasonal mean data by using student "t" test after suitable transformations, at 5 per cent level of significance and $(n_1 + n_2) - 2$ degrees of freedom.

3. Results and Discussion

3.1 Incidence of sucking pests, flower bud maggot and bollworms

In the present investigation, non-significant difference was observed in seasonal mean population of sucking pests, flower bud maggot and bollworms under HDPS and regular spacing in both genotypes and the population remained low throughout the season and seldomly reached ETL, owing to integration of various ecofriendly approaches and need based application of selective insecticides under IPM module. The seasonal mean population of sucking pests *viz.*, thrips, aphids, leafhoppers was 5.63, 2.58, 1.06 and 4.73, 2.14, 0.79 per three leaves under HDPS and regular spacing, respectively on ARBC-64, while the population on Bindaas BG II were 6.60, 2.98, 1.31 and 5.82, 2.31, 0.80 per three leaves under HDPS and regular spacing, respectively. Further, mean population of mirid bugs recorded was 5.21 and 5.06 per 25 squares under HDPS as compared to 4.56 and 4.14 per 25 squares under regular spacing in ARBC-64 and Bindaas BG II, respectively. Similarly, per cent twisted flower buds due to flower bud maggot damage was 4.03 and 4.11 per cent under HDPS as compared to 3.75 and 3.75 per cent under regular spacing in ARBC-64 and Bindaas BG II, respectively (Table 2).

The larval population of *H. armigera* was not observed on Bindaas BG II due to resistance afforded by *Bt* toxins, while on ARBC-64 mean population was low with 0.13 and 0.09 larvae per plant owing to additional spray of spinosad 45 SC provided protection, under HDPS and regular spacing, respectively. The incidence of PBW larvae on green bolls was comparatively higher (4.31 and 4.75/25 bolls) under HDPS as compared to 3.63 and 3.81/25 bolls under regular spacing in both genotypes, respectively but the difference remained non-significant. Similarly in ARBC-64, green boll damage, locule damage was 8.75, 6.14 and 7.25, 5.84 per cent, while in Bindaas BG II damage was 9.75, 6.80 and 7.75, 6.00 per cent under HDPS and regular spacing, respectively (Table 3).

The IPM components *viz.*, seed treatment with imidacloprid 70 WS, okra as a trap crop, installation of pheromone traps, sparying of 5 per cent NSKE, detopping at 80 DAS, target specific chemical interventions with selective insecticides against sucking pests and bollworms, resulted significantly lower population of all major pests and their damage [12]. The lower pests infestation was recorded in HDPS cotton under the umbrella of IPM practices [2].

3.2 Natural enemies

The observations made on beneficial fauna indicated higher population under HDPS as compared to regular spacing, though the difference remained non-significant, which might be due to presence of higher pest load under HDPS. The seasonal mean population of spiders, coccinellids, *Chrysoperla* spp. was 0.93, 0.48, 0.28 and 0.84, 0.40, 0.21 per plant under HDPS and normal spacing, respectively in ARBC-64 while on Bindaas BG II population was 0.91, 0.45, 0.26 and 0.85, 0.41, 0.25 per plant, under HDPS and regular spacing, respectively (Table 4). The higher incidence of spiders and coccinellids was recorded under closer spacing of 90 × 45 cm than wider spaced crop (120 × 60 cm) [8].

3.3 Yield and economics

The number of good opened bolls (GOBs) per plant was 7.40 and 7.33 under HDPS, while under regular spacing GOBs was 38.65 and 39.30 per plant on ARBC-64 and Bindaas BG II, respectively. Similarly, bad opened bolls (BOBs) was 1.77 and 2.10 per plant in HDPS, while under regular spacing it was 5.62 and 6.55 per plant. Nonetheless, higher seed cotton yield was recorded under HDPS (26.12 and 23.95 q/ha) as compared to regular spaced crop (20.35 and 21.20 q/ha) in both genotypes (ARBC-64 and Bindaas BG II, respectively) owing to higher number of plants per unit area which contributed more number of bolls per unit area under HDPS.

In cotton under different plant spacing of 15 × 75 cm, 22.5 × 75 cm and 30 × 75 cm, number of bolls per plant increased significantly as plant spacing increased *i.e.,* 21.89, 25.33 and 28.67 bolls per plant, respectively, while number of plants per unit area decreased significantly as plant spacing increased, 8.61, 5.71 and 4.26 plants per meter square, respectively and seed cotton yield was 22.01, 25.12 and 22.84 q ha^{-1}, respectively [1].

Comparatively higher cost of plant protection was recorded in HDPS owing to the requirement of high quantity of insecticides, okra seeds and labour costs for spraying as compared to regular spacing. Similarly, higher cost of production was also observed under HDPS owing to higher seed rate, higher fertilizer dose and more labour requirement. Nonetheless, higher net profit was recorded in ARBC-64 grown under HDPS (₹ 90,485/- per hectare), followed by Bindaas BG II grown under regular spacing (₹ 68,215/- per hectare) and HDPS (₹ 67,508/- per hectare). Whereas, the lowest net profit was observed on regular spaced block of ARBC-64 (₹ 66,976/- per hectare). Irrespective of the genotypes, the highest B:C ratio was registered in ARBC-64 under HDPS (2.70).

Table 1: Components of adoptable IPM modules in *Bt* and non-*Bt* cotton genotypes

Targeted pests and action time	Bindaas BG II (*Bt*) Treatments	ARBC-64 (non-*Bt*) Treatments
Sucking pests (sowing time)	Imidacloprid 600 FS treated seeds @ 10 mL/kg seed	Seed treatment with Imidacloprid 600 FS @ 10 mL/kg seed
For bollworm eggs and shoot weevil trapping (at sowing)	Okra as trap crop at 1:20 ratio	Okra as trap crop at 1:20 ratio
Sucking pests (at 35 DAS)	Nimbecidine 300 PPM @ 5 mL/L (Spray)	Nimbecidine 300 PPM @ 5 mL/L (Spray)
Monitoring of American bollworm moth activity (at 50 DAS)	Helilure, pheromone traps @ 5/ha	Helilure, pheromone traps @ 5/ha
Sucking pests (at 55-60 DAS)	Fipronil 5 SC @ 1 mL/L (Spray)	Fipronil 5 SC @ 1 mL/L (Spray)
Sucking pests (at 70 DAS)	Dinotefuran 20 SG @ 0.3 g/L (Spray)	Dinotefuran 20 SG @ 0.3 g/L (Spray)
Monitoring of PBW moth activity (at 75 DAS)	Gossyplure, pheromone traps @ 5/ha	Gossyplure, pheromone traps @ 5/ha
American bollworm (at 75 DAS)	_	Spinosad 45 SC @ 0.1 mL/L
Mirid bugs (at 90 DAS)	Profenophos 50 EC @ 2 mL/L	Profenophos 50 EC @ 2 mL/L
Pink bollworm (at 135 DAS)	Lamda cyhalothrin 5 EC @ 0.5 mL/L	Lamda cyhalothrin 5 EC @ 0.5 mL/L

Table 2: Incidence of sucking pests and flower bud maggot (twisted flower buds) under HDPS and recommended normal spacing in adoptable IPM module

Treatments		*Thrips/3 leaves	*Aphids/3 leaves	*Leafhoppers /3 leaves	#Mirid bugs/ 25 squares	##Twisted flower buds (%)
ARBC-64	HDPS (45 × 15 cm)	5.63	2.58	1.06	5.21	4.03
	Recommended normal spacing (90 × 60 cm)	4.73	2.14	0.79	4.56	3.75
Bindaas BG II	HDPS (45 × 15 cm)	6.60	2.98	1.31	5.06	4.11
	Recommended normal spacing (90 × 60 cm)	5.82	2.31	0.80	4.14	3.75
"t" test	HDPS vs Recommended normal spacing in ARBC-64	Non-significan (0.35**)	Non-significant (0.51**)	Non-significant (0.58**)	Non-significant (0.90**)	Non-significant (0.37**)
	HDPS vs Recommended normal spacing in Bindaas BG II	Non-significan (0.01**)	Non-significant (0.67**)	Non-significant (1.02**)	Non-significant (1.11**)	Non-significant (1.53**)

*Mean of 21 weeks #Mean of 14 weeks ##Mean of 11 weeks
**t-values were less than t-table values (2.02, 2.06 and 2.09)

Table 3: Incidence of bollworms and their damage under HDPS and recommended normal spacing in adoptable IPM module

Treatments		**Helicoverpa armigera* larvae/ plant	*PBW larvae/25 bolls	*Green boll damage (%)	#Locule damage (%)
ARBC-64	HDPS (45 × 15 cm)	0.13	4.31	8.75	6.14
	Recommended normal spacing (90 × 60 cm)	0.09	3.63	7.25	5.84
Bindaas BG II	HDPS (45 × 15 cm)	0.00	4.75	9.25	6.80
	Recommended normal spacing (90 × 60 cm)	0.00	3.81	7.75	6.00
"t" test	HDPS vs Recommended normal spacing in ARBC-64	Non-significant (0.18**)	Non-significant (0.45**)	Non-significant (1.26**)	Non-significant (0.52**)
	HDPS vs Recommended normal spacing in Bindaas BG II	Non-significant (0.00**)	Non-significant (0.68**)	Non-significant (1.76**)	Non-significant (1.67**)

*Mean of 16 weeks #Mean of five pickings
**t-values were less than t-table values (2.04 and 2.30)

Table 4: Natural enemies under HDPS and recommended normal spacing in adoptable IPM module

Treatments		*Spiders/ plant	*Coccinellids/ plant	**Chrysoperla* spp.
ARBC-64	HDPS (45 × 15 cm)	0.93	0.48	0.28
	Recommended normal spacing (90 × 60 cm)	0.84	0.40	0.21
Bindaas BG II	HDPS (45 × 15 cm)	0.91	0.45	0.26
	Recommended normal spacing (90 × 60 cm)	0.85	0.41	0.25
"t" test	HDPS vs Recommended normal spacing in ARBC-64	Non-significant (1.08**)	Non-significant (1.26**)	Non-significant (1.50**)
	HDPS vs Recommended normal spacing in Bindaas BG II	Non-significant (0.87**)	Non-significant (0.64**)	Non-significant (0.20**)

*Mean of 25 weeks
**t-values were less than t-table value (2.01)

Table 5: Yield parameters and economics

Particulars	ARBC-64		Bindaas BG II	
	45 x 15 cm	**90 x 60 cm**	**45 x 15 cm**	**90 x 60 cm**
GOB per plant	7.40	38.65	7.33	39.30
BOB per plant	1.77	5.62	2.10	6.55
Seed cotton yield (q/ha)	26.12	20.35	23.95	21.20
Value of yield (₹/ha)	1,43,679	1,11,901	1,31,728	1,16,573
Protection cost (₹/ha)	10,720	8,862	8,840	7,212
Cost of production (₹/ha)	42,474	34,824	55,380	42,385
Total cost of cultivation (₹/ha)	53,194	43,686	64,220	49,597
Net profit (₹/ha)	90,485	68,215	67,508	66,976
Returns per rupee spent (B:C ratio)	2.70	2.56	2.05	2.35

Current average market rate for kapas Rs. 5,500/q

4. Conclusion
Under the IPM module, irrespective of genotypes, non-significant difference was observed among pests population under HDPS and normal spaced crop. Further, HDPS blocks registered higher seed cotton yield of 26.12 and 23.95 q/ha as compared to 20.35 and 21.20 q/ha under normal spacing with net profit of Rs.90,485/- and Rs.67,508/- per hectare under HDPS compared to Rs.68,215/- and Rs.66,976/- per hectare in normal spaced crop in ARBC-64 and Bindaas BG II, respectively. So existing IPM module validated under HDPS but it requires comparatively higher amount of insecticides.

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