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Cotton Exchange Building, 2nd Floor, Cotton Green, Mumbai - 400 033
Phone: 30063400 Fax: 2370 0337 Email: cai@caionline.in
www.caionline.in

Pink Bollworm Strikes Bt-Cotton

(Dr. K.R. Kranthi, Director of Central Institute for Cotton Research (CICR), Nagpur has completed his Ph.D in Entomology from IARI, New Delhi. He has more than 20 years of experience in the field of cotton research.)

The pink bollworm is back with a vengeance. This insect was a serious concern for cotton in India about 30 years ago. There were very few reports of any major damage by pink bollworm to cotton since 1982 in the country. But all that has changed now. This year, severe damage to bolls by pink bollworm and yield-losses were observed in Bt-cotton in many regions of Gujarat and some parts of AP, Telangana and Maharashtra. More concerning is the fact that the worm is happily chewing up Bollgard-II-Bt-cotton which contains two genes (cry1Ac+cry2Ab) that were supposed to be highly effective in controlling the pest. Studies conducted by ICAR-CICR (Central Institute for Cotton Research, Nagpur) over the past two years, clearly showed that the pink bollworm developed resistance to two Cry toxins deployed in Bollgard-II. It is important to unravel the mystery as to why the worm has returned after 30 years to trouble cotton again. And that too, with a vengeance to break a technology called Bollgard-II that was supposed to be all powerful.

EXPERT's Column

Dr. K.R. Kranthi

I was in Gujarat last week with a team of three senior colleagues of ICAR-CICR. Dr. Sandhya Kranthi, Head Crop Improvement; Dr. A. H. Prakash, Project Co-ordinator and Head of our regional station in Coimbatore and Dr. Venugopalan, Head of the PME unit, were part of the team. We toured across Ahmedabad, Surendranagar, Rajkot, Junagarh, Amreli and Bhavnagar. Our visit was a follow-up to the concern expressed by an earlierteam of experts after their visit to Gujarat. My colleague Dr. Chinna Babu Naik and his team had visited Gujarat in the first week of November to assess pink boll worm infestation on Bollgard-II. Dr. Naik was categorical when he declared that 'this season the pink bollworm has spread across Gujarat mostly in green bolls for second picking that are affected seriously in Junagarh, Amreli, Bhavnagar and Bharuch'.

A woman farmer in Bhavnagar plucked a few green bolls randomly from a plant and pulled out a sickle to open them. She said something angrily in Gujarati, not a single word that I knew, but clearly understood what she conveyed. The interpreter confirmed that she said 'Look, every green boll has this red coloured insect inside, fully grown and feeding on developing seeds'. Another farmer remarked 'Bollgard-II is no longer effective on pink bollworm. We are using insecticides to control it'. The farmer echoed the feeling of many farmers in Gujarat who are just beginning to experience the failure of Bollgard-II to control the pink bollworm. The damage was more especially in the green bolls forsecond and subsequent pickings. Our approximate estimates indicate that Gujarat may have lost 7-8% of its cotton to the pink bollworm this year. More concerning is the fact that the farmer would get a lower price for the second and third picked cotton because of the poor quality. At a time when the market prices are low, this could compound the stress.

I remember my visit to Gujarat in November last year. It was clear that not many farmers were aware of the damage that the pink bollworm was causing to green bolls of Bollgard-II. This year, there was a huge difference. Farmers were not only aware of the impending problem of pink bollworm, but


Pink bollworm larva in damaged boll


Pink bollworm pupa and larva in freshly picked cotton


Pink bollworm damaged cotton at market yard

many also knew precisely how to manage it. Our personal interaction with farmers across Saurashtra this year in mid November, clearly mirrored the enormous efforts that were made by the Government departments and private agencies. These efforts clearly showcase a success story of how combined efforts from a central research institute ICAR-CICR, the Junagarh Agricultural University (JAU), the State Agricultural Department, the Central Ministry, the seed industry, (Krishi Vigyan Kendra) KVKs and NGOs to educate farmers on pest management could help farmers to efficiently manage insect pests to minimise yield losses. It was heartening to note that the weekly advisories issued by CICR on the institute's web site formed the core essence of the management strategies all across the state. It was also clear that wherever the recommendations were followed, the fields had very less infestation at negligible levels in the first picked cotton and as less as 5-10% in the green bolls for second picking. Interestingly, about 60-70% of the farmers whom we met had followed the recommendations.

Surveys conducted by ICAR-CICR showed that pink bollworms were also surviving on Bollgard-II not only in Gujarat but also in parts of AP, Telangana and Maharashtra. Though the following passages describe the situation with focus in Gujarat, the problem seems to be engulfing regions in other states especially where cotton crop is being extended beyond 180 days, sometimes extending it all through the year.

Pink Bollworm

Pink bollworm, Pectinophora gossypiella (Saunders) is presumed to have an Indo-Pak origin.


CICR experts interacting with a farmer in Gujarat

The larvae feed only on a few crops such as cotton, bhendi (okra), Hibiscus, and jute.Eggs are laid on flowers, young bolls, axils of petioles and underside of young leaves. After hatching, the young larvae penetrate ovaries of flowers or young bolls within two days of hatching. Larvae turn pink in colour in 3-4 days after hatching. The degree of pink depends on the food that the larvae eat. Dark pink results from eating maturing seeds. Moths are dirty brown in colour about 5 mm in length. Larvae prefer feeding on developing seeds and generally pupate inside the seeds and bolls. Affected bolls either open prematurely or get badly affected due to rotting. Fibre qualities such as length and strength are lowered. Further the cotton lint in the insect infested bolls gets damaged by secondary fungal infection. The seed-cotton carried to market yards acts as a source for the pest to spread. Pink bollworm generally arrives with the onset of winter and continues to survive on the crop as long as flowers and bolls are available. Long duration cotton allows the pest to thrive for a longer continued period in multiple cycles, thereby affecting the subsequent cotton crop. In the absence of cotton, or as a genetically pre-disposed condition, the pink bollworm undergoes hibernation or diapause that allows it to be dormant for 6-8 months, until the next season.

Symptoms

Stained lint in open bolls: This is a distinct symptom of damage. It occurs in the later stages of crop growth, once the damage is done.

Pheromone moth trap catches: Pheromones are scents that are released generally by female insects to attract male insects. These scents are synthesised artificially and used in traps to monitor the onset and levels of infestation. Pheromones at higher dosages or frequency of lures can also be used in mass trapping and to confuse mating. A good correlation has been obtained between the pheromone trap catches and larval incidence in the field.

Rosette flowers: Flowers do not open fully. They get twisted.

Spots on green bolls: black spots on a green boll

may often be indicative of pink bollworm damage. Pink bollworm damaged bolls often predispose the occurrence of secondary bacterial infection that results in the blackening of boll rind on the outside.

Exit holes on green bolls: A small hole of 1.5 to 2 mm diameter clearly indicates the exit of the insect from the boll.

Cotton In Gujarat

The total cotton area in Gujarat is about 26 to 30 lakh hectares. This year, cotton was sown in 27.58 lakh hectares in the state, including 5.5 lakh hectares under Desi cotton, Gossypium herbaceum. The major cotton growing districts are concentrated in Saurashtra, followed by central Gujarat and north Gujarat. Saurashtra has about 18.5 lakh hectares in Surendranagar (4.8 lakh ha), Amreli (3.9 lakh ha), Rajkot (3.8 lakh ha), Bhavnagar (3.0 lakh ha), Jamnagar (2.3 lakh ha) and Junagarh (0.7 lakh ha). Cotton in central Gujarat is cultivated in about 7.0 lakh hectares in Ahmedabad (2.2 lakh ha), Vadodara (2.0 lakh ha), Bharuch (1.3 lakh ha), Narmada (0.5), Gandhinagar (0.4 lakh ha) and Kheda (0.4 lakh ha). In north Gujarat, cotton is cultivated in about 3.4 lakh ha in Sabarkantha (1.6 lakh ha), Patan (0.7 lakh ha), Mehsana (0.6 lakh ha) and Banaskantha (0.5 lakh ha).

About 5.5 to 7.0 lakh hectares are under Desi (Gossypium herbaceum) commonly called as Wagad cotton, grown mainly in Kutch, Rajkot, Surendranagar, Ahmedabad, Mehsana, Patan and Banaskantha. Except the Wagad cotton, all other cotton is under Bollgard, with 85% of BG-II and rest under BG. Some parts of Gujarat also have illegal versions of Bt cotton, estimated to be less than 0.5 lakh hectares.

Pink Bollworm Reports In Gujarat

2009-2010:In January 2010, Monsanto reported the survival of pink bollworm larvae in Bollgard (Cry1Ac) and not in Bollgard-II (Cry1Ac + Cry2Ab) in Saurashtra region. Studies conducted by CICR on the performance of first generation Bt cotton against pink bollworm showed that there was a slightly higher level of pink bollworm infestation on Bt cotton specifically only in the Saurashtra region. However, the infestation levels were found to be more only in the late stage of the crop and there have been no reports or complaints from farmers about any possible yield loss. A scientific analysis on the reasons for the higher incidence showed that the unusual survival of the pink bollworm in Saurashtra was due to weather conditions that favoured the pest survival and also due to the fact that many farmers in Saurashtra continue to keep the cotton crop in fields for 2-3 extra months with extra irrigation for 1-2 more pickings until the end of March, which favours the multiplication of pink bollworms for the next

Rosetted flower due to pink bollworm

season.The data (www.cicr.org.in AICCIP, All India Coordinated Cotton Improvement Project reports 2009-10) showed that during 2009, there was indeed unusually high level of pink bollworm moth catches in the pheromone traps installed in Junagarh of Saurashtra region. Thus high infestation levels were responsible for the damage and resistance if any,may have also been a contributing factor.

2012-2014:Surveys conducted by CICR showed that pink bollworm larval survival on BG-II was recorded significantly higher in 2012, 2013 and 2014 mainly in Amreli and Bhavnagar districts in Saurashtra. However, larval survival on BG-II was also reported from several other districts of Saurashtra and central Gujarat in November-December of 2014. Farmer complaints were received from Amreli in September 2014 and from Vadodara and Bharuch in October 2014.

CICR deputed a team of scientists regularly every year. Samples of healthy and damaged bolls and surviving pink bollworm larvae were collected by CICR regularly for resistance monitoring and to ascertain the trait purity in the boll samples. Studies in 2014 clearly established that pink bollworm larvae were able to survive inside bolls of authentic BG-II hybrids. About 40-80% of the bolls harboured surviving larvae. Resistance monitoring results unequivocally showed that pink bollworms developed resistance to Cry1Ac, Cry2Ab and Cry1Ac+Cry2Ab in Amreli and Bhavnagar districts.

2015:Reports of pink bollworm damage in BG-II were received in July 2015. Farmers complained of pink bollworm in Amreli, Dhari, Jambusar in Bharuch, Karjan, Shinor-Padara and Daboi in Vadodara during July 2015. Pink bollworm damage was reported from Garaidar Taluka of Bhavnagar in August 2015.

CICR deputed a team of scientists to survey the regions and collect samples for analysis. The team reported extensive occurrence of rosette flower symptoms that are caused due to pink bollworm damage. The damage ranged between 0-80% on

Bollgard II at Bharuch, Vadodara, Anand, Bhavnagar, Amreli, Junagadh, Rajkot, Surendranagar and Ahmedabad districts. Damage ranged between 11.0 to 67.0 % in Amreli on BGII. Occurrence of pink bollworm, so early in the cotton crop of Bollgard II was unusual, but not unexpected.

Reasons For Pink Bollworm Occurrence On Bollgard-II

a) Cultivation of long duration hybrids that serve as continuous hosts of the pink bollworm.

b) Large number of hybrids with varying flowering and fruiting periods that, provide continuous food for the bollworms in an overlapping manner.

c) Long term storage of raw cotton in ginning mills and market yards that serve as a source of pink bollworms to the ensuing crop.

d) Early (April-May) sown crop started flowering that coincided with the minor seasonal peak pink bollworm that occurs in June-July.

e) Pink boll worm populations from Gujarat developed resistance to Cry1Ac and Cry2Ab together. Therefore the larvae are able to survive on BG-II.

f) Squares, flowers and developing seeds in young bolls have less Bt-toxin expression.

g) The segregating seeds in bolls of F-1 hybrid plants accelerate resistance development. India is the only country in the world that cultivates Bt cotton as hybrids. F1 plants harbouring the F1 bolls carry seeds that segregate in the ratio of 9:3:3:1 (Cry1Ac+Cry2Ab in 9; Cry2Ab alone in 3; Cry1Ac in 3 and none in 1). Thus a spectrum of non Bt seeds, seeds with Cry1Ac alone, seeds with Cry2Ab alone and seeds with Cry1Ac+Cry2Ab are present in a single boll. This situation is ideal for resistance development, due to selection of resistance to independent toxins.

h) Extending the crop beyond November. In many fields, extended the crop upto April-May provided continuous availability of cotton all through the year. Over the period 2009-2014, cotton prices were high and farmers extended the crop in about 11.0 lakh hectares of irrigated cotton fields in Rajkot, Surendranagar, Amreli, Bhavnagar and Jamnagar. Pink bollworm is a winter pest. It causes damage mainly in November, which can be prevented. The pupae enter into diapause in December in the absence of cotton crop or crop residues such as stalks. However, if the crop is available beyond November, the pest continues to survive on the fruiting parts. This extended phase intensified Bt-toxin selection pressure and resistance development was accelerated.

Cotton stalks stacked near fields

i) The crop was sown early under drip irrigation in many parts of Saurashtra. The early sown crop together with the extended crop of the previous season provided a continuous crop for the pink bollworm all through the year and facilitated multiplication of the pest with overlapping generations, intensive selection pressure, thus accelerating resistance development.

j) Non-compliance of refugia non-Bt cotton.

k) Lack of timely and appropriate management initiatives, which led to continuous proliferation of the insect pest. Farmers do not initiate ant control measures against any bollworms on Bt-cotton.

l) Surveys conducted by CICR in Saurashtra revealed that a combination of monocrotophos + acephate was sprayed 3-4 times on Bt-cotton by majority of farmers in Junagarh, Amreli and Bhavnagar. Monocrotophos + acephate during early stages of the crop induces growth of fresh green leaves, switches back the crop from reproductive to vegetative phase and delays maturity of the crop. Repeated spraying (3-4 times) of this combination results in staggered flowering and fruiting. Since flowers attract bollworms, there was a continuous influx of the pink bollworm in cotton fields due to continuous staggered flowering, especially wherever moncrotophos + acephate was repeatedly sprayed. Infestation of pink bollworm was high in the open bolls and green bolls of second picking in such fields. Wherever farmers had sprayed synthetic pyrethroids in late October or early November, pink bollworm infestation was negligible. In fields that were not repeatedly sprayed with monocrotophos + acephate, boll bursting was synchronous and pink bollworm was less.

Management Strategies

The following strategies were developed by ICAR-CICR to ensure that Bt cotton continues to be effective for the longest possible time.

a) Regular monitoring of bollworm resistance to Bt cotton including Bollgard-II.

b) Use of the parasitoid Trichogramma bactriae in Bt cotton fieldsfor pink bollworm management.

c) Refugia: Recommend planting of desi cotton/ conventional non-Bt G. hirsutum cotton and late planted bhendi as refugia crops.

d) Timely termination of the crop latest by December and avoiding ratoon and/or extended crop.

e) Utilisation or destruction of crop residues and cotton stalks immediately after harvest.

f) Crop rotation is strongly recommended to break the pest cycle.

g) Short duration single-pick varieties (150 days) provide high yields in high density and escape the pink bollworm.

h) Installation of light traps and pheromone traps in fields during the season and also near go-downs, ginning mills, market yards etc., to trap post season moths.

i) Mass trapping and mating disruption using pheromone traps.

j) Use of 'pheromone traps' and 'green boll dissection' for regular monitoring and initiate control interventions based on economic threshold levels of 8 moths per trap per night and/or 10% damage in green bolls.

k) Insecticides such as quinalphos or thiodicarb may be used in early stages and synthetic pyrethroids after October at economic threshold levels of damage.

l) Strictly avoid spraying pyrethroids before November or any insecticide mixtures at any time to prevent whitefly outbreaks.

m) Select hybrids / varieties that are tolerant to sucking pests. This will help to avoid application of insecticides such as monocrotophos, acephate, thiomethoxam, acetamiprid, imidacloprid or clothianidin. Application of these insecticides, especially at the early stage of the crop results in growth of fresh green leaves, switching back from squaring-flowering to vegetative phase and delays maturity of the crop. Avoidance of these insecticides helps in synchronous early maturity of bolls which helps in the escape of pink bollworm infestation.

Policy Intervention Needed

a) Seed companies must ensure that Cry toxins are present in the hybrids in homozygous form, instead of the segregating heterozygous form as in the current hybrids.

b) Recommendation for refuge in bag at 95:5 (Bt:NBt) seeds may partly help to decelerate the rate of development of bollworm resistance to Bt cotton. The non-Bt cotton seeds should be of the corresponding near-iosgenic hybrid.

Steps Taken BY ICAR-CICR

a) Regular field surveys, pest monitoring and resistance monitoring studies are carried out under IRM programme.

b) weekly advisories http://www.cicr.org.in/weekly_advisory.htmare issued in English and 8 local languages in the CICR web site. Advisories are issued regularly every Wednesday on the CICR website in English and nine regional languages, with mails and alerts sent to the State Agricultural Departments.

c) Voice mail weekly advisories (E-Kapas) to 1,80,000 farmers across India and 11,893 farmers in Gujarat

d) IRM (Insect Resistance Management) campaign through personal visits of CICR project staff and staff of Main Cotton Research Station, Surat under the IRM dissemination programme in 150 field sites across Gujarat.

e) Front-Line demonstrations were conducted through the All India Coordinated Crop Improvement Project.

Conclusion

Insect resistance to toxins is a signal that is dangerous to ignore. The problem can only get worse over the ensuing years, if left unattended. The best way to mitigate the problem is to look for answers in the problem itself. Pink bollworm was a major problem in India 30 years ago, primarily because of long duration varieties and the absence of any potent control measures. The simplest and most potent way to overcome the problem is to take up timely sowing and cultivate early maturing short duration varieties of about 150 days duration. All other management strategies such as avoidance of excess urea + OP insecticides, use of light traps, pheromone traps, bio-pesticides, biological control etc., can rally around such varieties to minimise the damage to zero levels. I earnestly hope that the good collaborative efforts made in Gujarat this year by the Government and private agencies are replicated all across the country to ensure that cotton survives the worm and not vice-versa.

(The views expressed in this column are of the author and not that of Cotton Association of India)