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Impact evaluation of insecticide resistance management strategies in cotton under Technology Mini-Mission on Cotton (*Gossypium hirsutum*)

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ABSTRACT

A location specific Insecticide Resistance Management (IRM) strategies module developed for pest management in *Bt* and Non Bt cotton was implemented and evaluated in cotton (*Gossypium hirsutum*) growing villages of Haryana .Large scale field evaluation of the technology indicated the reduction in number of insecticidal sprays (30.65%, 24.29% in 2007–08 and 2008–09, respectively) and shift in pesticide use pattern in adopted villages. Though the populations of sucking pests were not significantly different in IRM and Non IRM fields but total consumption of insecticides was 26.79% and 31.24% higher during 2007–08 and 2008–09, respectively in Non-IRM over IRM villages. Moreover, IRM adopted villages of Sirsa, Fatehabad and Hisar harboured higher number of natural enemies as compared to non IRM villages. The yield was found significantly higher in fields where IRM strategies were adopted (21.60 and 23.79 q/ha) over field that adopted farmers practices (i e non IRM) (20.74 and 21.61 q/ha) during 2007–08 and 2008–09.

Key words: Beneficial, IRM, Non-IRM, Strategies, Sucking pests, Yield

Insects impose severe limitations on profitable cotton (*Gossypium hirsutum* L.) production in India. Key pests prior to the introduction of Bt-cotton were the *Helicoverpa armigera*, *Earias* spp and *Pectinophora gossypiella*, whereas Bt-cotton suffered damage due to jassid, whitefly, thrips, and tobacco caterpillar. Mealybug and miridbug have been added recently (Nagrare *et al*. 2009 and Monga *et al*. 2009). Earlier, conventional insecticide use represented a significant proportion of variable cost of cotton production, a powerful driver for the selection of insecticide resistance and of rising environmental concerns.

Insecticide resistance is a severe problem; especially in cotton production worldwide (Luttrell *et al*. 1994). It is the goal of resistance management to preserve useful pesticides by slowing or preventing development of resistance in pests. In recent years greater emphasis has been placed on insecticide resistance management (IRM), based on the principles of Integrated Pest Management (Russell 2004). Synthetic pyrethroids, which occupied 50–70 percent of the insecticides sprayed over the cotton in India, evidenced a very high level of resistance. Over 70% of all cotton insecticide applications in North India and 33% in Central India are mixtures (Iyengar and Russell unpublished) which is responsible for the cross resistance. Not only bollworms, whitefly resistance to cypermethrin and chlorpyriphos has been widely reported from USA, Central America, Europe, Pakistan, Sudan and Israel, and high *B. tabaci* resistance levels to organophosphates in Sudan were also demonstrated. The cotton whitefly, *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae) has also emerged as a major pest of cotton and other crops in the tropical and sub-tropical regions of Asia, Africa and the Americas, and in a survey conducted, 16 of the 27 cotton producing countries reported *B. tabaci* as a major pest (Butler and Hennebery 1994).

India has one of the largest growing areas of cotton in the world. Cotton is highly susceptible to insect pests and consumes more than 50% of total insecticides used in this country, a fact which leads to severe problems in pest control (Kranthi *et al*. 2002). Excessive and indiscriminate use of insecticides against cotton pests has created several problems such as insecticide resistance, pest resurgence, destruction of beneficials and non-target organisms and crop failures leading to socio-economic problems. After the introduction of *Bt* cotton the spray application targeting bollworms had reduced significantly. Simultaneously the insecticide use for sucking pests had increased and a varying degree of resistance in leafhopper population against insecticides has been recorded from all zones of cotton in India (Kranthi *et al.* unpublished).

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So the emphasis of the IRM strategies disseminated in the adopted villages under the project was to reduce the number of insecticidal applications against insects, quantity of insecticides/ha, delay in resistance to insecticides in sucking pests to commonly used insecticides and to conserve the population of beneficial. Special initiatives for the management of mealybug were also given.

MATERIALS AND METHODS

Seventy five villages (25 each in district Sirsa, Hisar and Fatehabad) of Haryana were adopted for dissemination of a set of IRM strategies during 2007–08 and 2008–09. The villages selected during 2007–08 were not covered during 2008–09 under the programme so as to facilitate a wider reach of the IRM programme. Five villages adjoining to IRM villages were kept under observation and these constituted the non IRM villages or villages not adopting the recommended IRM practices. A total number of 50 farmers from each village were selected as a target group for dissemination of the following IRM strategies. Though the majority of area in these Districts of Haryana State is under Bt cotton but the IRM strategies disseminated cover both Bt and Non Bt cotton (Table 1).

The base line data variables, i e cotton type planted (cultivar/brand), spacing (R×R, P×P), planting date, seed rate, use of fertilizers, number of irrigations (all farmers used flood irrigation), number and type of product used in application of broad spectrum insecticides, herbicides and IGRs, and yield obtained were collected from the selected farmers of the adopted villages prior to the implementation of the project so as to study the impact of the project before and after implementation. However, to study the impact of IRM strategies disseminated in IRM villages over non IRM villages, the observations on data variables like number of insecticidal sprays applied, quantity of insecticide consumed/ha and group of insecticides used were recorded irrespective of Bt and non Bt. But the data recording like incidence of sucking pests, abundance of natural enemies, was done from the fixed locations from Bt cotton cultivars only as the majority of the area was under Bt cotton cultivation. The weekly data from 10 locations at each village were recorded both from IRM and Non-IRM farmers' field throughout the season. In case of Non-IRM conditions farmer adopted their own way of plant protections (farmer's practices), selection of insecticides etc and no interventions in the form of advice was done. Finally the data on yield was also recorded. The data was subjected to statistical analysis taking into consideration the impact of the project in terms of prior to and after implementation of project in IRM villages. Pair wise comparison (t- test) between IRM and Non-IRM villages was carried out for sucking pests, beneficial and yield.

RESULTS AND DISCUSSION

These IRM strategies disseminated relied on use of threshold and a logical window framework for restriction and rotation of insecticide groups. It also emphasized window based placement of different chemical and non chemical methods for the management of insect pests. Over the last two years IRM window based strategies were implemented with the aim to slow or reverse the development of resistance

Table 1 Detail of the IRM strategies*

Window-I Up to 60 days	Window-II 60–90 days	Window-III 90–120 days	Window-IV >120 DAS
1. Cultivation of sucking pest tolerant genotype (Bt or non-*Bt*)	1. Use Ha NPV on *Bt*-cotton at 50% bollworm infected plant	1. Peak bollworm infestation	1. Use pyrethroids ETL-based spray for PBW
2. Grow non-*Bt* cotton at boundaries of *Bt* cotton fields as refugia to avoid resistance in bollworms to cry toxins	2. Use endosulfan/any other safer insecticide	2. Use indoxicarb once only on non-*Bt* cotton	2. Use pheromone trap for monitoring of pink bollworm moth
3. Avoidance of chloronicotinyl and organophosphate groups of insecticide for sucking pests	3. Do not spray against minor lepidopteron	3. Use organophosphate or carbamates only once either on *Bt* or non-*Bt* cotton	
4. Stem or soil application of dimethoate or acephate at 30–40 DAS and 50 DAS	4. Do not spray *Bt* based formulation		
5. Neem oil @ 2.5 l/ha during the early part of the season	5. Use spinosad or emamectin benzoate only on non-*Bt* cotton for bollworms at ETL		

*Special initiative for mealybug like spot application, use of safe insecticides, uprooting and destroy of affected plants, management of weeds and conservation of the potential parasitoid and predators.

in the insect pest, to the major insecticide groups. The IRM strategies demonstrated in three districts of Haryana states (Sirsa, Hisar and Fatehabad) involved 10 355 farmers and 24 065 ha area during 2007–08 and 2008–09, respectively. Initially the farmers were educated about the IRM strategies and its window based positioning based on the crop growth period. A number of trainings, field days and field visits were conducted to demonstrate these strategies in the districts. Location specific IRM strategies were implemented as indicated in Table 1.

Impact of IRM strategies on pesticide use in Bt cotton before and after the implementation of the project in IRM villages: *Bt* cotton has inbuilt resistance to *H. armigera, E. insulana, E. vitella* and *P. gossypiella*. Transgenic cotton was subjected to IRM strategies with fewer broad-spectrum insecticides as well as use of relatively safer insecticides at ETL. Stem/spot application for management of sucking pests including mealy bug was resorted and the results indicated that impact of use of narrow spectrum insecticides over broad spectrum does not reduce control of insects (Table 2).

As per the baseline data collected for both years (2007 and 2008) from the IRM adopted villages prior to the implementation of project, the average number of insecticidal sprays applied by the IRM farmers for sucking pests were 3.09, 3.10 and 2.74 and for bollworms (the bollworm spray was for small area still under conventional cotton and not for transgenic cotton) 1.77, 2.42 and 0.56 in Sirsa, Fatehabad and Hisar, respectively. Window based positioning of IRM strategies reduced the number of sprays to 2.26, 2.15 and 1.58 (t-cal> corresponding p values) for sucking pests and 1.45, 1.81 and 0.38 for bollworm (t-cal>corresponding p values) respectively for Sirsa, Fatehabad and Hisar after the implementation of the project (Fig 1). This clearly indicated the impact of rational use of insecticides that the number of sprays were higher in IRM villages prior to the implementation of the project. The rational use of insecticides and adoption of alternative insect management strategies by IRM farmers after the implementation of the project helped in reduction in the number of insecticidal sprays. Adoption of IPM modules has resulted into reduction in population of sucking pests over recommended plant protection practices with lesser use of insectcides (Patil *et al*. 2011). Even, detopping resulted into reduction in infestation of bollworms in cotton (Renou *et. al*. 2011) in sub-Saharan areas of Africa which eventually reduced the insecticide use.

Impact of IRM strategies in terms of sucking pest's population, number of insecticidal sprays and total insecticide consumed in IRM vs Non IRM villages: Bollworm incidence and damage was negligible both in IRM and Non IRM villages as the majority of area was under transgenic cotton. The population of sucking pests like jassid, whitefly, thrip and mealy bug were recorded at regular intervals from fixed locations of each adopted villages under IRM and Non IRM sown with Bt cotton. The populations of jassid, whitefly, thrips and mealybugs recorded was 2.20, 3.56, 1.44 nymphs/3 leaves, 3.45, 6.99, 1.25 adult/3 leaves, 5.27, 6.45, 5.50/3 leaves and 1.29, 1.57, 1.93/5 cm central shoot, respectively in IRM villages of Sirsa, Fatehabad and Hisar. Whereas under Non IRM, the population recorded was 2.99, 3.59, 1.42 nymphs/3 leaves for jassids, 3.77, 6.69, 1.22 adult/ 3 leaves for whitefly 5.19, 6.39, 5.48/3 leaves for thrips and 1.44, 1.55, 1.89/5cm central shoot for mealybug, in Sirsa, Fatehabad and Hisar, respectively. The population recorded under IRM and in non-IRM villages of Sirsa, Fatehabad and Hisar respectively, were significantly indifferent (Fig 2) (t-calculated < corresponding p values). But the gap in adoption of insecticide group (broad spectrum insecticides, higher doses of chlornicotynil and non adoption of ETL) in

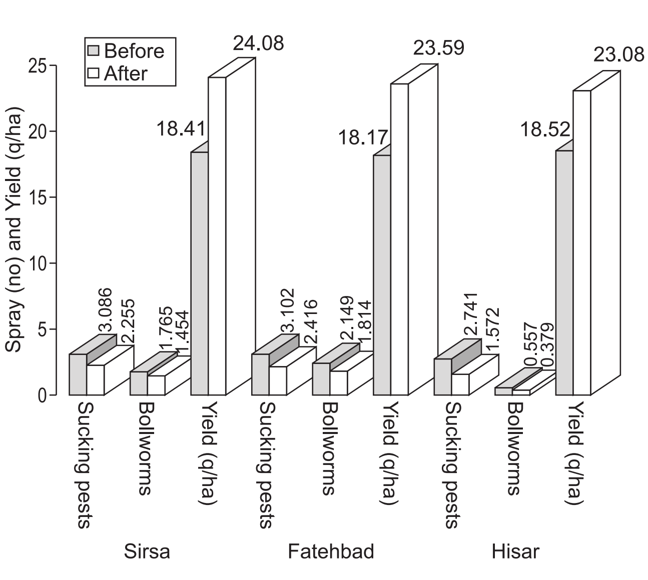

Fig 1 Number of insecticide sprays and yield in IRM adopted villages before and after implementation of project

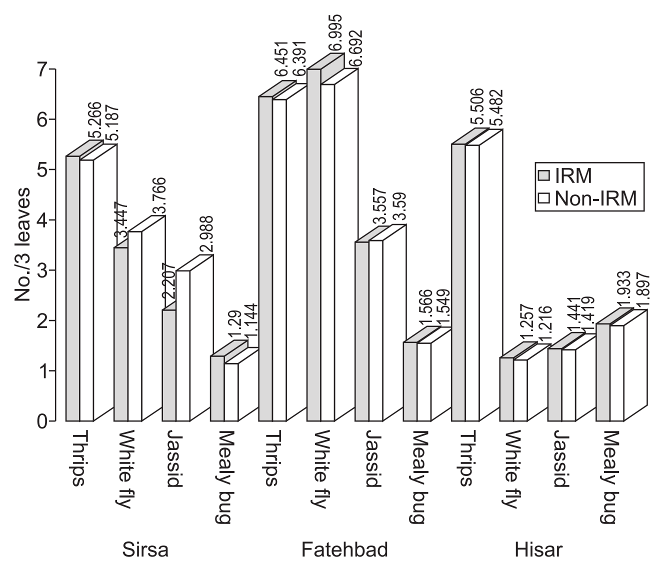

Fig 2 Population of sucking pests in IRM and Non-IRM farmers in different districts of Haryana

Table 2 Shift in pesticide use pattern in IRM adopted villages before and after implementation of project

Stage	Days after sowing	Before project	After project
I	Up to 60 days	Imidacloprid, Thiomethoxam, Acetameprid, Monocrotophos	Stem or soil application of dimethoate or acephate or Neem oil 2.5 lit./ha mixed with Nirma washing powder
II	60–90 days	Thiomethoxam, Lamda-cyhalothrin, Thiomethoxam +Confidor, Spinosad and synthetic pyrithroid Cypermethrin+Monocrotophos	Ha NPV, Endosulfan, spinosad or emamectin benzoate
III	90–120 days	Thiodicarb, Acephate, Profenophos, synthetic pyrithroids, Cyhalothrin+Actara, Cypermethrin+ Acephate, Thiodicarb	Indoxacarb, organophosphate or carbamates
IV	>120 days	Spinosad, Novaluron, Cypermethrin+Acephate	Synthetic pyrithroids for pink bollworm and hand picking of larvae.

non–IRM villages due to lack of awareness led to increase in number of unwanted sprays. In accordance with the present findings, the adoption of the IRM programme, based mainly on economic thresholds and on the use of selectively acting insecticides, resulted in significantly lower incidence of cotton bollworms and of homopteran pests (Aggarwal *et al*. 2006) and more beneficial (predatory bugs and spiders). The findings, low sucking pests populations in IRM over non-IRM in the present studies, lend credence from the studies conducted by Dhawan *et al*. (2009) where population of sucking pests like jassid, whitefly, thrips and grey weevil was also recorded low in IRM villages of Punjab over Non-IRM.

The average numbers of insecticidal sprays in Haryana (Sirsa, Fatehabad and Hisar) were 3.13 and 2.59 in IRM villages as compared to 4.52 and 3.37 in non-IRM villages both during 2007–08 and 2008–09 (Table 2). Under IRM, no chloronicotyl insecticides were used during initial stage and only the spot applications for mealy bugs and neem based insecticides during earlier part of season were applied (Table 1). Both in IRM and Non-IRM villages the spray application and insecticidal consumption was only for sucking pests included with the sprays applied for the foliage feeder especially tobacco caterpillar (*Spodoptera* spp). A total of 30.65% and 24.69% reduction in number of pesticide sprays in IRM over Non-IRM villages of three districts of Haryana were recorded during 2007-08 and 2008-09. The total insecticide consumed was 2.03 and 1.75 litre in IRM and 2.79 and 2.54 l/ha in non-IRM during 2007–08 and 2008–09 with a reduction of 26.79 and 31.24% in IRM over non-IRM during 2007–08 and 2008–09. Total quantity of insecticides used in IRM was significantly less than the non-participatory villages because of blanket spray applied for mealy bug. The visible impact of IRM strategies was recorded in participatory and non participatory farmers. Similarly the awareness created in participatory villages about the role of alternate host on mealy bug infestation and its non-chemical way of management has played an important role in mealy bug management. Similarly, Aggarwal *et al*. (2006) recorded the number of insecticide sprays per season in IRM plots (9.5) was less than in non-IRM plots (14.5). Laboratory tests showed that the IRM strategy resulted in a significant decline (1 to 2.9-fold) in resistance of *H. armigera* larvae to cypermethrin, fenvalerate, endosulfan, methomyl, quinalphos and chlorpyriphos. Under the IRM-IPM programme in Punjab 30% reduction in insecticides consumption and 15% reductions in number of sprays were recorded (Peshin *et al*. 2009). The 41.2% reduction in insecticidal sprays was recorded in Punjab by Dhawan *et al*. (2009) and Dhawan and Randhawa (2009).

Impact of IRM strategies on beneficial insects

The population of natural enemies like, spider (0.63, 0.65 and 0.38 in IRM and 0.36, 0.26 and 0.28 in non-IRM),

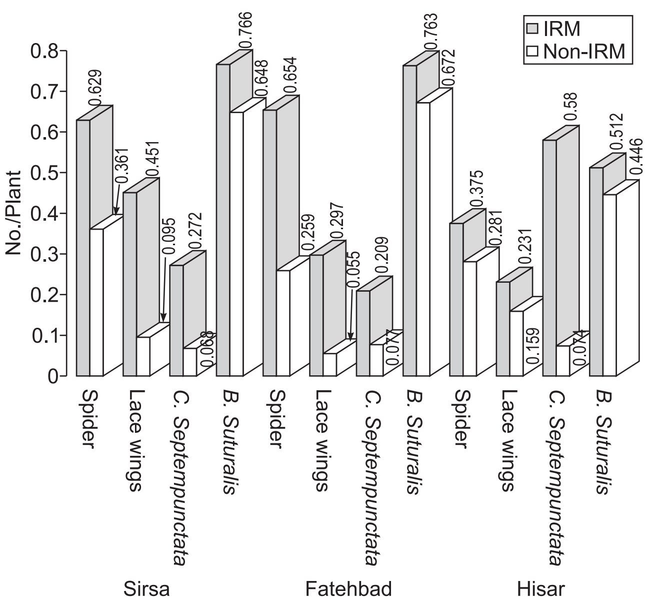

Fig 3 Population of beneficial insect in IRM and Non-IRM farmers in different districts of Haryana

green lace wings (0.45, 0.29 and 0.23 in IRM and 0.09, 0.05 and 0.16 in non-IRM), lady bird beetle (0.27, 0.20 and 0.58 in IRM and 0.07, 0.07 and 0.07 in non-IRM) and *B. suturalis* (0.77, 0.76 and 0.51 in IRM and 0.65, 0.67 and 0.44 in non-IRM) (Fig 3) was affected significantly(t-calculated >corresponding p-values) by over use of insecticide under non-participatory situations as compared to IRM villages where judicious use of insecticides has managed the population of harmful along with conservation of natural enemies. The large scale use of chloronicotynil for sucking pests in non-IRM initiated from earlier part of season has disturbed the natural fauna of crop. The significant difference among population of natural enemies in IRM over non-IRM (significant 2 tailed P value) was observed for all the natural enemies during both years in 2007–08 and 2008–09. The data is supported by record of Dhawan *et al*. (2009) where more number of predators/plant was observed under IRM practices. The strategic positioning of insecticides coupled with ecofriendly technologies were lead to abundance of natural enemies in cotton ecosystem in IRM fields, while these were low in non-IRM fields due to insecticidal sprays (Aggarwal *et al*. 2006, Prasad *et al*. 2009 and Patil *et al*. 2011)

Impact of IRM strategies on yield of cotton

Average yield of cotton has increased to a great extent with the introduction of *Bt*-cotton in combination with adoption of IRM strategies. Average yield of cotton during 2007–08 and 2008–09 were 21.60, 23.79 in IRM and 20.74, 21.61 q/ha in non-IRM, respectively (Table 3). Although yield difference of cotton did not vary significantly in IRM and non-IRM but the reduction in cost of spray in IRM over non-IRM make the difference significant. The C: B ratio obtained during 2007–08 was 1: 4.15 in IRM and 1: 3.67 in non-IRM, whereas in 2008–09 it was 1: 3.96 in IRM and 1: 3.34 in non-IRM. Cotton yield significantly increased in IRM adopted villages as compared to non-IRM practicing as revealed in an analytical study of IRM strategies of cotton adopted by cotton growers of Punjab (Dhawan *et al*. 2009). The economic analysis showed a net return of $ 291.3/ha in IRM plots compared to non-IRM plots but the costs of advice and scouting are not included here. The results demonstrated the superiority of IRM strategy over the present farmer's practice (unnecessary use of insecticides, practically no monitoring) where a significant increase in cotton yield (28.7%) was observed (Aggarwal *et al*. 2006)

The population of sucking pests was not different in IRM and Non-IRM villages but pattern of insecticide use, their dosages and reduction in number of insecticide sprays clearly indicated the impact of the dissemination of the IRM strategies. It is responsible for a more sustainable system due to the abundance of predators and parasitoids.The awareness among the farmers about the judicious use of insecticides will be helpful in dissemination of the strategies among the non-participating farmers of the adjoining villages of area.

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Table 3 Economics of *Bt*-cotton production in the IRM and non-IRM dissemination programme in Haryana

Details	2007–08		2008–09	
	IRM	Non-IRM	IRM	Non-IRM
No of farmers	4 637	407	4 511	800
Total area covered (ha.)	9 354	1 331	11 253	2 127
Average yield (q/ha.)	21.60	20.74	23.79	21.61
Number of spray	3.13	4.52	2.59	3.37
% decrease in spray over non-IRM villages	30.65		24.29	
Insecticides consumption (l/ha.)	2.031	2.797	1.75	2.54
Per cent reduced insecticides consumption over non-IRM villages	26.79		31.24	
Cost of spray (₹/ha)	1 960.86	2 987.78	2 212.52	3 484.67
Reduced cost of spray over Non- IRM villages (₹/ha)	1022.91		1 272.12	
C : B ratio	1: 4.15	1: 3.67	1: 3.96	1: 3.34
Net profit (₹/ha)	37 719	34 714	48 020	40 862
Net profit over non-IRM villages (₹/ha)	3 276.91		7 140.00	

During 2007–08 and 2008–09 price of seed cotton was ₹ 2 300/q and ₹ 2 700/q both for IRM and non-IRM

Net profit=Total income - (Cost of spray+₹ 10 000/ha. added as other costs) during 2007-08 and total income - (Cost of spray+Rs.14, 000/ha added as other costs) during 2008–09. C: B ratio: Gross profit/Cost of cultivation (cost of spray + ₹ 10 000 and 14 000/ha. added as other costs during 2007–08 and 2008–09)

REFERENCES

Aggarwal N, Brar, D S and Basedow T. 2006. Insecticide Resistance Management of *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) and its effect on pests and yield of cotton in North India. *Journal of Plant Diseases and Protection* **113** (3): 120–7.

Butler G D and Henneberry T J. 1994: *Bemisia* and *Trialeurodes* (Homoptera: Aleyrodidae). (*In*) Insect Pests of Cotton, pp 170–97. (Eds.) G A Mathews, J P Tunstall. CAB International, Wallingford, UK.

Dhawan A K and Randhawa P K. 2009. Impact of insecticide resistance management strategy on pest complex in Faridkot district of Punjab. *National Conference on Applied Entomology-2009,* pp 125.

Dhawan A K, Poonam, Kaur K, Aneja A and Singh J. 2009. Knowledge level of farmers in villages about IPM of cotton on Punjab. *National Conference on Applied Entomology-2009,* pp 207.

Kranthi K R, Jadhav D R, Kranthi S, Wanjari R R, Ali S S and Russell D A. 2002. Insecticide resistance in five major crop pests of cotton in India. *Crop Protection* **21:** 449–60.

Kranthi S, Kadu S, Bajaj S, Kakde G, Desai H, Rishi Kumar, Dharajothi and Kranthi K R. 2009. Resistance monitoring to insecticides in cotton jassids (*Empoasca devastans*). *ICAR News* (Submitted).

Luttrel R G, Fitt G P, Ramalho F S and Sugonyaev E S. 1994. Cotton pest management: Part 1. A worldwide perspective. *Annual Review of Entomology* **39:** 517–26.

Monga D, Rishi Kumar, Vijendra Pal and Jat M C. 2009. Mealy bug, a new pest of cotton crop in Haryana. -A survey. *Journal of Insect Science* **22**(1): 100–3.

Nagrare V S, Kranthi S, Biradar V K, Zade N N, Sangode V, Kakde G, Shukla R M, Shivare D, Khadi B M and Kranthi K R. 2009. Widespread infestation of the exotic mealybug species, *Phenacoccus solenopsis* (Tinsley) (Hemiptera: Pseudococcidae), on cotton in India. *Bulletin of Entomological Research* **10:** 1–5.

Patil S B, Patil B V, Vanda N B, Hirekurubar R B and Udikeri S S. 2011. Development and validation of integrated pest management strategies for Bt cotton under rainfed ecosystem. *Indian Journal of Agricultural Sciences* **81**(5): 450–4.

Peshin R, Dhawan A K, Kranthi K R and Singh K. 2009. Evaluation of the benefits of an insecticide resistance management programme in Punjab in India. *International Journal of Pest Management* **55**(3): 207–20.

Prasad N V V S D, Chinna B N V and Krishna M S R. 2009. Implementation of Insecticide Resistance Management strategies on *Bt* cotton. *Annals of Pant. Protection Scence*. **17** (1): 94–8.

Renou A, Téréta I and Togola M. 2011. Manual topping decreases bollworm infestations in cotton cultivation in Mali. *Crop Protection* **30:** 1 370–5.

Russell D. 2004. Integrated pest management for insect pests of cotton in less developed countries. (*In*) *Insect Pest Management, Field and Protected Crops*, pp 141–79. A R Horowitz, I Ishaaya (Eds.). Springer, Berlin, New York.