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COTTON IPM AND ITS CURRENT STATUS

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INTRODUCTION

Cotton occupies 5% of the total cropped area distributed among three different agroclimatic zones in India, and consumes 55% pesticide share accounting for 40% of total production costs. This fact signifies the impact of insect pests and the increased agrochemical use in cotton production. Concern over human health and environmental consequences of agrochemicals besides pest resistance to pesticides has been a corner stone from the eighties. Despite the fact that IPM has been in practice for almost a decade and a half, except for realization of natural control operating in field, their conservation and augmentation, better cultural practices, use of resistant cultivars, established monitoring and scouting based economic threshold levels (ETLs) and alternate pest control techniques such as matting disruption through pheromones, use of botanicals and insect pathogens, there has been little reduction in pesticide use. This bulletin presents concisely the status of cotton insect pests, their management, potentialities, constraints and future needs of IPM to augment crop protection for an increased cotton production.

STATUS OF COTTON INSECT PESTS

Indeterminate growth characteristics of the cotton crop offer food and shelter to a broader class of Insecta both directly as well as indirectly. Nearly 130 species of insect pests occur on Indian cotton with a dozen of these arthropods requiring their management for realizing better cotton yields. Existing species associations among insect pests seem to avoid competition among themselves as well as to match with the phenology of cotton growth. Sucking pests viz., jassids (Amrasca biguttula biguttula Ishida), aphids (Aphis gossypii Glover), whiteflies (Bemisia tabaci Gennadius) and thrips, (Thrips tabaci Lindeman) are deleterious to the process of cotton growth and development with their ability to build up to serious proportions as a result of rapid and prolific breeding in cotton plant. The wide range of alternate hosts, especially continuous production of vegetables besides wild hosts facilitate their sustenance in the absence of cotton. While direct effects of sucking pests during early season are visualized in terms of poor crop stand and yield reduction, their late season attack (especially aphids and whiteflies) indirectly decreases cotton fibre quality due to deposits of honey dew on lint. In addition to lint contamination, whiteflies transmit leaf curl virus disease.

The reproductive phase of cotton crop growth suffers damage inflicted by bollworm complex consisting three genera of bollworms viz., Earias, Helicoverpa and Pectinophora. Associated with cotton are two species of the former genera viz., E.insulana (Boisd) and E.vittella (F) and single species of the latter two genera viz., H.armigera (Hubner) and P.gossypiella (Saunders). While alternate host plants of Earias and Pectinophora are chiefly Malvales, Helicoverpa is polyphagous and has become the important bollworm of cotton because of the increased severity of attack in almost all cotton growing areas of the country.

The important foliage feeders are lepidopterans especially semilooper Anomis flava (Fabricius), and Spodoptera litura (Fabricius) and leaf roller Syllepte derogate (Fabricius), although grasshoppers and ash weevils chew or notch off the leaves. These are sufficiently numerous only at times and are insignificant to cause significant yield loss.

Mention has to be made of the stem weevil Pempherulus affinis (Fabricius) wit its occurrence only in Tamil Nadu of south zone deserving control attention during the eighties on account of its ability to reduce crop stand. The incidence has declined considerably since 1988. Stainers viz., red cotton bug Dysdercus cingulatus (Fabricius) and dusky cotton bug Oxycarenus hyalipennis (Costa) are potential late season pests in the rainfed tracts of central zone, but have never deserved any control measures from farmers as their damage is qualitative. The major cotton insect pests among cotton growing zones in India with their damage symptoms and seasonal occurrence are given in Table 1 and 2, respectively. In general, period of peak occurrence is almost similar for insect pests over years; however variations occur on a geographical basis. Of late there has been changes in the status of pest occurrence mainly related to weather, cropping systems, and insecticide use pattern.

Table 1. Major Cotton Insect Pests and Their Symptoms of Damage

Insect pest	Scientific name	Symptoms of damage
Sucking pests		
Jassids	Amrasca biguttula biguttula	Affected leaves curl downwards, turn yellowish, then to brownish before drying and shedding, "hopper burn" stunts young plants
Aphids	Aphis gossypii	Leaf crumpling and downward curling of leaves, sticky cotton due to deposits of honey dew on open bolls.
Thrips	Thrips tabaci	Leaves of seedlings become wrinkled and distorted with white shiny patches, older crop presents rusty appearance from a distance.
Whiteflies	Bemisia tabaci	Upward curling of leaves, reduced plant vigour, lint contamination with honey dew and associated fungi, transmission of leaf curl virus disease
Bollworms		
Spotted & spiny bollworms	Earias vittella & E.insulana	Boremark in main shoot, dried and withered away shoot, twining of main stem due to auxillary monopodia, feeding holes in flower buds and bolls blocked by excrement.

American bollworm	Helicoverpa armigera	Small amount of webbing on small squares injured by young larvae, squares have a round hole near the base, larval frass and flaring of bracts on larger squares, clean feeding of internal contents of bolls, excessive shedding of buds and bolls.
Pink bollworm	Pectinophora gossypiella	"Rosetted" bloom pink larvae inside developing bolls with interloculi movement
Stainers		
Red cotton bug	Dysdercus cingulatus	Feed on developing and mature seeds, stain the lint to typical yellow colour, reddish nymphs seen in aggregations around developing and open bolls.
Dusky cotton bug	Oxycarenus hyalipennis	Associated with ripe seeds, all stages characterized by a powerful smell, discolour the lint if crushed.
Foliage feeders		
Semi-looper	Anomis flava	Causes significant loss of leaf area to young plants, larvae with looping action are seen on plant parts.
Leaf roller	Syllepte derogata	Leaves are folded and larvae are seen in groups amidst fecal materials, commonly seen on leaves at the bottom of crop canopy at low infestation levels, severe infestation defoliates the whole plant.
Spodoptera leafworm	Spodoptera litura	Young larvae in groups skeletinise leaves and older larvae voraciously defoliate leaves
Grey weevil	Myllocerus subfasciatus	Marginal notching- off of leaves

Grass hopper	Cyrtocanthacris ranacea	Defoliation of leaves-partial or full
Root / Stem feeder		
Stem weevil	Pempherulus affinis	Root damage by grubs kills young seedlings, gall like swelling seen on lower stem, wilting of seedlings

Table 2. Seasonal Occurrence of Major Insect Pests of Cotton

Insect pest	Seasons of peak occurrence (zonewise)		
	North	Central	South
Jassids	July-Sep.	July-Nov.	Nov.-Jan.
Aphids	October	July-Feb.	Nov.-Jan.
Thrips	July	Sep.-Oct.	Aug.-Sep
Whiteflies	July	Sep.-Oct.	June-Aug. & Dec.-Jan.
Spotted & spiny Bollworms	July-Sep.	Sep.-Jan.	Nov.-Jan.
American bollworm	Aug.-Oct.	Aug.-Oct.	Nov.-Dec.
Pink bollworm	Aug.-Nov.	Oct.-Nov.	Dec.-April
Stem weevil	-	-	Aug.-Sep.
Semi-looper	Aug.-Sep.	Aug.-Sep.	-
Leaf roller	-	Aug.-Sep.	-
Red cotton bug	-	Nov.-March	-
Dusky cotton bug	-	Dec.-April	-

EVOLUTION OF COTTON PEST MANAGEMENT

As early as 1911, cultural control in the form of removal of cotton sticks by first August every year was made compulsory by law to minimize incidence of pink bollworm on cotton in Madras State. The removal of all crop remains of harvest such as stubbles of cotton was advocated to prevent carry over of pests on the crops during the following season. Early effort at controlling various pests of cotton using pesticides started with commercial availability of DDT in 1940. Their high residual toxicities and the advent of organophosphorus and carbamate insecticides during late 1960's shifted and increased the latter groups of insecticides to be used in insect control. Registration of synthetic pyrethroids during 1983-84 and their usage on cotton from 1984-85, widened the horizons of insect control more specifically the chemical control. Simultaneous with the advent of agrochemicals there has been increase in the area of upland cotton (Gossypium hirsutum) replacing the more pest tolerant desi (G.arboreum and G.herbaceum) cottons, large scale cultivation of high yielding, fertilizer responsive hybrids and varieties, increase in irrigated area and change of cropping systems. All these changes led to considerable change in cotton pest scenario resulting in over dependence and extensive use of insecticides. Pesticides have become synonymous with modern agriculture.

However, outbreaks of whiteflies in Andhra Pradesh, parts of Karnataka, Maharashtra and Tamil Nadu during 1984 and 1985 and in North zone during 1995 became apparent. Severe pyrethroid resistance in H.armigera was first recorded in Andhra Pradesh in 1987. Out breaks of H.armigera occurred at Punjab, Gujarat, Madhya Pradesh and Andhra Pradesh. Resurgence of jassids due to excessive and indiscriminate use of quinolphos and chlorpyriphos for management of H.armigera was noticed. The pink bollworm, a native pest of cotton causes tremendous loss inspite of its rich native natural enemy component recorded, as the latter got lost with the chemical use. With the associated problems of insecticide use compounding, IPM approach was also gaining momentum in India in eighties, tuning research and developmental activities to adopt a more rational approach to pest control. Thus historical analyses of cotton pest management in India reveal the same patterns as in other regions of the world, characterized by a series of successional phases viz., subsistence phase, exploitation phase, crisis phase and integrated control phase. The concepts of IPM involve methods of crop protection as a subset of sustainable crop production. Various components of IPM in cotton production, their levels of integration in research and implementation, and their potentialities and constraints are discussed here under.

CURRENT PRACTICES OF COTTON IPM

In cotton pest management, strategies have to cope up with complex of pests, so that the choice of insecticides and other tactics will depend upon the pests concerned and their relative importance as member of the complex. Sucking pests during early phase of crop growth and bollworms during the mid and late seasons, are the key pests and their control is essential for good production of cotton crop. IPM is an essential component for a sustainable cotton production system having two essential elements. First comprises a series of measures which help in keeping the insect pests below economic threshold levels (ETL). Such control methods include natural control agents, host plant resistance, manipulation of agronomic factors such as rotations, spacings, time of sowing and fertilizer applications besides biological control and use of botanicals.

Natural Control

Naturally occurring native predators viz., Chilomenes sexmaculatus (Fab.) and Chrysoperla carnea (Steph.) offer significant control of the early season sucking pests. A predatory prey ratio of 1.5 in respect of jassids and 0.1 for aphids was found optimal for natural control in presence of coccinellids and chrysopids. As the use of broad spectrum insecticides like organophosphorus components for sucking pest control eliminates these natural enemies, strategy of using sucking pest tolerant genotypes in conjuction with natural enemy exploitation is advocated. Hymenopterous and tachinid parasitoids [Compoletis chlorideae Uchida, Microchelonus spp, Palexorista laxa Curran, Carcelio illota (Curran) and Goniophthalmus halli (Mesnil)] are common on H.armigera larvae with parasitisation ranging from 9-12% while Rogas aligarhensis Qadri.parasitisation on E.vittella larvae varies between 4 and 18%. Pink bollworm control by Apanteles angalati Mues. And Bracon greeni Ashm. Is 2 and 8% respectively. Natural mortality of A.flava and H.armigera due to Nomuraea rileyi could be up to 8% during cooler months and years of epizootics. Spiders and birds also execute a fair amount of natural control of cotton insect pests, however their potential remains unestimated thus far.

Host Plant Resistance

Resistance to insects in cotton is relative. Thus differences in cotton cultivars can be utilized to the growers' advantage. The most valuable contribution of host plant resistance is avoidance or escape from damaging levels of pests by early maturing and rapid fruiting cultivars. Hairy cultivars (e.g., PKV 081, NHH 44, PKV Hy2 etc.) are successfully used to resist jassids. Glabrous plant types offer resistance to aphids, whiteflies and Helicoverpa ; fregobract to Helicoverpa and pink bollworm. The intra hirsutum hybrid AHH 468 and hirsutum varieties G. cot 12, G.cot 10, Khandwa 2, DHY 286, B 1007 (tolerant to jassids);Kanchana, Supriya, LK861 (tolerant to white fly);Abhadhita (tolerant to bollworms) have reduced loss in yield due to insect pests through mechanisms of host plant resistance.

Cultural Control

Timely removal and destruction of cotton stubbles followed by deep ploughing to expose the carry-over population of bollworms, crop rotation with cereals or pulses, early sowing of cotton on ridges and furrows, should be adopted. The optimum sowing times for different zones are: northern zone- mid May; central zone-15th to 25th May (irrigated), 25th June-8th July (rainfed); southern zone-August (winter irrigated tracts of Tamil Nadu0, January-February (rice fallow and summer irrigated tracts) and with the onset of monsoon (rainfed). A minimum of 60 x 30 cm and 90 x 60 cm spacings for varieties and hybrids, respectively are to be followed for efficient pest management. Fertilizer doses of 60:30:30 and 90:45:45 and 120:60:60 NPK/ha for varieties, hybrids of rainfed cotton and irrigated cotton, respectively have been found to be optimizing in terms of less insect pest attacks and higher yields.

Biological Control

Utilization of mass produced bioagents in a large way are viewed to supplement IPM focused to reduce over-dependence on insecticides and their consequent ill effects. Release of Trichogramma chilonis @ 1,50,000 six times starting after six weeks of germination at weekly intervals supplemented with two to three releases Bracon brevicornis @ 15000 starting after second release of T.chilonis against spotted bollworm, continuing weekly releases of T.chilonis against pink bollworm, and release of T.chilonis Bio C1 or C3 @ 1,50,000 six to eight times after 60 days of germination or after visual observation of infestation supplemented with HaNPV spray @ 250 larval equivalents (LE) (one LE=@ 2X 10^9 polyhedral inclusion bodies) four to five times during the crop season are recommended in bio-intensive IPM modules.

Use of Botanicals

Neem seed kernel extract @ 5%, neem formulations @ 21/ha and neem or karanj oil @ 1%, having antifeedent / deterrent properties are recommended against sucking pests as well as bollworms. All botanicals serve similar purposes of biocontrol agents towards conservation of native as well as augmented bioagents, and reduction in insecticide use vis-à-vis their selection pressure on pest population. Their high photoinstability, suspected quality and inconsistent pest control efficiency are serious problems requiring research cum demonstration before an effective component of IPM.

Second element of IPM comprises control methods involving interventions that are necessary to make, if the pests reach economic threshold level (ETL). The ETLs for different cotton insect pests are given in Table 3.

Table 3. Economic Threshold Levels (ETL) for important Insect Pests of Cotton

Insect pest	Age of the crop(days)	ETL
Jassids	1-50	1-2 nymphs/leaf
Aphids	1-50	15-20% infested plants
Whiteflies	35-110	8-10 adults or 20 nymphs/ leaf
Thrips	1-30	10 thrips / leaf or 15-20% infested plant
Spotted & spiny bollworm	35-110	10% or more of attacked shoots or reproductive parts
American bollworm	65-110	1 egg/plant or 1 larva / plant or 5-10% damaged fruiting structures
Pink bollworm	65-110	10% or more of attacked bolls
Stem weevil	25-60	10% or more plants with galls.

No action threshold exist for foliage feeders, but treatments are advocated if a significant proportion of cotton stand is destroyed.

Chemical control

At present intervention measures based on ETLs involve the use of recommended insecticides (Table 4).

In areas where H.armigera is a key pest having developed resistance, strategies on efficient use of insecticides are imposed with great emphasis for insecticide resistance management along with the IPM technologies involving other methods of control. Growing of sucking pest tolerant genotypes to facilitate no spray situation upto 60 days followed by endosulfan against H.armigera populations is recommended when the latter's resistance levels are lower (i.e.) up to 90 days after sowing. Later, the sequence of insecticides recommended include biorationals like HaNPV, Bt., and neem. Organophosphorus insecticides and pyrethroids coinciding with 80-90, 90-110 and 110-130 days of crop growth are recommended based on economic thresholds of insect pests.
Thus insecticide use is confined to windows related to stages of crop development.

Table 4.Recommended Insecticides for Cotton Insect Pests

Pest	Insecticide	Qty. of insecticide / ha
Jassids,Aphids, Thrips	Methyl demeton 25EC Dimethoate 30EC Phosphamidon 100EC	500-750 ml 500-750 ml 100-250 ml

Whiteflies	Methyl demeton 25EC Neem oil + Teepol Fish oil resin soap Phosalone 35EC	500-750 ml 3.0-3.51+500 ml 14-15 kg 2.5-3.0 litres
Spotted, Pink and American bollworms	Endosulfan 35EC Chlorpyriphos 20EC Quinalphos 25EC Monocrotophos 40EC Carbaryl 50WP Fenvalerate 20EC Cypermethrin 10EC Decamethrin 2.8EC	__" "__ __" "__ __" "__ __" "__ 1.5-2.5 kg 400-500 ml 800-1000 ml 600-700 ml
Spodoptera leafworm	Chlorpyriphos 20EC Fenvalerate 20EC Cypermethrin 10EC Decamethrin 2.8EC	1.5-2.0 litres 400-500 ml 800-1000 ml 600-700 ml
Ash weevil	Aldicarb 10G Carbofuran 3G	10 kg/ha 30 kg/ha
Stem weevil	Drenching stem Portion on 20th & 35th day with Monocrotophos 40EC Phosalone 35EC	 1.5 ml/litre of water 2.0 ml/litre of water
Mite	Dicofol 25EC	1.5-2.0 litres

Because it is the operational influences such as nature of chemicals and their application methods that have contributed more towards H.armigera resistance, efficient choice and rotation of chemical groups along with cultural methods that contribute biological disadvantage to H.armigera are advocated so as to delay or slow down the build up of resistance as well as to prolong the life of insecticides.

Increasingly alternative intervention technologies are being developed and introduced including the pheromones (e.g., mating disruption against pink bollworm), microbials (e.g., Bacillus thuringiensis (Bt.) formulations) and products of biotechnology (e.g.,Bt.transgenics). IPM propositions should avoid any standardized set of pest management techniques but should promote an approach utilizing agroecological principles and translate them into a socioeconomic frame work respecting farmer's objectives.

LEVELS OF INTEGRATION IN COTTON IPM

Most of the research and developmental activities of IPM in India have arisen in response to pest outbreaks/ resistance with no holistic approach. Currently practiced pest management packages in India are specific to insect (s), disease(s), and weed(s) arising out of unidisciplinary research results involving integration of different control tactis against single pest and cotton crop is no exception. Development of insecticide resistance in H.armigera made high dosages and number of sprays ineffective resulting in unprofitable cotton production. This has been the driving force for using other pest control options ranging from conservation of natural enemies, cultural practices, use of biorationals such as botanicals, Bacillus thuringiensis and HaNPV besides products of biotechnology viz., Bt.transgenic cotton.

With pesticide management as a key issue of cotton production system. IPM integrates only methods of crop production practices such as specific planting patterns, pest resistant varieties, planting time, water and fertilizer applications related to reduction in pest damage. Methods of crop protection as a subset of sustainable crop production continues along first level of integration whereby control strategies are integrated for single species management mostly practiced in a field by an individual.

POTENTIALITIES AND CONSTRAINTS OF IPM PRACTICES

Analysing IPM in the current context relating to cotton crop, two essential components are to be emphasized. The first comprises practices that would keep pests below economic thresholds levels, and secondly of pest control interventions if pest reach ETLs that are curative in nature. Table 5 presents the current IPM techniques in the present context of cotton production with their potentialities and constraints.

Table 5. Potentialities and Constraints of IPM Techniques

IPM techniques	Potentialities	Constraints
Cultural control		
i) Harvesting and management of residues	Reduces the carry-over Population of pests	Not followed on an area wide basis
ii) Early sowing	Avoids early peaks of pest population	Risk of dry spell following onset of monsoon
iii) Uniform planting date	Avoids suitable niche for many pests	Fragmented land holdings and labour shortage
iv) Crop rotation	Avoids carry-over & affects pest perpetuation	Disrupts natural control by beneficials
v) Intercropping	Increases the abundance of natural enemies, in few cases	Inconvenient for adoption Because of spatial and temporal limitations of intercrops and labour
vi) Fertilization	Optimum fertilization rationalizes insect pest attack and yield	Imbalanced use succumbs To insect pest attack

Host plant resistance i) Early maturing varieties	 Less exposure to late season pests	 Low compensation for early fruiting structure loss
ii) Hairy varieties	Resistant to jassids and whiteflies	Susceptible to H.armigera
Mechanical control Hand picking	 Eliminates selection pressure due to insecticides	 Time consuming and unprofitable over large areas
Biological control	Alternative to insecticides and environmental friendly Eliminates selection pressure due to insecticides	Perpetuation of bioagents hampered by annual habitat of cotton Complexity of cotton pests makes ‘insecticide use’ a must affecting sustenance of bioagents Slow action of biocontrol agents and their suspectibility to environmental factors Mass production and application methods need refinement Short life span, storage and quality control of bioagents poses problems Impact of augmentation of bioagents vary among locations and over years in the same location
Behavioural control Mating disruption using pheromones	 Effective for internal feeders like pink bollworm	 Formulation complexity exists Costly and less effective in isolated fields
Insecticidal control **I. Botanicals**	 Environmental friendly, abundant availability, and amenable for in situ formulations	 Inconsistent in stability as well as quality
II. Synthetics Seed treatment	 Early protection against sucking pests Protect beneficial insects establishes better crop stand	 Expensive strategy for rainfed areas Risk of increased population of thrips

Systemic sprays of organophosphates (OPs) Against sucking pests	Protection against sucking pests	Eliminates natural control due to natural enemies
	Maintains better crop stand	Predisposes plants to bollworm attack
Bollworm control using cyclodeines, OPs and pyrethroids	Have quick knock down effect and are efficient for need (ETL) based sprays	Selection of proper insecticides based on resistance levels is difficult Pyrethroids outbreaks of sucking outbreaks of sucking pests Not safe against natural enemies.

In a farm survey conducted in the states of Maharashtra, Andhra Pradesh, and Madhya Pradesh multiplicity of genotypes, use of non-certified seeds, inability to adopt intercropping and timely sowing, non-adoption of proper spacing, more than recommended number of sprays and tied up credit with pesticide dealers were identified as constraints undoing the cotton productivity gains. All these constraints have direct implications in extending IPM technologies. Of all the constraints, plant protection is the weakest link in the production process, where extension could not make a dent in the producer-dealer nexus through tied up credit, with the later having an edge in advocating the time, dose and type of chemicals to be used. Tied up credit in case of pesticides was noticed in more than 80% of the cases. One positive feature is that above said constraints are controllable than the uncontrollable ones like weather and soil, and this offers scope for relaxation of the constraints through further research, development and extension efforts. Concerted community action has to be called for promoting IPM, on the lines of some east Asian countries pre-dominated with smaller holdings and have succeeded in this front.

CONCLUSION

The integrated in the cotton production history will not be an easy one. Effect of IPM programs vary because of heterogeneity across regions, time and types of crop growth. While IPM can be a success if applied over wide areas, besides offering best opportunities to measure benefits of IPM, Indian farm holdings are fragmented. Success of IPM depends on research programs as well. Currently practiced IPM practices include making control decision based on ETL of single pests. However, to address to problems of multiple pests, and to take advantage of computer decision models through quantification of pest interactions, estimation of ETLs for concurrent multiple pests is must and holds promise for future. Also increasing understanding of the biology and population dynamics of the pests and beneficials, improves our ability to introduce preventive measures to keep pests below damage thresholds- but this work proceeds at a much slower pace than development of control techniques. Pest management options should be arrived in consonance with weed and alternate hosts of pests, in addition to climatic factors. Further, forewarning systems are a must for effective decision making in pest management. With improved information technologies, regional advisory services should gear up to guide farmers for situations ranging from "spray or no spray" to "grow or don't grow cotton" decisions.

Given the fact that in most cotton growing systems pesticide applications are usually required, improved pesticide management must be the starting point for introducing IPM. For judicious use of pesticides on a need basis, developing practical methods of pest monitoring is a priority for biological and social science research. Biologists and economists have not yet conducted studies on positive IPM externalities and, research investments vis a vis IPM returns. Sustainable cotton production incorporating the principles of IPM requires political and economic stability and a continuously developing and evolving supporting infrastructure which includes research, advice, input supply and marketing. Whatsoever, the search for 'appropriateness' in research will not provide the solution to the problem of non-adoption of new technologies unless the constraints which prevent farmers benefiting from scientific research are removed.

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