DOW AGROSCIENCES SOLUTIONS FOR COTTON BOLLWORMS IN INDIA

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Abstract

India has the largest area under cotton in the world but has one of the lowest yields per unit area. It has many diverse production segments ranging from subsistence to high technology hybrids and genetically modified (GM) hybrids. Dow AgroSciences LLC (DAS) has a long history of exporting and marketing products to the Indian cotton farmers and is one of the leading insect solution companies today. Products targeting bollworms (*Helicoverpa armigera, Spodoptera litura, Earias vittella and Pectinophora gossypiella*) include chlorpyrifos, chlorpyrifos + cypermethrin, and spinosad. WideStrike[®] is a new generation stacked trait that expresses Cry1F and Cry1Ac proteins in cotton. WideStrike[®] proteins against major cotton bollworms in India was studied. Initial observations from these studies and the potential for WideStrike[®] in India will be discussed.

Cotton in India

In India, cotton is grown on 8 to 9 million hectares annually, which represents 25% of the total global area under cotton (Huesing and English, 2004). It is ranked third in global production, after China and the U.S. (Kambhampati et al., 2005) and contributes around 4% to India's Gross Domestic Product (GDP) and 14% to India's industrial production. Cotton fetches 27% of India's export earnings with a significant 30% contribution to India's agricultural GDP. Around 60 million Indians, with an average land holding of about 2 ha, derive their livelihood from cotton (Barwale et al., 2004, and James, 2003).

Cotton occupies 5% of cropped area and consumes around 52 to 59% of all pesticides in India (Bennett et al., 2005). However, productivity levels are one of the lowest in the world. In 2002, it was approximately one third of China and half of the world's average. Over the last couple of years, productivity has increased marginally and is reported to be 460 kg lint/ha for the current year (Mayee and Rajendran, 2005). Some of the factors attributed to this increase include favorable monsoon rains (two-thirds of the India's cotton area is dependent on timely rains), new chemistries like spinosad, indoxacarb and Bt technology.

Cotton is mainly grown in 9 key states across three geographic regions – South, Central and North. The germplasm, growing conditions and practices vary across these three regions. India produced 240 lakh bales (One bale = 170 kg) in 2005, thus contributing more than 15% of the world lint production. The crop is valued at USD 3.5 billion and the hybrid cotton seed business is valued at USD 130 million. More than 50% of the cotton area is planted with proprietary hybrids and this area continues to grow each year. For 2005, the pesticide market in cotton was estimated to be USD 100 million, of which bollworms alone was USD 66 million (unpublished data).

Cotton production systems are diverse across the cotton growing regions in India. Plant spacing of 120 X 45 cm in irrigated conditions and 90 X 60 cm rain-fed conditions are recommended. Some cotton planting happens all over the year but majority of the crop is sown between July15th - August 15^{th} . This coincides with the monsoon rains in India. In the north zone, most planting is complete by May 31^{st} . The crop duration is generally around 20-25 weeks.

Category	Planting Rate (gm)	Seed Cost (US \$)
Bt hybrids	450-650	35
Non-Bt hybrids	450-650	7-8
Non-Bt varieties	8000-10000	1

Although self sufficient, India is a net importer of cotton, mainly to handle the demands from export oriented textile industry. Efforts to meet these additional needs will need increased output of better quality cotton or augmented imports. Hence, future growth in cotton imports will depend on how well India can manage to improve yield as well quality of fiber.

Bollworm Complex in India

Bollworm complex in India comprises of *Helicoverpa armigera* (Hubner) [Old-world bollworm], *Earias vittella* (Fabricius) [Spotted Bollworm] *Earias insulana* (Boisduval); [Spiny Bollworm], *Pectinophora gossypiella* (Saunders) [Pink Bollworm] (Jalali et al., 2004). Additionally, *Spodoptera litura* (Fabricius) [Tobacco caterpillar], mainly a foliage feeder may become an important pest under certain conditions. Of all the major lepidopteran pests on cotton, *H. armigera* is the most difficult to control and causes loss worth US \$350 million annually (King, 1994). Yield losses from bollworms may reach 50% and the quality of the harvest is affected.

Pesticide Spray Patterns on Cotton in India

Apart from bollworms, various sucking pests like aphids, jassids, thrips and whiteflies also attack cotton. Continuous insect activity during major part of the crop stand period warrants pesticide sprays at regular intervals. A typical spray program with DAS cotton product portfolio is shown below (Table 2).

Days after sowing	Target Pest	Product	Dose (gms or ml/acre)
20	Aphids/Jassids	Pride [®]	20
35	Aphids/Jassids/ Thrips	Pride [®]	20 - 30
50	Early season Bollworms	Dursban [®]	1000
60	Bollworms	Tracer®	75
70	Bollworms + Jassids	Nurelle- $D^{\mathbb{R}}$ + Pride ^{\mathbb{R}}	500+30
80	Bollworms	Tracer®	75
90	Bollworms + Aphids/Whiteflies	Nurelle-D [®] + Pride [®]	500+50
100	Bollworms	Tracer [®]	75
110	Bollworms + Whiteflies	Nurelle- $D^{\mathbb{R}}$ + Pride ^{\mathbb{R}}	500+50
120	Bollworms	Dursban [®]	1000

 Table 2: Window of insect spectrum occurrence and recommended control

Regulation of Transgenics in India

Department of Biotechnology (DBT) is the nodal agency for regulating transgenic material in India. There are four government ministries involved in permitting commercial cultivation of transgenic crops. They are a) Ministry of Environment and Forests, b) Ministry of Science and Technology, c) Ministry of Agriculture, and d) Ministry of Health and Family Welfare. Four levels of committees involved in the process are a) Institutional Biosafety committee (IBSC, formed at the individual institutional level involved in transgenic research), b) Review Committee for Genetic Modification (RCGM, constituted by DBT, oversees research level trials), c) Monitoring and Evaluation Committee (MEC, monitors field performance trials) and d), Genetic Engineering Approval Committee (GEAC, oversees commercial level technology release).

Bt Cotton in India

The application for the import of Bt seeds containing Cry1Ac gene was made in 1996. This gene was transferred into Mahyco's cotton hybrids for control of bollworms on cotton (Farah et al., 2003). After a series of regulatory and biology trials, India allowed commercial cultivation of Bt cotton in 2002. Initially, three Bt hybrids from MAHYCO were permitted at the time of release, and an additional five were approved in 2004 (Kranthi et al., 2005). Currently, there are more than 20 Bt hybrids from MAHYCO, RASI, ANKUR, NUZIVEEDU grown across the three cotton zones in India (Table 3). Area under Bt cotton in India has grown tremendously over the last four years (Fig. 1).



Fig.1: Area under Bt cotton in India

North Zone	Central Zone	South Zone
ANKUR 651	ANKUR 09	MECH 162*
ANKUR 2534	ANKUR 651	MECH 184*
MRC 6304	MRC 6301	MRC 6322
MRC 6301	MECH 12	MRC 6918
RCH 134	MECH 162	NCS 145
RCH 317	MECH 184	NCS 206
	NCS 145	RCH 2
	NCS 206	RCH 20
	RCH 2	RCH 368
	RCH 118	
	RCH 138	
* Not ap	proved for Andhra	Pradesh

Future Bt Cotton Products in India

Around 30 private and public research institutes in India are actively involved in developing transgenic crops for various traits (**Sharma et al., 2003**). In cotton, these include Cry1Ac and Cry2Ab containing BG-II hybrids from Monsanto, Vip-3 gene from Syngenta, Bt fusion gene with Nath Seeds, and Bt gene sourced from a public sector institute with JK hybrids. Dow AgroSciences has imported Cry1F and Cry1Ac containing WideStrike[®] seeds into India and is currently conducting various studies towards deregulation of the product.

India presents tremendous potential for information exchange and collaborative research programs in developing novel insect traits for bollworm and sucking pest resistance, improving drought tolerance and fiber quality, management of disease transmission by insects, and management of resistance development to pesticides and Bt cotton.

Dow AgroSciences in India

Dow AgroSciences India Private Limited, a wholly owned subsidiary of Dow AgroSciences LLC, is the third leading agrochemical company in India. DAS products include insecticides, fungicides, herbicides and growth regulators for various crops. With country headquarters in Mumbai, it has 600 dedicated distributors and 22 warehouses spread across in India. DAS has a comprehensive portfolio for different pests in cotton (Table 4).

Product	Chemical Name	Target pests
Tracer®	Spinosad 45% SC	Helicoverpa armigera
Dursban®	Chlorpyriphos 20% EC	Helicoverpa armigera, Spodoptera litura, and Pectinophora gossypiella
Nurelle D-505®	Chlorpyriphos 50 % + Cypermethrin 5% EC	Helicoverpa armigera, Spodoptera litura and Pectinophora gossypiella
Predator®	Chloropyriphos 50%	Helicoverpa armigera and Spodoptera litura
Imiden [®]	Imidacloprid 17.8 % SL	Jassids, Thrips, Aphids
Pride [®]	Acetamaprid 20% SP	Thrips, Jassids, Aphids, Whitefly

WideStrike[®] Protein Bio-efficacy against Bollworms in India

Laboratory studies were conducted where in Bt proteins; CRY1F, CRY1AC and combination of proteins were mixed with diet and fed to cotton bollworm neonates. Results indicated excellent control of all three borer pests. Efficacy of greenhouse grown WideStrike[®] plants against native cotton bollworms was studied in leaf disc and whole plant bioassay studies. Results obtained from 6, 12, 14, 18th node stage homozygous and hemizygous plants showed excellent control of all three bollworms. Whole plant assays, conducted by caging selected plants and releasing the bollworms also gave excellent control of the bollworms. Thus, WideStrike[®] is effective in providing season-long protection against major cotton bollworms in India

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