Recent Advances in Cotton Production for Efficient Insect Pest Management

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ABSTRACT

Insect pests sometimes cause a complete crop loss in India. Integrated pest management programmes world-wide emphasize the importance of agronomic practices but the bet options are seldom exercised. With the current scenario in India of pest management problems in cotton where none of the methods offer adequate control, it is felt increasingly that one of the reasons for the crisis is neglect of appropriate agronomic practices. This paper describes agronomic strategies for pest management based on all insect ecological aspects studied so far, including crop phenology relative to insect attacks. Strategies that have been demonstrated successfully so far by the Central Institute for Cotton Research (CICR) include crop rotation with sorghum, destruction of crop residues and alternate hosts, selection of sucking pest tolerant cultivars, synchronized sowing with correct spacing for the soil type, paired row planting irrigation, balanced application of organic and inorganic nutrients, intercropping with crops such as cowpea, green gram, foxtail millet or onion, avoidance of intercrops like bhendi, tomato, brinjal, castor bean and removal of weeds with clean cultivation and discouragement of monocropping.

Introduction

Cotton consumes nearly 54% of the total insecticides used in India. The major problems with insecticide use: 1. Use of inappropriate chemicals at incorrect doses, 2. Use of faulty pesticide delivery systems, such as ineffective spray application methods, 3. Badly timed sprays, 4. Availability of substandard chemical formulations and 5. Insect resistance to insecticides. Even if these problems are addressed and farmers trained in the proper use of the appropriate insecticides at the right time with a proper method, most of the current problems would be solved. Biological intervention can be used to support a pest management system basically built through sensible and uncomplicated approaches essentially supported by good agronomic practices that do not aggravate pest problems and preferably help minimize pest populations.

The agronomic factors found responsible for insect outbreaks include:

Staggered sowing. In most parts of India, especially the central zone where more than 90% farmers are dependent on rainfed cultivation, decisions on sowing time are based on the temporal occurrence of rainfall and availability of labour, draught animals and implements. These results in staggered sowing spaced over about a month and half. Staggered sowing results in differential crop growth thus making available a niche for different insects simultaneously. This also leads to the presence, proliferation and spread of more than a single insect pest at the same time. Where germination is poor, either due to poor seed quality or insufficient soil moisture, gap filling is done. Gap filled plants are younger and act as niches for insect pests due to their susceptibility.

Multiplicity of cultivars. Indian farmers have access to more than a hundred different varieties and hybrids. Insect pest problems are aggravated when susceptible cultivars favour pest infestations and thereby act as insect reservoirs for tolerant genotypes.

Imbalanced fertilizers. Overuse of N has adverse effects, causing vulnerability to insect pests. High dose of nitrogenous fertilizers can cause increased insect pest problems as shown from trials at AICCIP Akola (Table 1) and Surat (Table 2).

Monoculture. Continuous cultivation of cotton crop each year in the same field provides a continuum for many insect pests, thereby aggravating infestations. For example, ratooning favours pink bollworm survival and acts as a source for main season crops.

Alternate hosts of insect pests. Many cultivated crop hosts, wild plants and weeds act as hosts to a number of insect pests and help insects to survive throughout the year. Alternate hosts such as castor, bhendi, pigeonpea, chickpea and tomato, favour the multiplication and survival of pests such as jassids, spotted bollworm and American bollworm. Weeds such as *Abutilon* spp. *Sida* spp. and *Xanthium* spp. harbour whitefly populations. *Legascea mollis, Datura metel, Chenopodium album* and many other weeds support *Helicoverpa* populations.

Natural control in cotton

A great deal may be done to reduce the reliance on toxic insecticides in India. In an environment that is

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highly disturbed by the onslaught of chemicals, it is not easy for many insect species, including the natural enemies of certain insect pests, to survive and establish an equilibrium with the host insects. However, it is likely that the intense insecticide use which selects for resistance in pests, also selects resistant entomophages that allow part of the population to survive. Parasites and predators that are regularly observed in the cotton ecosystem include *Chrysoperla* spp., *Cheilomenes* spp., *Apanteles* spp., *Campoletis chloridae*, *Microchilonus* spp. and several tachinid flies and ichneumonids. From a large sample of nearly one million eggs collected over the five years 1993-98 (Kranthi *et al.*, unpublished), it was observed that parasitization due to *Trichogramma* was negligible, with a maximum of about 0.01% during a few months in 1995. This is, however, variable with some studies reporting significant mortality due to parasitoids. The egg/larval parasitoid *Microchilonus curvimaculatus* and larval parasitoid *Campoletis* are regular mortality causing factors in larvae collected from cotton fields, albeit to a lesser extent of 0.1 to 2% as compared to 2-35% in larvae from pigeonpea. *Chrysopa* populations coincide mostly with peak flowering period of cotton while the ladybird beetles, *Cheilomenes* spp. that are regular predators of soft bodied insects such as aphids, occur initially in the season. They must be conserved by avoiding the use of broad spectrum organophosphates during their occurrence. There is a wide range of beneficial fauna, including spiders, in the cotton ecosystem that can help in pest management if they are not disturbed or destroyed.

Drawbacks of biological intervention in the cotton ecosystem

The use of bioagents for cotton pest management has been fraught with difficulties for the following reasons:

- Cotton is cultivated as an annual crop commercially. This system does not provide a sustainable niche for natural enemies. For biocontrol to be effective, continuous releases are required. This is neither possible nor economically feasible.
- Cotton has an indeterminate growth habit that provides a continuous source of food for a wide range of insect pests throughout the season, necessitatinges insecticide use since releases of inundative bioagent seldom prevent the pest from reaching action thresholds. The reliance on chemicals to control a range of insect pests makes cotton an unfavourable environment for sustaining natural enemies.
- Any damage to cotton squares or flowers results in flaring and shedding. Biological control is slow in nature and does not prevent larvae from damaging squares, causing loss of fruiting bodies.
- Production of bioagents is very cumbersome and uneconomical, so the market availability of these agents has been very poor. Moreover, results with bioagent releases in cotton over the past decade have not been consistent and despite the claims of being economically feasible, have not been popular with farmers. The efficacy is marginal and inconsistent and has not convinced farmers to continue their use.

Generally good crop cultural practices hold the key to successful integrated pest management but the field release of biocontrol agents usually takes precedence over good agronomic methods. IPM programmes are often mistakenly considered synonymous with biocontrol programmes, due to over emphasis on the release these agents. Studies at CICR and elsewhere trace poor agronomy as a contributing factor in insect outbreaks. Good agronomic practices are necessary if IPM is to succeed.

Current status of pheromone use and biocontrol strategies in India

Sex pheromones can be extremely valuable for detection, population monitoring, mass trapping, mating disruption and lure and kill. In cotton pest management to date, only monitoring and mating disruption have been found to be feasible, with most of the success reported only for the pink bollworm. Since control of this pest by conventional chemicals is difficult due to the burrowing habit of the insect which keeps it away from insecticide exposure, pheromones offer an attractive method for early detection of moth incidence. This can enable application of insecticides that are toxic to moths. Traps baited with lures have been shown to be important decision making tools in determining effective control action (Dhawan and Sidhu, 1984). Surulivelu (1985) showed that pheromone treatment using hand application of hollow fiber gossyplure dispensers reduced larval infestation. Traps with lures from National Research Institute (NRI), UK. used in Integrated Resistance Management (IRM) field trials in Maharashtra, have been useful indicators of action thresholds at 8 moths/trap/night for three consecutive nights (Kranthi *et al.*, unpublished observations). The value of pheromones in controlling *P.gossypiella* is now well established and they are widely used in countries like Egypt and Pakistan (Critchley *et al.*, 1991). The prospects of using gossyplure in cotton are promising and efforts must be directed to refine the technology to perfection and popularize it, although the simultaneous presence of other cotton bollworms in the field may limit its economic effectiveness.

The *Helicoverpa* pheromones have been mostly considered for detection and population monitoring. However, a consistent relationship between trap catches and field infestation has been elusive (Leonard *et al.*, 1989). Damage and larval densities tend to correlate only marginally with the trap catches and then only at the beginning of the seasonal cycle or when the moth densities are low (Jayswal, Personal communication). The prospect of using the trap catch data for action thresholds has been negated by the high levels of inter-trap variation for *H. armigera* in India (ICRISAT, 1986). Recently, mating disruption experiments with *Helicoverpa* pheromone in the Indian and Pakistan Punjabs have indicated that although the formulation had successfully disrupted mating of female moths in the treatment plots, there was no reduction in either egg or larval numbers (D. Chamberlain, T. Singh and D. Russell, personal communication). It is presumed that the main reason for the lack of progress in the use of mating disruption pheromone technique for *H. armigera* is the high mobility and polyphagous nature of the pest. Though IPM programmes in India have *Helicoverpa* monitoring with pheromone as a key component, the technology in its present state does not appear to offer any meaningful contribution to the cotton IPM strategies.

Microbial control of *H. armigera* in cotton has attracted a lot of attention recently, resulting in the commercialization of at least two major groups of pathogens, HaNPV (Nuclear Polyhedrosis Virus) and *Bacillus thuringiensis.*

Bacillus thuringiensis Berliner (commercial strain Bt var. Kurstaki- HD-1) has been an important component of IPM programmes world over for the past 20 years. However, its field performance in cotton on *Heliothis* spp. had been far from satisfactory since its introduction. Repeated field trials in the Delta and RioGrande Valley of Texas in the 1970s showed that Bt failed to provide satisfactory commercial control (Allen, 1983). This is explicable as *Heliothis/Helicoverpa* spp. feed only sparingly on the foliage and move rapidly on to squares and bolls, where they feed internally thus escaping the toxins. This also applies to the inefficacy of HaNPV that is only effective when the larvae consume a specific number of polyhefral inclusion bodies (PIBs). In addition to NPV and Bts, baculoviruses are rapidly inactivated by UV radiation. When exposed in the open to direct solar radiation, half lives of the NPVs of *Heliothis* spp. and *Spodoptera littoralis* (Boisduval) were less than one day or even only a few hours (in the USA) and less than one hour (in Egypt), respectively (Ignoffo and Couch, 1981., Jones, 1988). The average half-life of *Heliothis zea* (Boddie) NPV on the upper surface of *Gossypium hirsutum* was 12.8 ± 5.1 hours and three quarter-life was 41.25 ± 21.96 hours (Entwistle and Evans, 1985). Inactivation of the NPV also takes place on the alkaline leaf surface of cotton (Jones, 1988) resulting in reduced efficacy.

Yearian and Phillips (1983) reviewed the field efficacy of Bt and the *Heliothis* Baculovirus in Arkansas for several years and concluded that neither microbial product provided adequate control of *Heliothis* spp. in cotton. Beegle (1983) evaluated several Bt strains with activity higher than that of the standard HD-1, but found that an improvement in the larval toxicity did not produce consistent yield increases in field trials conducted over several seasons. The control of *Helicoverpa* with NPV in India was reported to be inconsistent (Jayaraj *et al.*, 1989).

The production cost and market price are high for both NPV and Bt. The cost of a single application of Bt at 1-2 Kg/ha ranges between US $ 60 and 100. The production cost of NPV currently stands at US$ 0.04 (Rs 1.75) per infected larva which yields approximately 2 x 10^9 PIBs, 1500 such larvae (cost US $ 60.0) are required to produce 500 LE (Larval equivalents with one HaNPV LE = 6 x 10^9 PIBs) or 3 x 10^{12} PIBs/ha which is the recommended dose for achieving a meaningful pest control in cotton. This is not affordable in India, as compares to an average expenditure of about US $ 10 per ha if an insecticide were to be sprayed.

Augmentation and Innundative Biological Control

A number of countries have attempted augmentative biological releases for bollworm control mostly with *Trichogramma*, with variable success. Reports of satisfactory control using *Trichogramma* have been primarily from the former USSR, China and Mexico. Though it is not clear on which crops were these used. In 1992 in Uzbekistan, 4000 Kg of *Trichogramma pintoi* Voegele and smaller quantities of *Bracon hebator* Say were applied to cotton fields for control of *H. armigera.* It is reported that insecticide use there has declined from 60,000 tonnes in 1975 to 2000 tonnes in 1992 (Matthews, 1993). A total of eight hectares were reported to have been covered by *Trichogramma* releases in USSR and two million in China (King *et al.*, 1985). In the USA, a number of on-station trials were conducted but the technology was not adopted in IPM programmes in Texas and Arkansas as it was not cost effective (Cate, 1985). In India, a similar situation exists wherein trials on research stations were reported promising (Dhandapani *et al.*, 1992) but records of field successes are rare. Inadequate control with *Trichogramma* was reported from Queensland in Australia (Twine and Loyd, 1984) and hence its use is not encouraged in cotton IPM programmes. The reasons for the popularity of *Trichogramma* in the USSR and a few other countries is mostly due to its lower production cost in these countries as well as other factors, such as lower pest densities (King *et al.*, 1985). The production costs of *Trichogramma* are relatively low in India with cost of releases at US $ 3-5 per hectare and it should have provided a good opportunity for large scale use, but this has not happened. Some of the major reasons appear to be the poor vigour of the insects, the searching ability of the wasps, negligible recovery and weak adaptability that do not allow good control. Control is grossly inadequate when oviposition by *Helicoverpa* is high and continuous throughout the reproductive phase of the crop, which is usually the case in almost all cotton growing areas in the country. It is unlikely that the inundative releases of *Trichogramma* would reduce pest pressure where such persistent egg loads are delivered by moths each night throughout the season especially where efficacy is highly dependent on the time of release, prevailing weather conditions.

The use of other biological control agents such as *Chrysoperla carnea*, or *Mallada boninensis* has been tried in cotton in several countries but without success. The case in India is no different and the production costs seem to be much higher than the normal estimates of US $ 12 per 50,000 to 100,000 larvae that are recommended per hectare in cotton. However the main problem seems to be availability, as production constraints are severe with the technology being cumbersome and complicated. At the given state of art, the technology does not hold promise for a mass culturing and release that can lead to a convincing pest control in cotton.

Crop production practices for good cotton pest management in India

Good agronomy can go a long way to minimizing the need for toxic insecticides. The following strategies were tested during the past three years on-station at the Central Institutes for Cotton Research (CICR) at Nagpur, Coimbatore and Sirsa and in farmers' fields in at least 100 acres in several villages. They were found to be successful in establishing sustainable pest management systems.

- Avoid growing upland cotton (*G. hirsutum*) in orchards as it favours whitefly outbreaks.
- Avoid growing tur, moong and bhendi in and around cotton field as they harbour insect pests.
- Immediately after the season, allow animal grazing in fields and ensure timely removal and destruction of cotton residues, followed by deep ploughing to expose the carry-over population of bollworms.
- Do not stack cotton stalks near fields.
- Hybrids must be grown in medium –deep soils having good drainage
- Application of weedicide Stomp 30EC or Basalin at45EC 2.5 lt/ha and harrow immediately to prevent degradation.
- Harrowing must be done twice after pre-monsoon showers and field should be levelled.
- Prepare a good seed bed to ensure good plant stand
- Grow only Old World, *G. arboreum* cotton in cotton leaf curl virus (CLCV) hot-spot areas
- Only recommended varieties/hybrids from reliable sources should be procured.
- Apply 5-10 tonnes of well decomposed compost or farm yard manure (FYM) /ha before sowing.
- Destroy weeds such as *Sida*, *Abutilon* and *Xanthium* before sowing to reduce spotted bollworm, whitefly and CLCV incidence.
- When available, use acid-delinted seed
- Treat seeds with Ceresan wet or Agallol at 1 g/ltr water and Captan or carbendazim at 2g/kg.
- Grow sucking pest tolerant genotypes. It helps in delaying the first spray, thus conserving the initial build-up of natural enemies. If Jassid tolerant cultivars are treated with imidacloprid or carbosulfan, it is possible to avoid spraying for at least two months.
- Sow at a row spacing of 67.5 cm with minimum in-row spacing of 30 cm for varieties and 75cm for hybrids.
- Apply fertilizers, taking account of the crop history, previous crop and its fertilizer use pattern. Nitrogen rates recommended for *G. hirsutum* varieties range from 40-60 Kg/ha in rainfed and 60-90 Kg/ha in irrigated cotton and for hybrids, 90 Kg/ha in rainfed and 100-120 Kg/ha in irrigated cotton. P and K doses depend on soil test values or, in their absence, N:P:K is used at a ratio of 2:1:1.
- Sowing must be completed by the third week of May in North India and mid July for central and south India (except Tamilnadu).
- Gap filling must be completed within 10 days after sowing
- Thinning should be done within 20 days after sowing.
- First hoeing can be done 30-40 days after sowing, followed by a second after 15-20 days.
- Spotted bollworm can cause damage to growing points initially, hence scouting is necessary during the first two months and removal of affected parts helps in minimizing future damage.
- Set up five pheromone traps per ha for pink bollworm. The action threshold is eight moths /trap/night for three consecutive nights.
- Set up pheromone traps at 5/ha for *H. armigera* to identify brood emergence.
- Do not use any insecticide within three months of sowing, except endosulfan as emergency option against jassids at 2/leaf (resistance levels have been found to be invariably low early in the season), as it is relatively less toxic to natural enemies.
- Avoid use of broad spectrum organophosphates such as monocrotophos, acephate etc. especially as

early season sprays, as these strongly disrupt the natural enemy populations.

- Pyrethroids should be used only once. Either over dose or use as repeated sprays synthetic pyrethroids lead to excessive whitefly flareup.
- Do not spray pyrethroid during or after September as resistance has been found to rise later in the season.
- Consider egg based ETLs for Helicoverpa at one egg/plant and use NPV 500 LE/ha (6 X 10^9 PIB's/LE) or Neem seed kernel extract 20-25 Kg seed/ha can be used as initial sprays. This helps in conservation of natural enemies.
- Resistance levels against certain organophosphate group of insecticides (quinalphos, chlorpyriphos and profenophos) and carbamates such as methomyl have been found to be relatively lower in most populations tested. Hence, it is preferable to use these as effective larvicides during mid-season (Sept-Oct) based on ETLs when the situation warrants.
- Pyrethroid resistance is high in many parts of India and they can be effective on *H. armigers* only on younger larval stages, or adults or if used along with synergists such as sesamum oil. However, pyrethroids are still effective against spotted and pink bollworm. Hence pyrethroids can be used either as early season sprays to target spotted and pink bollworm or *Helicoverpa* moths and young larvae.
- Handpicking of larvae 2-3 days after insecticide sprays effectively eliminates any surviving population which can cause future resistance problems.
- Always use insecticides as need based applications based on threshold levels to obtain better result from the use of insecticides.
- Always target younger stages of *Helicoverpa* as younger stages of resistant larvae are known to be killed at normal recommended doses.
- Rotation of chemical groups helps in preventing the build up of resistance against insecticides, especially carbamates, organophosphates and endosulfan.

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Table 1. Impact of fertiliser rates on insect infestation at Akola.

Fertilizer dose	Infestation / 3 leaves		% damage to bolls /plant
N:P:K	Jassids	Whiteflies	*Helicoverpa armigera*
25:12:0	10.3	9.8	10.5
50:25:0	11.4	10.5	11.8
75:35:0	11.6	10.7	12.0

(courtesy: AICCIP report 1993-94 from Akola)

Table 2. Impact of nitrogen rates on bollworm infestation at Surat.

Nitrogen level	Average % bollworm infestation	
	Open bolls	Loculi
160 kg/ha	20.77	17.59
240 kg/ha	20.54	16.62
320 kg/ha	24.04	18.99
sd at 5%	3.04	N.S

(courtesy: AICCIP report 1996-97 from Surat)