Impact of Insecticide Resistance Management Strategies in Cotton Ecosystems in North India

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Insecticide resistance management (IRM) strategies were devised by Central Institute for Cotton Research (CICR) with objectives of ensuring sustainable efficacy of insecticides on sucking pests with least possible disturbance to the natural ecosystems. The strategies rely on varieties resistant to sap-sucking pests, bio-pesticides, spot application methods for systemic insecticides, sequential deployment of insecticides with different modes of action and that cause the least disturbance to the crop ecology, in consonance with the integrated pest management (IPM) practices. The strategies were disseminated in main cotton growing districts of Punjab and Haryana during 2010, 2011 and 2012. Data showed that there was a reduction in populations of sucking pests concomitant with an increase in the populations of generalist predators. Implementation of the IRM strategies resulted in effective pest management, yield enhancement and reduction in number of insecticide sprays. The average population of sucking pests i.e. leafhopper, whitefly and thrips per three leaves, in IRM villages of Haryana was 2.72, 5.90, and 5.93 in comparison to 3.26, 6.56, 7.18 in non IRM fields during the three years, respectively. Similarly, the average population of leafhopper, whitefly and thrips in IRM villages of Punjab were 0.84, 2.17 and 0.72 in comparison to non-IRM fields i.e. 1.63, 3.96, 1.48 during the three years, respectively. The Average number of sprays applied for major sucking insect pests was 2.80 & 5.09 in IRM and 3.90 & 7.06 in non-IRM villages of Haryana and Punjab, respectively. Pest management in the IRM fields was mainly based on neem preparations, entomopathogens and insecticides with a relatively safer rating of WHO classification, in place of the conventional organophosphate, synthetic pyrethroid and neonicotinoid group of pesticides or their mixtures. The overall reduction in usage of synthetic chemicals through a rational approach such as IRM resulted in significant ecological and socio-economic benefits in North India.

Introduction

Cotton is cultivated in 11.0 to 12.0 M hectares in India. Genetically Modified cotton with cry (crystal) toxin genes from *Bacillus thuringiensis* (Bt) was introduced in India in 2002 and occupies more than 93.0 per cent of the current area under cotton in India. Cotton is cultivated in about 1.5 M hectares in the three north Indian states, Punjab, Haryana and Rajasthan. Bt cotton occupies more than 95.0 per cent of the area. Bt cotton has been effective in controlling bollworms but are non-toxic to sap-sucking insect pests, predators and parasitoids in the cotton ecosystem. Kranthi (2012) reported that insecticide usage on sucking pests in India increased from 2374 M tonnes in 2006 to 6372 M tonnes in 2011. The reasons ascribed were mainly, the increase in the levels of insecticide resistance in sap-sucking insect pests and the replacement of sucking-pest resistant varieties with the several Bt cotton hybrids. The recent revival of CLCuD (Cotton leaf curl virus disease) is also attributed to the increased infestations of the whitefly vector populations in North India. Insecticide resistance management is a comprehensive program of alternative management strategies, applied to minimizing the development of insecticide resistance. Resistance occurs when a pest, develops an ability to survive doses of an insecticide, fungicide or herbicide that would normally have controlled it. It usually develops after frequent uses of one class of chemical (National Farmers Federation 1997). Evolution of pest resistance to pesticides is an important problem that threatens agriculture worldwide with resistance recorded in at least 546 species of arthropod pests, 218 species of weeds and 190 species of plant pathogens (Fungicide Resistance Action Committee 2013, Heap 2013, Whalon *et al.* 2013). Resistance to insecticides 'a heritable change in the sensitivity of a pest population not only render the insecticide ineffective but often confers cross-resistance to other related compounds usually share a common target site within the pest, and thus share a common mode of action (MoA). Resistance management strategies should incorporate all available methods of control for the insect pest concerned and helps in conservation of ecosystem and management of field-selected and practical resistance that reduces the efficacy of a pesticide and has practical consequences for pest control (Tabashnik 1994, Tabashnik *et al.* 2000, Burkness *et al.* 2001).

Poor efficacy of insecticides due to development of insecticide resistance in insects and performance inconsistencies of biopesticides and biological control have been making IPM unsustainable and require a strong resistance management program. The present insecticide resistance management program, basically on the window based strategies where rotation of group of insecticides (to control cross-resistance), proper dilution and thorough coverage along with use of biopesticides for conservation of natural enemies **(Table 1)** helped in management of insecticide resistance and its impact in terms of pest incidence, natural enemies abundance and economics in cotton ecosystems has been studied in North cotton growing zone of India.

MATERIALS AND METHODS

80 villages (Sirsa and Hisar) of Haryana and 75 villages of Punjab (Mansa, Ferozepur, Muktsar, Bathinda, Faridkot and Barnala) were adopted for dissemination of a set of IRM strategies during 2010-11, 2011-12 and 2012-13, more than 95 per cent of cotton areas of these villages was under transgenic cotton. But the strategies formulated and disseminated for pests management were both for Bt cotton as well as conventional cotton (*G. hirsutum* or *arboreum*) **(Table 1).**Efforts were made to select new villages every year so as to facilitate a wider reach of the IRM program. 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 group of 50 farmers from each village were selected as a target group for dissemination of IRM strategies. 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, IGR's and herbicides, 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 after implementation in the adopted villages.

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. But the data recording like incidence of sucking pests, abundance of natural enemies, was recorded from the 4 fixed locations in each village from Bt cotton cultivars in IRM & non IRM villages 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) of means between IRM and non-IRM villages was carried out for sucking pests, beneficial and yield.

RESULTS

The IRM strategies disseminated relied on use of threshold and a logical window framework for restriction and rotation of insecticide groups' along with incorporation of ecofriendly strategies including different chemical and non chemical methods for the management of insect pests. Over the last three years IRM window based strategies were implemented with the aim to slow or reverse the development of practical resistance in the insect pest to the major insecticide groups. The IRM strategies demonstrated in two districts of Haryana states (Sirsa and Hisar) involved 11086 farmers and 20284 ha area and six district of Punjab state (Mansa, Ferozepur, Muktsar, Bathinda, Faridkot and Barnala) involved 20630 farmers and 49478 ha area during 2010–11, 2011–12 and 2012-13, 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 to create awareness among the farmers.

Impact of IRM strategies on pesticide use in 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 the use of relatively safer insecticides. Stem/spot application of insecticides for management of sucking pests including mealybug 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)** and helped in conservation of natural enemies, found active during the earlier part of cotton season. Need based and neem based insecticide, not prevalent among the farmers, was also promoted during this window, and that helped in reducing sucking pests population.

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. The baseline data collected for three years (2010, 11 and 2012) from the IRM adopted villages prior to the implementation of project, the average number of insecticidal sprays applied by the farmers were 6-7 in Punjab , reduced subsequently to 4-5 for sucking pests after the implementation of the project. Similarly, in Haryana, numbers of insecticidal sprays applied by the farmers were 5 to 6, which were reduced to 2 to 3 after implementation of the project and a significant reduction in total quantity of insecticidal consumption was also recorded **(Table 1).**

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: The population of sucking pests like leafhopper, whitefly and thrips were recorded at regular intervals from fixed locations of each adopted villages under IRM and non-IRM in Bt cotton. The populations of sucking pests recorded was 2.72, 0.84 leafhopper nymphs/3 leaves, 5.90, 2.17 whitefly adults/3 leaves, 5.93, 0.72 thrips nymphs & adults /3leaves, respectively in IRM villages of Haryana and Punjab. Whereas under non-IRM, the population recorded was 3.26, 1.63 nymphs/3 leaves for leafhopper, 6.56, 3.96 adults/ 3 leaves for whitefly and 7.18, 1.48 nymphs & adults/3 leaves for thrips in Haryana and Punjab, respectively. The population recorded under IRM and in non-IRM villages of Haryana and Punjab, respectively were not significantly different (Fig 2) but the reduction in number of insecticidal sprays make the difference significant.

The average numbers of insecticidal sprays in IRM villages of Haryana were 2.64, 2.99, 2.79 and in IRM villages of Punjab were 3.61, 5.57, 6.08 as compared to 3.77, 4.02, 4.32 and 5.52, 6.80, 7.73 in non-IRM villages of Haryana and Punjab, respectively during 2010–11, 2011-12 and 2012–13 **(Fig 1,Table 3)**. Under IRM, avoidance of chloronicotinyl and organophosphate sprays for sucking pest and neem based insecticides and entomopathogens were applied during earlier part of season **(Table 1)**. Both in IRM and non-IRM villages, the spray application and insecticidal consumption was only for sucking pests and was statistically different (p values <0.05). Reduction (%) in number of spray applications recorded was 30.00, 25.74, 35.34 in Haryana and 34.60, 18.09, 17.05 in Punjab in IRM over non-IRM villages during 2010-11, 2011-12 and 2012-13. The total insecticide consumed(liter/ha) in Haryana was 1.95, 2.67, 2.69 liter in IRM and 2.88, 3.77, 3.72 l/ha in non-IRM during 2010–11, 2011-12 and 2012–13 with a reduction (%) of 32.30, 29.08, 27.68 in IRM over non-IRM during 2010–11, 2011-12 and 2012–13. Whereas in Punjab the data pertaining to total insecticide consumed/ha was not available.

In this study, area wide implementation of insecticide resistance management strategies on Bt cotton formulated with several cost effective, eco-friendly novel approaches (botanicals and biopesticides) and rotation of insecticides for managing the pest complex for stabilizing the cotton ecosystem and improving the social economic status of the cotton growers helped in reduction of incidence of sucking pests in IRM field as compare to non IRM fields and reported earlier also (Prasad *et al*, 2009, Singh *et al*, 2011). Stem application, found better in suppression of the sucking pests' population (Wang *et al.* 1994, Ramarao *et al.* 1998) and adopted as earlier season application strategy in the present study especially during earlier part of the season (Kumar *et al. 2012).* Softer options insecticides showed substantially higher gross margins (Hoque *et al*. 2000). The strategies devised both for Bt and non Bt cotton and implemented under the project helped in reduction of sucking pests population in IRM villages over non-IRM villages and reduction in use of insecticide sprays (Rajak *et al.* 1997, Kranthi *et al.*, 2000).Under the IRM-IPM program in Punjab 30 per cent reduction in insecticides consumption and 15% reductions in number of sprays were recorded (Peshin *et al.* 2009). The 41.2 per cent reduction in insecticidal sprays was recorded in Punjab by Dhawan *et al.* (2009); Dhawan, and Randhawa (2009).

Impact of IRM strategies on beneficial insects: Natural enemies deserve special note and predators as well as parasites may slow the rate of resistance development, if mortality from natural enemies is higher for resistant insects. There are number of insecticide which show highly disruptive effects on beneficial as hard option insecticides, in the study avoidance of all such interventions is attempted. The main emphasis in the IRM program was to adopt 'soft option', includes a combination of a restricted set of selective insecticides which have a relatively harmless effect on beneficial insects compared to the alternatives are more important in the early crop (i.e. pre-flowering) phases when beneficial insects are more abundant. The population of natural enemies 0.46, 0.32 in IRM and 0.41, 0.21 in non-IRM of Haryana and Punjab **(Fig 2)** was affected significantly by over use of insecticide under non-participatory situations as compared to IRM villages, though the difference is statistically not significant. The strategic positioning of insecticides coupled with eco-friendly technologies helped in increase in 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; Dhawan *et al* 2009; Prasad *et al.* 2009; Patil *et al.* 2011 and Singh *et al*, 2011). Stem application practiced during the earlier part of season significantly less disrupted predator population (Kumar *et al*, 2012) in the present study

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 in Haryana and Punjab. Average yield (q/ha) of cotton during 2010-11, 2011–12 and 2012-13 in IRM villages of Haryana and Punjab were 23.62, 25.59, 25.26 and 25.86, 18.83, 21.78 respectively. Whereas under non-IRM villages, the yield obtained was 20.96, 21.33, 20.87 and 20.42, 16.95, 19.75 q/ha, 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 2010-11, 2011-12 &2012-13 in Haryana was 1: 3.77, 3.74 & 2.46 in IRM and 1: 3.22, 3.01 & 2.08 in non-IRM villages. C: B ratio obtained in Punjab was 1:4.20, 3.96 & 2.87 and in non-IRM villages it was 1:3.18, 2.29 & 1.99, respectively during three years.

Even though Bt cotton is resistant to bollworms and helped in increasing cotton yield but the incidence of non-target pest species especially sucking pests has made the IRM strategies relevant. By implementation of IRM strategies farmers had realized higher seed cotton yield with a low investment on insecticides by reduced number of insecticidal sprays (Rajak *et al.*, 1997 and Kranthi *et al.*, 2000, Prasad *et al,* 2009 and Singh *et al.* 2011). 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 and Agarwal *et al* 2006).

The population of sucking pests, 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 also 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.