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Cotton Exchange Building, 2nd Floor, Cotton Green, Mumbai - 400 033
Phone: 23704401/02/03 Email: cai@caionline.in
www.caionline.in

Retaining Early Formed Squares, Will Lay a Robust Foundation for Pink Bollworm Management in India

Dr Kranthi works as Chief Scientist, at the International Cotton Advisory Committee (ICAC), Washington DC. Before joining the ICAC in March 2017, Dr. Kranthi worked as a cotton scientist at the Central Institute for Cotton Research (CICR) Nagpur, for 26 years. Dr. Kranthi has invented immunological kits to detect Bt in GM crops, insecticide resistant insects and spurious pesticides and has patents in India, South Africa, Mexico, China and Uzbekistan. Dr. Kranthi is the recipient of two international awards and 10 awards in India.

EXPERT's Column

Dr. Keshav R. Kranthi
Chief Scientist, ICAC

The pink bollworm (PBW) (scientific name: *Pectinophora gossypiella*) has emerged as a major menace in India in the past 10 years. The worm is now feeding on BG-II cotton bolls because it has developed high levels of resistance to *Bt*-cotton in India. Several strategies have been recommended for its management (Kranthi, CAI Newsletter, No. 35, 2015). While these strategies are important in reducing PBW damage, they can be made more effective when coupled with one main strategy of 'retaining early formed squares'. This article explains the science behind the recommendation. It describes a simple set of novel strategies to retain the first formed squares in high density planting, which not only helps to obtain high yields, but also helps the peak boll stages to escape the infestation peaks of the worm.

I would like to explain a little bit more as to why the strategy of retaining early formed squares can hold fort against pink bollworm damage. The strategy is based on the following four main scientific observations:

1. Research conducted by the ICAR-CICR and the AICRP clearly shows that the pink bollworm is a late season pest in India and late formed bolls are damaged mostly. In North India, the PBW populations appear in mid-September to assume a peak that generally occurs by mid-October; in Central India PBW infests in November and peaks in early December; in South India the worms appear in December and reach peak levels by the beginning of January. Based on the recommended sowing months of April-May in North India; June-July in Central India and July-August in South India, it can be surmised that in all the three zones, pink bollworm infestation on green bolls mainly starts after the plants attain 130 days of age. Green bolls formed within 130 days of the plant growth are

Photo credit : Dr. Mahesh Upender

generally safe from the pink bollworm. Data show that the worm occurs in 4-5 generation cycles in the cotton season starting with very low populations in the first generation that coincides with peak flowering stage, gradually leading to the third and fourth generations that cause maximum damage in late formed bolls.

2. PBW pestilence is high if the seasonal duration of preceding cotton crop was six to eight months or more. Cotton crop harvested within 150 to 160 days and terminated immediately, seldom gets affected by the pink bollworm.

3. PBW moths rarely prefer to lay eggs on green bolls that are older than 21 days. Green bolls grow to their full size in 21 days after which they are generally considered to be safe from fresh bollworm attack. It takes 45 to 50 days for a square bud to reach the stage of a full-size safe green boll. Tender green bolls are most vulnerable to fresh bollworm infestation when they are one to three weeks old.

4. In general, a 40 days old plant starts producing square buds. On an average one square bud is produced per day: the production rate being dependent on genetics and environment. Presuming that all squares are retained, and no square is shed, a plant at 130-days of age is expected to produce about 40 full-sized green bolls that are safe from fresh infestation by PBW. The plant could also have about 10-15 younger green bolls and will produce more squares/ flowers and younger bolls subsequently that are most likely to get caught in PBW infestation.

Square and boll shedding are common phenomena in cotton fields across the globe. It is generally accepted that despite best management practices it may be possible to retain about 50% healthy open bolls from the squares produced by a plant, after 30% square shedding and 30% shedding or damage of the bolls that are formed out of the remaining squares. Therefore a 130-days old plant may have at best about 20 retained full-sized bolls that are safe from fresh PBW attacks and 8-10 younger green bolls that will be vulnerable to PBW infestation. Because PBW is a cryptic (hidden) pest, the crop, which is vulnerable to PBW after 130 days, can only be partly protected from PBW damage by resorting to integrated pest management strategies that include pheromone mass trapping using the traps and prolonged-effect lures developed by ICAR-CICR. The lures can also be used for mating confusion. Whenever necessary, insecticides such as chlorantraniliprole or spinosad or indoxacarb or novaluron or thiodicarb can be used at economic threshold levels of 8 moths per trap per night for three consecutive nights.

Data show that in Central India, pink bollworm infestation starts in November and reaches a peak by late November to early December. Green bolls that reach full-size by the end of October escape the pink bollworm and green bolls that are formed later, which are less than 20 days old are vulnerable to PBW oviposition and infestation. Green bolls formed before the end of October are also likely to receive the benefit of residual soil moisture and available nutrients depending on moisture retention capacity of the soil and the seasonal rainfall pattern. Under a normal monsoon pattern, most soils in rainfed farms become dry by the end of October and late formed bolls suffer stress. Bolls harvested from the shorter season crop are healthier and produce clean good quality fibres, because they are rarely starved of water and nutrients and also because they escape PBW infestation.

Table 1. Predicted crop phenological stages in Central India

Date	Age of the crop	Phenological stage
15 June		Sowing
20 June	0	Seedling emergence
30 July	40 days old	Square formation starts
10 September	80 days old	40 squares are produced per plant
5 October	105 days old	40th square blooms into a flower
30 October	130 days old	40th square produced by the plant will have turned into a full-size green boll that is safe from a fresh bollworm attack. The chances are that from the 40 squares produced, only 20 green bolls or less will be retained per plant.
1 November	131 days old	Pink bollworm starts attacking tender green bolls (<20 days old). Green bolls produced after mid-October are tender and vulnerable to a fresh attack by the pink bollworm in November and later.
1 December	161 days old	PBW populations reach a peak and cause significant damage

Cotton plants compensate square shedding. Shedding of early formed squares prompts plants to shift towards vegetative growth by producing new fruiting branches and new squares in efforts to compensate for the lost squares and bolls. However, compensation needs energy; it leads to elevated requirements of water and nutrients thereby accelerating stress; further loss of fruiting parts and a longer crop duration. A longer season leads to late formed bolls that are most vulnerable to PBW infestation, which in turn leads to a higher number of PBW generations and a need to extend the crop to recover lost yield. A longer season, thus supports higher pestilence in the current and the subsequent cotton crop.

Research clearly confirms that 'retaining early formed squares' enables higher 'water-use-efficiency', better 'nutrient-use-efficiency' and efficient energy partitioning without subjecting plants to any additional stress. Further, higher yields can be obtained from a timely sown, shorter season crop of 150 to 160 days by combining the strategy of 'retaining early formed squares' with high density planting (see explanation below).

Technologies that help to retain early formed squares and bolls may optimally enable a retention of 50% healthy bolls from the total number of squares produced and at worst enable 30% retention. Data indicates that low yields in India and Africa are mainly due to low density of plant population coupled with higher rate of square/boll shedding/damage which could reach as high as 80 per cent or even more.

How Can High Yields be Obtained from a Short Season Crop of 150 to 160 Days?

High yields can be obtained from any crop irrespective of the level of plant population density, by preventing shedding of early formed squares and bolls to the best extent possible. However, to obtain the same level of yield, a crop with low density plant population will require a longer duration, while a crop with a higher density plant population will require a shorter duration depending on the density levels. I am presenting two tables below to explain how plant population density influences the crop duration to harvest the same level of yield and how high yields can be obtained from a short season crop of 150 to 160 days.

Table 2. Yields (kg/ha) from a short season crop of 150 to 160 days at different plant densities.

Plant spacing (90 cm between rows)	Plant population per hectare	Number of healthy bolls retained per plant on 130 days old plants, that escape PBW infestation	*Calculated lint yield kg/ha @ 20 healthy bolls retained per plant on 150 to 160 days old crop
90 x 90cm	12,345	20	247
90 x 60cm	18,518	20	370
90 x 45cm	24,691	20	494
90 x 30cm	37,037	20	741
90 x 15cm	74,074	20	1481
90 x 10cm	111,111	20	2222

**The average lint weight in Indian bolls is about 1.3g. For calculation purposes of a worstcase scenario, each open boll was assigned a value of 1.0g lint.*

Table 2 shows a hypothetical case as an example where technologies are used to ensure retention of 20 healthy full-formed bolls from 40 squares formed on a 130-days old plant by retaining 70% of the first formed squares and 70% bolls that resulted from the retained squares. At a low plant density of 12,345 plants per hectare, with each boll providing 1g lint, the calculated yield is 247 kg lint per hectare from a 150-160 days old crop. In stark contrast, the calculated yield would be 2,222 kg lint per hectare from the same duration of 150-160 days old crop at a plant population density of 111,111 plants per hectare.

Table 3 estimates the number of bolls and the duration of the crop required to achieve a target of the world average lint yield of 778 kg/ha., at different plant densities. The table highlights the need for a longer duration of 247 days and a higher number of 62 healthy bolls at 50% retention rate at a low plant population density of 12,345 plants per hectare to harvest a target lint yield of 778 kg/ha, in stark contrast to high density planting system of 111,111 plants per hectare which needs only 7 bolls per plant and just 134 days to achieve the same target yield of 778 kg/ha.

Thus, fields with low density of plant populations require retention of a greater number of squares per plant to obtain the same target yield. Retention of a greater number of squares and bolls per plant means a longer seasonal window for similar yields that can also be obtained from a shorter season with higher density of plants per hectare.

A long duration crop is not desirable from a management perspective because it mandates a long vulnerable management window. A longer window of flowering and tender green bolls imposes higher challenges for a longer vigilance-window to provide adequate water, nutrients and protect the crop against bollworms.

Table 3. Number of retained healthy bolls required to get 778 kg lint/ha (2018 world average) and calculated crop duration for the target yield at different plant densities.

Plant spacing (90 cm between rows)	Plant population per hectare	Number of healthy bolls (@ 50% retention), required to get 778 kg lint/ha	Calculated crop duration (days) to get 778 kg lint/ha at 50% boll retention
90 x 90cm	12,345	62	247
90 x 60cm	18,518	42	205
90 x 45cm	24,691	31	184
90 x 30cm	37,037	21	162
90 x 15cm	74,074	10	141
90 x 10cm	111,111	7	134

For example, to retain 127 squares for 62 bolls per plant at 49-50% retention, it would require a vigilant management window of up to 177 days to minimize shedding, starting from the square initiation stage until ensuring the safety of the last batch of bolls.

On the other hand, retaining 14 squares for 7 bolls per plant would require an initial vigilant management window of only 64 days to minimise shedding starting from the square initiation stage until ensuring the safety of the last batch of bolls. A longer season is a recipe for disaster in terms of crop management and bollworm management, especially because it necessitates higher use of water, fertilizers and pesticides apart from creating a perennial cyclic problem of the pink bollworm.

Retaining Early Formed Squares and Bolls

Squares are formed sequentially on the fruiting branch, first at the first position node (see Figure 1 below), followed by the next square on the second position approximately after six days (depending on genetics and environment) and so on.

Figure 1. Position of fruiting parts on a fruiting branch

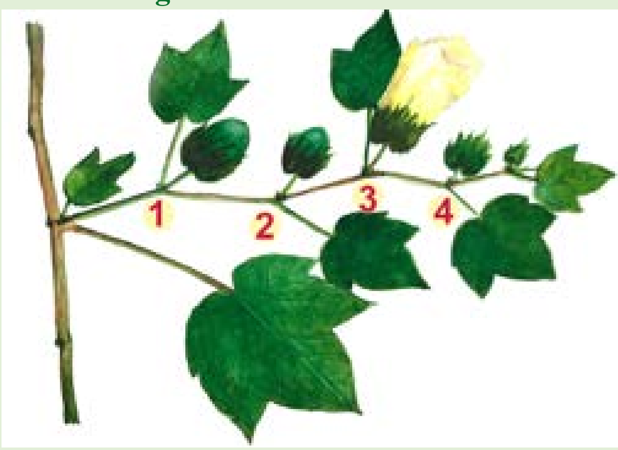

Image copyright Kranthi, ICAC

The first position square/bolls are most favored by the plant for nutrition and water, followed by the second and third position fruiting parts. Data show that the first and second position bolls have the best quality fibre because they receive a preferential treatment. Shedding of these fruiting parts imposes high levels of stress to the plant. Research across the world showed that bolls at the first, second and third position of the fruiting branches contribute most towards harvestable yields at about 60%, 30% and 10% respectively.

Therefore, retention of at least the first and second position squares/bolls, which represent the early formed fruiting parts, is crucial for high yields. Minimising shedding of early formed squares/bolls results in higher production efficiency of plants, synchronous early maturity, escape of damage by pink bollworms, high yields in a short season and facilitates timely termination of the crop.

Formation of fruiting parts depends on ideal conditions of heat, light, water, nutrients and absence of biotic and abiotic stress. Early formed squares are shed mainly due to one or more of three major factors:

a) Canopy-shading or cloudy conditions or waterlogging or drought or extreme temperatures

b) Deficiency of nitrogen or phosphorus or boron

c) Insects such as plant bugs, mirid bugs or bollworms

Square shedding can be effectively minimized by using any of the following technologies

a) Chemical sprays to interfere with abscission: A number of chemicals that interfere with abscisic acid and ethylene levels in the plant have been used as foliar sprays early in the season to minimise physiological square shedding. For example, spray of 1-Naphthalene Acetic Acid (NAA) @ 40ppm during early square formation stage has been found to minimise physiological square shedding. Ethylene inhibitors such as Aminoethoxy Vinyl Glycine (AVG) and 1-Methyl Cycloprene (MCP) have also been found to minimise physiological shedding of squares and bolls. Several other chemicals such as Amino-oxy-acetic acid (AOA), Triacontanol, 2,3,5-Tri-Iodo-Benzoic Acid (TIBA), Silver thiosulphate, Silver nitrate and Trans-cyclo-octene have been tested across the world in cotton for their role in inhibiting square and boll shedding. There is a need to validate their dose and application at proper growth stage under local conditions.

b) Canopy management: Mepiquat Chloride (15 to 30g a.i/ha) is commonly used in developed countries at 50-80 days after sowing for canopy management at thresholds of >4.0 cm average internodal length of the main stem to prevent canopy-shading. Canopy management in the early stages of square formation is crucial for proper light penetration to reduce shedding of

Table 4. Districts where boron deficiency has been recorded in majority of the farms tested

Maharashtra	Jalna, Nagpur, Nanded and Satara
Punjab	Bhatinda and Patiala
Karnataka	Bagalkot, Belgaum, Bellary, Bidar, Bijapur, Chikballapur, Chikmagalur, Gulbarga, Hassan, Haveri, Koppal, Mysore, Tumkur and Uttar Kannada.
Madhya Pradesh	Betul, Dhar and Neemuch
Tamilnadu	Coimbatore, Cuddalore, Dindigul, Erode, Madurai, Namakkal, Sivaganga, Tiruchirappalli, Tirunelveli, Tiruvannamalai, Tuticorin, Villupuram and Virudhunagar
Telangana	Nagarkurnool and Rangareddy
Haryana	Sirsa
Odisha	Anugul, Balangir, Boudh, Ganjam, Kalahandi, Kandhamal, Kendujhar, Koraput, Nabarangpur, Nayagarh, Nuapada and Sonepur
Gujarat & AP	No data

squares and early formed bolls. Alternatively, Paclobutrazol (40g a.i/ha) can also be used as one or two applications during 50 to 80 days for canopy management and to prevent square and boll shedding.

c) Nutrient management: Application (basal dose or foliar sprays at early squaring stage) of nitrogen / phosphorus / boron based on soil fertility helps in minimizing square and boll shedding.

d) Boron application: Boron plays an important role in square and boll retention. A list of cotton growing districts where majority of farms were reported to be boron deficient, is presented below (Table 4). Boron must be applied in fields where it is reported to be deficient. Depending on the deficiency, Borax must be applied as band placement at 10 to 20 kg/ha at the time of planting and if necessary, as foliar sprays of 0.1 to 0.3% on 40-80 days old crop, to minimise square shedding.

e) Soil moisture management: Draining of waterlogged fields and providing irrigation as and when required by the plants helps in minimising square shedding.

f) Insect pest management: Plant bugs, mirid bugs and bollworms cause square shedding. Bugs can be controlled using selective insecticides such as Azadirachtin-based insecticides or Diafenthiuron or Buprofezin or Flonicamid. Early season bollworm infestation can be efficiently controlled with biological control or Indoxacarb or Chlorantraniliprole or Spinosad or Flubendiamide or Emamectin benzoate at doses and ETLs recommended by ICAR-CICR. These insecticides are relatively selective with higher toxicity to target pests and lesser toxicity to beneficial insects.

Conclusion: The pink bollworm is a monophagous pest with cotton as the primary host. A 'closed season', where no cotton or PBW alternate host crops are allowed to be grown between two cotton seasons, is almost universally enforced, wherever cotton is cultivated to prevent carry over of PBW from the previous crop. Currently strict adherence to this 'closed season' is the only effective method available for the control of pink bollworm in Africa and a key IPM strategy across the world. Deployment of 'short season' and 'closed season' are the most common universally recommended strategies for PBW management. These two strategies along with high density planting were used to produce high yields and effectively combat the serious menace of PBW in the desert valleys of southern California and Arizona in the mid-1970s to the mid-1980s; and would be most applicable to combat the current PBW crisis in India. Pink bollworm is known to cause least problems in countries that cultivate short-season cultivars and implement a closed-season of at least 5 to 6 months. Therefore, the best strategies for PBW management in India would be to ensure timely sowing in an area-wide manner and retention of early formed squares in high density planting so that high yields can be obtained from a short season crop.

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

UPCOUNTRY SPOT RATES

(Rs./Qtl)

Standard Descriptions with Basic Grade & Staple in Millimetres based on Upper Half Mean Length [By law 66 (A) (a) (4)]								Spot Rate (Upcountry) 2019-20 Crop January 2021					
Sr. No.	Growth	Grade Standard	Grade	Staple	Micronaire	Gravimetric Trash	Strength /GPT	11th	12th	13th	14th	15th	16th
3	GUJ	ICS-102	Fine	22mm	4.0 – 6.0	13%	20	7761 (27600)	7761 (27600)	7789 (27700)	7789 (27700)	7789 (27700)	7789 (27700)
								Spot Rate (Upcountry) 2020-21 Crop					
1	P/H/R	ICS-101	Fine	Below 22mm	5.0 – 7.0	4%	15	10770 (38300)	10770 (38300)	10770 (38300)	10770 (38300)	10770 (38300)	10770 (38300)
2	P/H/R (SG)	ICS-201	Fine	Below 22mm	5.0 – 7.0	4.5%	15	10911 (38800)	10911 (38800)	10911 (38800)	10911 (38800)	10911 (38800)	10911 (38800)
3	GUJ	ICS-102	Fine	22mm	4.0 – 6.0	13%	20	- -	- -	- -	- -	- -	- -
4	KAR	ICS-103	Fine	23mm	4.0 – 5.5	4.5%	21	8492 (30200)	8492 (30200)	8520 (30300)	8520 (30300)	8464 (30100)	8464 (30100)
5	M/M (P)	ICS-104	Fine	24mm	4.0 – 5.5	4%	23	10545 (37500)	10545 (37500)	10573 (37600)	10573 (37600)	10573 (37600)	10573 (37600)
6	P/H/R (U) (SG)	ICS-202	Fine	27mm	3.5 – 4.9	4.5%	26	11867 (42200)	11923 (42400)	11951 (42500)	11951 (42500)	11810 (42000)	11810 (42000)
7	M/M(P)/ SA/TL	ICS-105	Fine	26mm	3.0 – 3.4	4%	25	9420 (33500)	9420 (33500)	9476 (33700)	9476 (33700)	9476 (33700)	9448 (33600)
8	P/H/R(U)	ICS-105	Fine	27mm	3.5 – 4.9	4%	26	12007 (42700)	12063 (42900)	12092 (43000)	12092 (43000)	11951 (42500)	11951 (42500)
9	M/M(P)/ SA/TL/G	ICS-105	Fine	27mm	3.0 – 3.4	4%	25	9983 (35500)	9983 (35500)	10039 (35700)	10039 (35700)	10039 (35700)	10011 (35600)
10	M/M(P)/ SA/TL	ICS-105	Fine	27mm	3.5 – 4.9	3.5%	26	10714 (38100)	10714 (38100)	10770 (38300)	10770 (38300)	10770 (38300)	10742 (38200)
11	P/H/R(U)	ICS-105	Fine	28mm	3.5 – 4.9	4%	27	12092 (43000)	12148 (43200)	12176 (43300)	12176 (43300)	12035 (42800)	12035 (42800)
12	M/M(P)	ICS-105	Fine	28mm	3.7 – 4.5	3.5%	27	11867 (42200)	11867 (42200)	11895 (42300)	11895 (42300)	11867 (42200)	11838 (42100)
13	SA/TL/K	ICS-105	Fine	28mm	3.7 – 4.5	3.5%	27	11923 (42400)	11923 (42400)	11951 (42500)	11951 (42500)	11895 (42300)	11867 (42200)
14	GUJ	ICS-105	Fine	28mm	3.7 – 4.5	3%	27	11951 (42500)	11951 (42500)	12007 (42700)	12007 (42700)	11951 (42500)	11923 (42400)
15	R(L)	ICS-105	Fine	29mm	3.7 – 4.5	3.5%	28	11979 (42600)	12035 (42800)	12063 (42900)	12063 (42900)	12035 (42800)	12035 (42800)
16	M/M(P)	ICS-105	Fine	29mm	3.7 – 4.5	3.5%	28	12092 (43000)	12148 (43200)	12204 (43400)	12204 (43400)	12204 (43400)	12176 (43300)
17	SA/TL/K	ICS-105	Fine	29mm	3.7 – 4.5	3%	28	12148 (43200)	12148 (43200)	12204 (43400)	12204 (43400)	12204 (43400)	12176 (43300)
18	GUJ	ICS-105	Fine	29mm	3.7 – 4.5	3%	28	12148 (43200)	12148 (43200)	12204 (43400)	12204 (43400)	12204 (43400)	12176 (43300)
19	M/M(P)	ICS-105	Fine	30mm	3.7 – 4.5	3.5%	29	12429 (44200)	12429 (44200)	12485 (44400)	12485 (44400)	12485 (44400)	12457 (44300)
20	SA/TL/K/O	ICS-105	Fine	30mm	3.7 – 4.5	3%	29	12457 (44300)	12457 (44300)	12513 (44500)	12513 (44500)	12513 (44500)	12485 (44400)
21	M/M(P)	ICS-105	Fine	31mm	3.7 – 4.5	3%	30	12710 (45200)	12738 (45300)	12795 (45500)	12795 (45500)	12795 (45500)	12766 (45400)
22	SA/TL/ K / TN/O	ICS-105	Fine	31mm	3.7 – 4.5	3%	30	12738 (45300)	12766 (45400)	12823 (45600)	12823 (45600)	12823 (45600)	12795 (45500)
23	SA/TL/K/ TN/O	ICS-106	Fine	32mm	3.5 – 4.2	3%	31	12907 (45900)	12907 (45900)	12963 (46100)	12963 (46100)	12963 (46100)	12935 (46000)
24	M/M(P)	ICS-107	Fine	34mm	3.0 - 3.8	4%	33	17828 (63400)	17940 (63800)	18081 (64300)	18081 (64300)	18194 (64700)	18194 (64700)
25	K/TN	ICS-107	Fine	34mm	3.0 - 3.8	3.5%	34	18390 (65400)	18503 (65800)	18643 (66300)	18643 (66300)	18756 (66700)	18756 (66700)

(Note: Figures in bracket indicate prices in Rs./Candy)