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The ICAC RESEARCHER OF THE YEAR AWARD

The ICAC RESEARCHER OF THE YEAR AWARD is internationally recognized as the top-most award in cotton science. It is globally accepted as the most prestigious and the highest International recognition for cotton scientists. The Award was initiated by the International Cotton Advisory Committee (ICAC) in 2009 and as of now it is the only International Award for Cotton Scientists.

THE CRITERIA USED TO GRANT THE AWARD

Researchers from Universities and Public Sector Research Organizations, working in any discipline of cotton production and processing research are eligible to apply for the award. Researchers can apply directly or through heads of their institutions. The ICAC and the Award Panel accept applications (on-line) from February to April 30 each year and the winner is announced in the first week of June.

Applications are evaluated by an Award Panel consisting of five experts located in at least four countries. The Award Panel is anonymous and known only to the chairman of the Award Panel and the ICAC. Applicants will be judged based on the evidence of scientific contribution (research papers, citations, books, patents, innovations, technologies developed and commercialized); awards/recognition (national and international), major contributions to the cotton industry and overall impact on the cotton sector.

The winner is conferred with the title “ICAC Cotton Researcher of the Year” and receives a trophy, certificate and an honorarium of US$ 1000 at the ICAC Plenary meeting where 35 to 40 Governments are represented. The winner will be invited to make a special presentation at the ICAC Plenary Meeting.

PREVIOUS WINNERS OF THE ‘ICAC RESEARCHER OF THE YEAR AWARD’

- Dr. Keshava Raj Kranthi, India. ICAC Researcher of the Year Award winner 2009
- Dr. Fred Bourland, USA. ICAC Researcher of the Year Award winner 2010
- Dr. Sukumar Saha, USA, ICAC Researcher of the Year Award winner 2011
- Dr. Yusuf Zafar, Pakistan. ICAC Researcher of the Year Award winner 2012
- Dr. Andrew H. Paterson, ICAC Researcher of the Year Award winner 2012
- Dr. Ibrokhim Y. Abdurakhmonov, Uzbekistan. ICAC Researcher of the Year Award winner 2013
- Dr. Mehboob-ur-Rahman, Pakistan. ICAC Researcher of the Year Award winner 2014
- Dr. Greg Constable, Australia. ICAC Researcher of the Year Award winner 2015
- Dr. McCarthy. USA. ICAC Researcher of the Year Award winner 2016
- Dr. David M. Stelly. USA. ICAC Researcher of the Year Award winner 2017
- Dr Baohong Zhang, USA. ICAC Researcher of the Year Award winner 2018
- Dr John Yu, USA. ICAC Researcher of the Year Award winner 2019
- Dr Raja Reddy, USA, ICAC Researcher of the Year Award winner 2020
- Dr Bruce Tabashnik, USA, ICAC Researcher of the Year Award winner 2021
- Dr Jonathan F. Wendel, USA, ICAC Researcher of the Year Award winner 2021

Application for the 2022 Award is now opened until 30 April 2022

The winner will be announced 1st June 2022

AWARD NOMINATION PACKAGE

Return the Nomination Package **here**
with the subject 'ICAC RESEARCHER AWARD APPLICATION'

Application Details to the Award

- The application form titled '**Nomination Package**' can be downloaded **here**.
- Applications received in any other format and/or incomplete in any respect shall not be considered.
- Researchers from universities and public sector research organisations can apply for the award directly or through their heads of institutions.
- Researchers from all disciplines of cotton production research, including ginning, fibre quality and textile research are eligible for the award.
- Only researchers from ICAC members are qualified to apply.
- The list of ICAC members (countries including EU nations) can be found here.
- Previous applicants can re-apply afresh using the Nomination Package.
- **The last date of submission: 30 April 2022.**
- Please send your completed form to the email address nominations2022@icac.org with the subject 'ICAC RESEARCHER AWARD APPLICATION'.
- The applications will be received directly by the Award Selection Panel.
- An independent Award Panel, consisting of five experts from at least four countries, representing the major disciplines in cotton, evaluates and decides the ICAC Cotton Researcher of the Year.
- The Award Panel is anonymous and known only to the Chairman of the Award Panel.
- The Award Panel will judge nominees based on evidence of: major innovative and impactful achievements and contributions to the cotton sector; awards/recognitions (National and International); publications (citations, peer-reviewed papers, books, chapters and conferences presentations).
- The Chairman of the Award Selection Panel will notify the ICAC Secretariat of the winner.
- **The winner will be announced on 1st June 2022.**
- The winner will receive a shield, an honorarium of US$1,000, a certificate, and the title "ICAC Cotton Researcher of the Year" at the next ICAC Plenary Meeting.
- The winner will be invited to make a special presentation at the Plenary Meeting on his/her contributions to cotton research and his/her vision for the future.

MATING DISRUPTION: AN EFFECTIVE AND ECO-FRIENDLY TOOL FOR THE MANAGEMENT OF PINK BOLLWORM ON COTTON

A. G. Sreenivas, Poornima G, S. G. Hanchinal, Venkatesh and Vijayalakshmi
Research Scientist & Head, Cotton (Retd.)
Main Cotton Research Station,
NAU, Surat 395007, India
drvkumar255@gmail.com

Introduction:

Cotton is one of the world's most essential fiber crops having global significance, popularly known as white gold. It is cultivated in tropical and subtropical regions of more than 70 countries. In India, cotton is mainly cultivated in three distinct agro-ecological zones (North, Central, and South) covering an area of 13.47 million hectares with average productivity of 455 kg/ha during 2019-20. India is the country that grows all four species of cultivated cotton and major cotton production states are Punjab, Haryana and Rajasthan, Gujarat, Maharashtra, and Madhya Pradesh, Telangana, Andhra Pradesh, and Karnataka. Cotton also plays a significant role in the Indian economy by means of the Indian textiles industry contributing around 5% to the country's gross domestic product (GDP), 14% to industrial production, and 11% to total export earnings.

Cotton is vulnerable to an array of insect pests comprising of a complex of sucking pests and a number of caterpillar species feed on leaves, squares, and bolls. The sucking pests can be managed satisfactorily by seed treatment, sticky traps, effective systemic insecticides, etc. But, managing the bollworm complex is a prodigious task. Due to this Indian cotton yields were stagnant from 1985 until 2002 at or below 300 kg lint per ha in spite of an average of 12-14 sprays of all kinds of insecticides. Before the introduction of *Bt*-cotton, cotton occupied only 5% of the cropped area with approximately 45% of the insecticides used in all crops, of which 80% for the protection against bollworms, particularly *H. armigera.* As a consequence, *H. armigera* evolved resistance to a broad range of insecticides and resulted in the outbreak of the pest. Hence, there was a need/search for the method which would set back the drawbacks associated with cotton cultivation.

As a color of hope, Genetic Engineering Appraisal Committee approved the commercial cultivation of transgenic cotton (*Bt* cotton) on 26th March 2002, which could suppress *H. armigera* and *Earias* species satisfactorily as on date. Since, the release of Bt cotton there was a sharp increase in area under cultivation from a mere 86.24 hundred thousand ha in 2002-03 to 125.84 hundred thousand ha in 2019-20 (Anon, 2020). Introduction of *Bt* has caused 24 % increase in cotton yield per acre through reduced pest damage and nearly, 50 % gain in cotton profit and it reduced pesticide usage from 46.5 % to less than 21 % (Kranthi, 2012) which contributed to positive economic and social development along with the positive effect on cotton production, trade, farmers' livelihoods, and the environment.

The benefits of growing *Bt* cotton along with profit realization made farmers to earn the confidence and enhanced the cultivation of *Bt* cotton over another traditional non-Bt cotton. However, due to the lack of knowledge about the possibility of pests developing resistance to *Bt* cotton, the farmers neglected the recommendation to grow structured refuge with non-Bt cotton in spite of the compulsion made by the Genetic Engineering Appraisal Committee accompanied by the Government of India. This resulted in the failure of the *Bt* technology confirming that no technology is foul proof and long-lasting. Since Pink bollworm was the late age bollworm and its monophagous nature compelled the pest to struggle for existence which resulted in the development of resistance to Cry toxin. The 2010 stray cases reported in India were confirmed by 2013-14 (Mohan *et al.,* 2016; Naik *et al.,* 2018; Naik *et al.,* 2020).

The main reasons for the predominance of pink bollworm in *Bt* cotton are:

- Cultivation of long-duration hybrids.
- The large number of hybrids (varying flowering and fruiting periods) provides continuous food for bollworms.
- Squares, flowers and developing seeds in young bolls have less *Bt*-toxin expression.
- Non-compliance of refugia crop.
- Early (April-May) sown crop starts flowering that coincides with PBW peak that occurs in June-July.
- Extending the crop beyond November.
- Lack of timely and appropriate management.
- *Bt* toxin expression in transgenic cotton decreases with the increase in the age of plant.
- Long term storage of raw cotton (ginning mills and market yards) serves as a source of PBW.
- Segregating seeds F-1 hybrid plants accelerate resistance development.

Central Institute for Cotton Research, Nagpur, the pioneer cotton research centre in India, has developed Integrated Pest Management (IPM) schedule for Insecticide Resistance Management (IRM): Dissemination of Pink bollworm Management Strategies and has a pilot project being demonstrated in 8 major cotton-growing states of the country covering 22 districts under participatory mode involving SAU, KVK'S, KSDA from 2018 onwards. This project involves timely sowing, selective and need-based use of insecticides, use of botanicals (Neem base products), use of pheromone traps (monitoring purpose), and release of egg parasitoids i.e., *Trichogramma bactrae*. By following IPM strategies 3-4 rounds of sprays can be reduced but adoption of this technology in toto by the farmers is very less, because of untimely or non-availability of some of the tools. Hence, there is a need for another alternative technique/tool which is easy to adopt and less laborious. Hence, the mating disruption technique was developed, under public-private-partnership (3P's) mode (between UAS, Raichur and ATGC Biotech Pvt. Ltd., Hyderabad), with Specialized Pheromone and Lure Application Technology (SPLAT)-PBW: a wax formulation which is eco-friendly, long-lasting and novel tool for the management of PBW and it has been demonstrated over an area of 600 acres in Raichur district from 2018 to 2021.

Specialized Pheromone and Lure Application Technique (SPLAT)-PBW was applied on leaf petiole of growing tip (Fig. 1) at 500 g per acre in four splits with 125 g per each application at 35-40, 65-70, 95-100 and 125-130 days after sowing, at 30 days interval, with 400 source points per acre. Other plant protection measures were undertaken only to manage the sucking insect pests with selective systemic insecticides (as per UAS, Raichur recommendations). This treatment was compared with the conventional farmers' practice. Observations on the pest incidence were recorded at weekly intervals along with the cost of cultivation at the end of the crop season.

Results revealed that the overall incidence of pink bollworm was minimum with rosette flowers of 8.23%, green boll damage of 7.36%, locule damage of 8.41% and average moth catches of 14.10 moths/trap/week in SPLAT-PBW treated fields. However, the results differed significantly with conventional farmer practice wherein, rosette flowers recorded were 17.31%, green boll damage was 30.95% and locule damage was 35.98% even after taking up 5 to 6 times of insecticides spray exclusively for pink bollworm management. SPLAT-PBW applied at 500 g per acre has resulted in a higher yield of 33.59 quintals per hectare in comparison with farmers' practice who harvested 22.33 quintals per hectare. In toto, in SPLAT applied field the additional gain in yield was 10 to 11 quintals per hectare (Table 1).

Cost economics of SPLAT-PBW

SPLAT-PBW applied at 500g per acre was found efficient with higher profit over conventional farmers practice by considering the percent decrease in PBW incidence (70.23) with an increased yield of 33.6 quintals per hectare over 22.3 quintals per hectare in conventional farmer's practice. Hence, SPLAT-PBW incurred the net return of Indian Rs. 97460/ha with benefit: cost ratio (B:C) of 2.38 against 1.65 in conventional farmers practice with net returns of Indian Rs. 44150 /ha (Table 2).

Conclusion

SPLAT-PBW is an eco-friendly, long-lasting, and novel tool that fits for area-wide management of dreaded pests and has brought down the chemical insecticidal applications (at least 4-5 rounds as of now). So, under the present situation, the only way to curb the menace of pink bollworm and to save the farming community is to advocate the farmers to adopt insect family planning by using mating disruption techniques. This technology not only increases the cotton yield and brings profit for the farmers, it but also protects our mother Earth from the contaminations caused by the chemicals and avoids the resistance to insecticides, the resurgence of insect pests, and mainly lowers the residue problem that occurs in the nature at various levels. In this way, the SPLAT-PBW mating disruption technique protects the harmony of the ecosystem activities by ensuring the safety of every organism associated with the ecosystem.

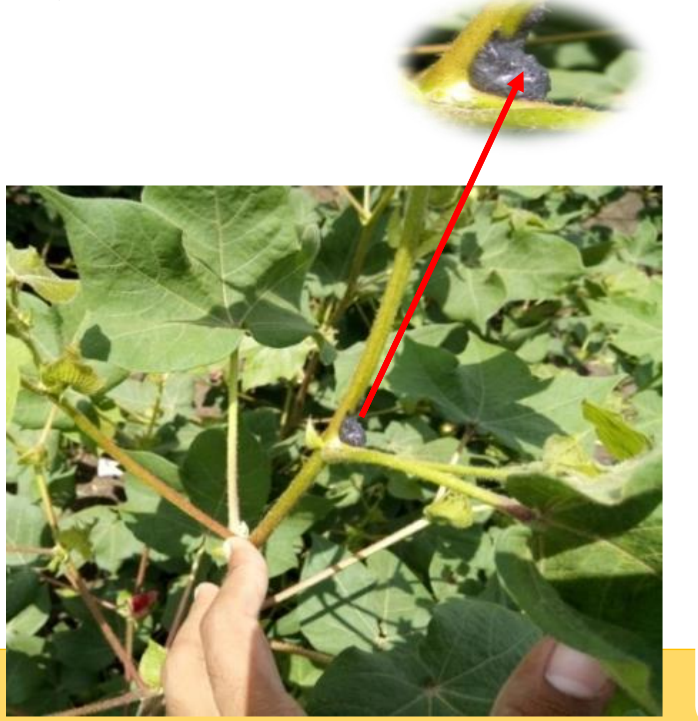

Table 1. Evaluation of Specialized Pheromone and Lure Application Technology (SPLAT) against pink bollworm on *Bt* cotton during 2017-18 and 2018-

Treatment details	Per cent Rosette flowers*			Per cent green boll damage*			Per cent Locule damage*			Per cent Mean PBW incidence			Per cent decrease in PBW incidence over farmers practice			Average number of moths catches/week**			Cotton yield (q/ha)		
Demonstrated seasons	2017-18	2018-19	Mean	2017-18	2018-19	Mean	2017-18	2018-19	Mean	2017-18	2018-19	Mean	2017-18	2018-19	Mean	2017-18	2018-19	Mean	2017-18	2018-19	Mean
SPLAT @ 500 g/acre	11.76 (20.05)	4.70 (12.52)	8.23 (16.67)	10.20 (18.62)	4.52 (12.27)	7.36 (15.74)	8.65 (17.10)	8.18 (16.61)	8.41 (16.86)	10.20	8.18	8.00	63.57	76.88	70.23	9.29 (3.20)	18.92 (4.40)	14.10 (3.88)	40.50	26.67	33.59
Conventional farmers Practice	20.96 (27.24)	13.67 (21.69)	17.31 (24.59)	37.93 (38.01)	23.97 (29.31)	30.95 (33.80)	34.34 (35.87)	37.63 (37.83)	35.98 (36.86)	31.07	37.63	28.08	-	-	-	240.38 (15.33)	155.03 (12.47)	197.70 (14.09)	24.67	20.00	22.33
S. Em (±)	0.98	0.58	1.40	0.86	1.47	2.70	0.68	2.14	3.64	-	-		-	-	-	0.15	0.55	0.92	0.98	0.56	1.15
CD @ 5%	3.03	1.81	7.68	2.64	4.54	8.08	2.09	6.60	6.73	-	-		-	-	-	0.46	1.70	6.59	2.94	1.68	6.08
CV (%)	10.13	12.33	5.35	8.20	13.52	4.83	7.13	11.38	4.63	-	-		-	-	-	5.40	12.72	2.98	10.33	10.23	4.95

** Figures in the parentheses are arc sin transformed values*

*** Figures in the parentheses are square root ($\sqrt{?+ 1}$) transformed values*

Table 2. Cost economics for SPLAT-PBW in Bt- Cotton (2017-18 and 2018-19)

Treatment details	Cotton yield (q/ha)	Costof cultivation (Rs./ha)	Cost of Treatment (Rs./ha)	TotalCost (Rs./ha)	Gross returns (Rs./ha)	NetReturns (Rs./ha)	B:C ratio
SPLAT @ 500 g/acre	33.59	55000	15490	70490	167950	97460	2.38
Conventional farmers Practice	22.33	55000	12500	67500	111650	44150	1.65

**Applied in 4 splits*
Note: Price of cotton: Rs. 5000/q
Cost of SPLAT: Rs. 6200 (Rs. 1299/application hence, for 4 applications it is 5200 plus cost of application Rs.1000 for four times)
Cost in farmer's practice: Rs. 5000/acre (Rs. 4000 is chemical cost and Rs. 1000 for labor four times application

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PROPER BIOASSAY METHOD, MOST VIRULENT AND INSECTICIDE COMPATIBLE ENTOMOPATHOGENS CAN HELP REDUCE CHEMICAL PESTICIDE LOAD TO CONTROL WHITEFLY IN COTTON

Satish Kumar Sain[1*] and Dilip Monga[2]
[1]Principal Scientist at ICAR-Central Institute for Cotton Research Regional Station, Sirsa,
Haryana (India) & Principal Investigator of Plant Pathology under AICRP on Cotton
[2]Ex-Head and Principal Scientist, Plant Pathology, ICAR- Central Institute for Cotton Research (CICR), Regional Station, Sirsa-125055 Haryana-**India**
Email: sain.skumar@gmail.com

Introduction:

Cotton (*Gossypium* spp.) known as "White Gold" is the most commercially important natural textile fiber crop and a significant contributor of oilseeds. It was cultivated on 12.9 million ha in India during the 2020 *Kharif* season with the production of 37.1 million bales (each bale of 170 kg lint) and productivity of 487 kg lint per ha. In the North Zone of India, it was cultivated on 1.91million ha with the production of 6.4 million bales and productivity of 570 kg lint per ha (AICRP, 2020). Among several insect pests, *Bemisia tabaci*, a vector of cotton leaf curl virus disease, is one of the most devastating pests. *B. tabaci* together with CLCuD causes huge economic losses (up to 80%) to cotton yield and quality (Fig.1). Excessive use of chemical pesticides causes insecticide resistance (Sain *et al*., 2020; Monga and Sain, 2021). Entomopathogenic fungi (EPFs) have an important role as mycoinsecticides. More than 20 species of EPFs can infect whiteflies however, among 115 pesticide products registered and recommended for cotton pest management in India, about 39 insecticide formulations including 19 insecticides, 8 mixtures and 2 biopesticides are marketed for whitefly management in India. So far, only one myco-insecticide (*Lecanicillium lecanii*) is commercially available for whitefly management (Anonymous, 2020). Additionally, worldwide several bioassay techniques have been reported in the past for evaluating the bioefficacy of a limited number of EPFs against whitefly. However, there has been the problem of leaf survival for conducting large-scale screening bioassay for up to 7-10 days and inoculation of EPFs. Therefore, the studies were conducted to compare previously reported and new modified bioassay techniques to find out the most virulent EPF strains among a large number of available EPFs at National Culture Collection Centers in India, and newly isolated EPFs from cotton growing fields in Northern India. The selected EPFs were evaluated for their compatibility with insecticides in the laboratory and their bioefficacy against whitefly nymphs under field conditions. The study aimed to find out the most virulent, insecticide-compatible EPF which can be used singly or in a sustainable IPM program.

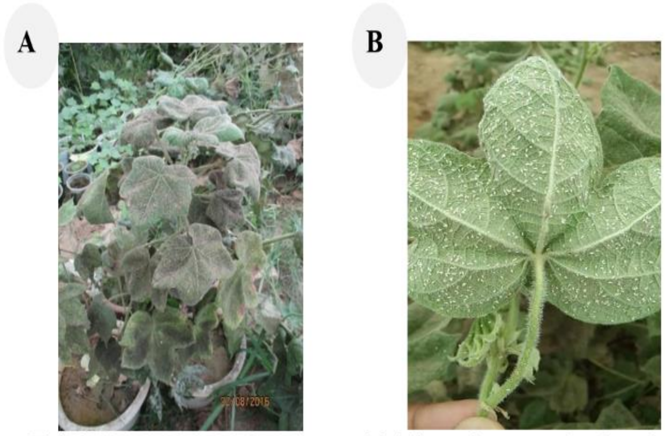

Fig.1. Symptoms of sooty mold (A) and cotton leaf curl disease with whitefly (B). (Photo courtesy- Dr SK Sain)

New modified polyhouse bioassay method (NPBM):

Six different methods including leaf disc, detached leaf method (0.2% agar plate), detached leaf (0.2% sucrose solution in 5 ml vial) in insect breeding disc, detached leaf (0.2% sucrose solution in 15 ml in plastic cups), detached leaf (0.2% sucrose +0.1% NPK on a plastic tray) and the new modified polyhouse bioassay method (NBPM) (modification in IRAC 2009: Susceptibility Test Methods Series Method No:016 Version: 3 www.irac-online.org33) were compared for their suitability to evaluate EPFs. In NBPM, one-month-old potted plants are kept inside the whitefly rearing polyhouse for egg-laying (50-60 whitefly/leaf). 24-hour post-egg-laying, whitefly adults are gently removed from the potted plants and transferred to another nethouse aseptically for the next 10 days. Subsequently, the number of nymphs on the abaxial surface of the leaf is recorded and marked (40-50 nymphs/leaf). The freshly prepared conidial suspension (1 x 10^7 ml^1) of EPFs is applied at a volume of ~2 ml/leaf. In the control treatment, leaves are sprayed with 0.01% Tween 80 solution only. The nymphal mortality is recorded at 3-, 5- and 7-day-post-treatment using 20X hand magnifying lance. Corrected mortality is used before subjecting data for analysis of variance (Püntener, 1981) (Fig.2.). The percent mortality of the nymphs by all the EPFs was observed in the increasing trend under NPBM, while in the other methods the mortality trend was uneven due to reduced turbidity of the leaves. This method provided the highest leaf tenderness and survival period (> 30 days) by maintaining turgidity of leaves that is must for a longer duration for bioassay. Also, NPBM proved to be easy, less time/labor consuming for egg-laying as well as marking and recording the nymphal observations. On other hand, IRAC method No:016 Version: 3 includes potted host plants, insect holding cages for egg-laying and rearing, aspirator for transferring whiteflies, scissors to remove host plant leaves (three fully expanded leaves), and triming of the selected leaves, which is more time, labor-consuming and costly. Also, also the cut leaves attract other fungal contaminants and may change the physiology. Thus, the NPBM is comparatively better than IRAC methos and can play an important role in evaluating large numbers of EPFs, and to find out the most virulent one (Sain *et al*. 2019).

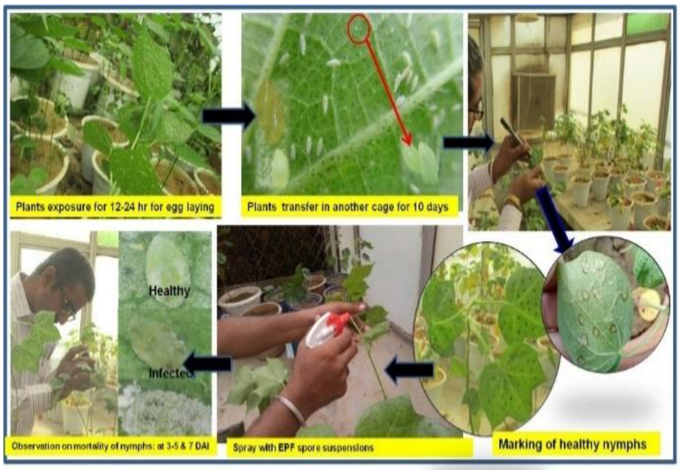

Fig. 2. Entomopathogenic virulence screening method against whitefly nymphs-NPBM

Identification and selection of most virulent EPFs against whitefly nymphs

Using NPBM, the virulence of 373 EPF strains (EPFs) was evaluated to find out the most virulent EPFs against whitefly. The top ten EPFs caused 80% nymphal mortality (at 10^{-7} spore ml^{-1}). The significantly highest corrected nymphal mortality at seven DAI was recorded by Bb-4511 (95.1%) (*B. bassiana*), Bb-4565 (89.9%) (*B. bassiana*) and Ma-1299 (86.7%) (*M. anisopliae*). However, to select the prominent EPFs, mycelial growth, sporulation and mortality character were considered and the overall bioefficacy index was calculated using the formula of Sain et al., (2019a) for final selection and field evaluation [BI=mycelia growth (mm), sporulation (conidia 1 x 10^8); nymphal mortality 7 DAI (%); BI = 35* (MG) + 15 (SP) + 50 (MO at 5 DAI)]. Based on the bioefficacy index the best-performing EPFs were found to be the Cj-102, Cj-089, Fm 083, and Bb-4511 (Fig. 3)

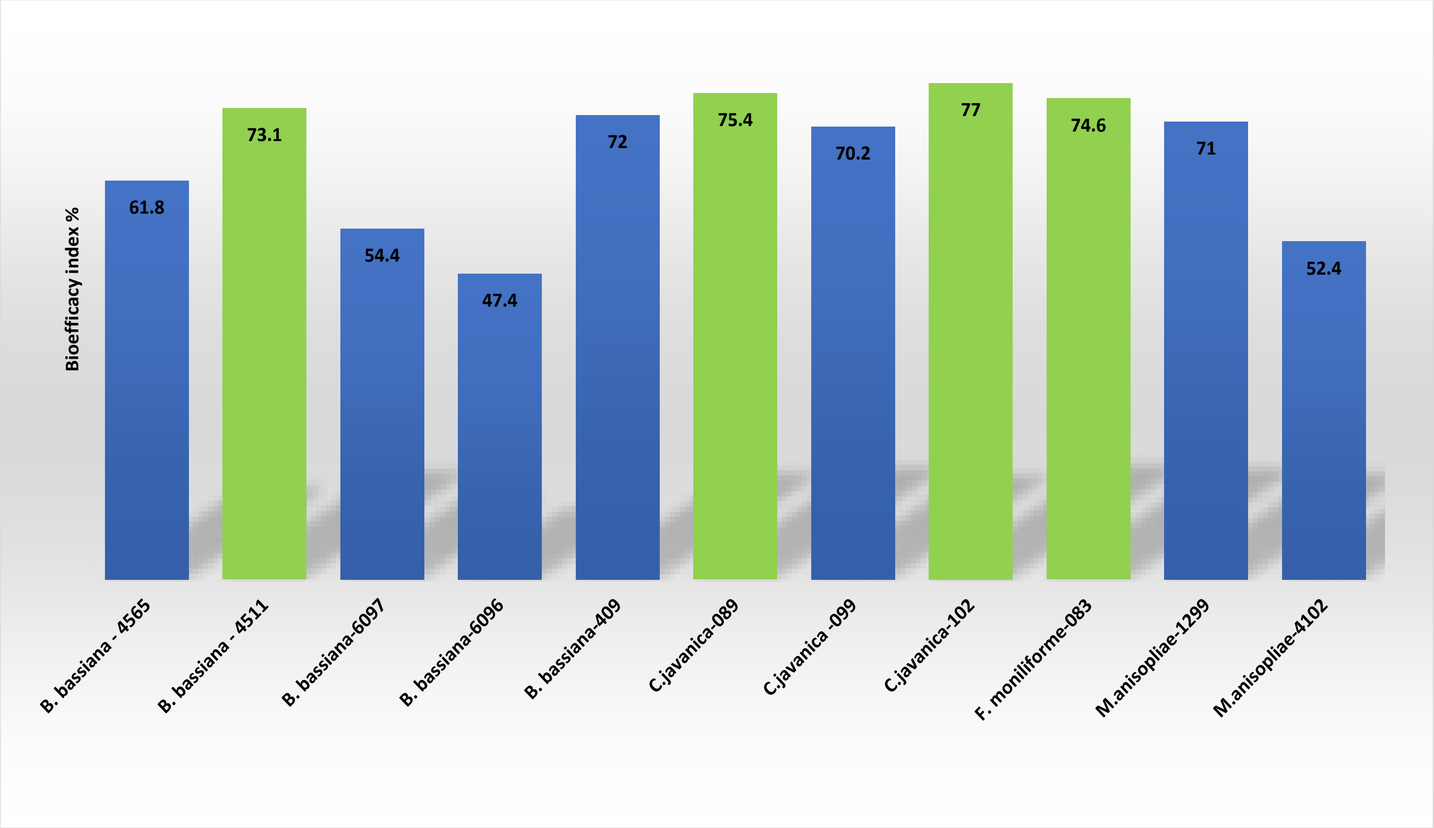

Fig.3. Bioefficacy index values of different entomopathogens (at 33.7- 26.7 °C Max. Mini Temp & 80.3 - 68.4 % RH.)

Table 1: Compatibility classification of chemical and botanical insecticides, in relation of fungi toxic effect on selected strains of EPF

Treatment	Compatibility classification*									
	Cj-102	Cj-99	Cj-89	Bb-6097	Bb-4511	Bb-409	Bb-4543	Bb-4565	Fm-83	Ma-1299
Neem 300 ppm (1ml/L)	C	C	C	MT	C	T	T	MT	C	C
Neem 300 ppm (5ml/L)	C	C	MT	VT	T	VT	T	T	T	MT
Pongamia (1ml/L)	C	C	C	C	C	T	T	MT	C	MT
Pongamia (5ml/L)	MT	C	MT	VT	C	T	T	MT	MT	MT
Castor oil (5ml/L)H	T	T	C	T	T	VT	T	C	MT	MT
Castor oil (10 ml/L)	T	VT	C	VT	T	VT	VT	C	MT	T
Spiromesifen 22.9 %SC (0.5ml/L)	C	C	C	C	C	MT	C	MT	C	C
Spiromesifen 22.9 %SC (1 ml/L)	C	C	C	C	MT	T	C	T	C	C
Flonicamid 50% WG (0.2g/L)	C	C	C	C	C	MT	MT	MT	C	C
Flonicamid 50% WG (0.4g/L)	C	C	MT	C	MT	MT	MT	MT	C	C
Diafenthiuron 50% WP (0.5g/L)	MT	C	C	C	C	MT	C	C	C	C
Diafenthiuron 50% WP (1. g/L)	MT	C	MT	T	MT	MT	MT	T	C	C
Buprofezin 25% SC (0.8ml/L)	C	MT	C	C	C	C	C	MT	C	C
Buprofezin 25% SC (1.6ml/L)	C	MT	MT	T	C	MT	C	MT	C	C
Pyriproxifen 10% EC (1.25 ml/L)	C	C	C	MT	C	T	MT	C	C	C
Pyriproxifen 10% EC (2.5ml/L)	C	C	MT	MT	MT	T	T	C	C	C
Profenophos 50% EC (1 ml/L)	T	VT	C	T	C	VT	T	C	MT	C
Profenophos 50% EC (2 ml/L)	T	VT	C	T	C	VT	VT	C	MT	MT
Trizophos 40% EC (1.5ml/L)	MT	VT	T	T	VT	VT	VT	C	C	C
Trizophos 40% EC (3 ml/L)	MT	VT	T	T	VT	VT	VT	MT	C	MT
Imidacloprid 70% WG (0.5 ml/L)	T	MT	C	T	C	VT	T	C	MT	MT
Imidacloprid 70% WG (1 ml/L)	T	T	C	VT	C	VT	T	C	MT	MT
Fipronil 5% EC (1 ml/L)	MT	T	MT	MT	C	VT	VT	MT	MT	C
Fipronil 5% EC (2 ml/L)	T	T	T	T	MT	VT	VT	MT	T	MT

**Toxicity grades were considered as follow: VT = 0 to 30 (very toxic); T=31 to 45 (toxic); MT-46 to 60 (moderately toxic); C=>60 (compatible).*

Insecticide Compatibility with Entomopathogens

The combined use of insecticides with EPFs is a promising pest-control option through IPM to minimize adverse chemical effects. Thus, the most virulent EPFs were evaluated for their compatibility with 12 chemical and botanical insecticides recommended for whitefly management. For decision making, the toxicity index of chemicals and botanicals against EPFs was calculated using the formula of Alves *et al*., (1998) where T= [20 (VG) + 80 (ESP)]/100. Where values for vegetative growth (VG) and sporulation (ESP) were given in relation to control (100%). Neem oil and pongamia oil were compatible to moderately toxic with all the EPFs except Bb-6097, Bb-409, Bb-4543. The castor oil was toxic to very toxic except EPF strain Cj-89, Bb-4565 and Fm-83. Among the insect growth regulators, flonicamid, and diafenthiuron were compatible to moderately toxic while the organophosphate group of pesticides and fipronil were compatible to very toxic. Overall, EPF strains namely, Cj- 89, Cj-102, Ma-1299, Bb-4511 were found to be the most compatible with full and half doses of the chemical and botanicals *tested (Table 1).*

These *in vitro* studies expose the EPFs to the maximum action of the pesticides that usually do not happen under field conditions. Therefore, the study indicates the fair scope of the best and the most virulent and insecticide compatible EPFs have the maximum likelihood for successful IPM of *B. tabaci* under the cotton field (Sain *et al.* 2019b).

Comparative field study of bio-insecticides and chemical insecticides

The field trials were also conducted at ICAR- CICR Regional Station Sirsa during 2017-18 and 2018-19. The oil-based bioformulation of EPFs and chemical treatments were significantly superior over control. The highest nymphal mortality at the seventh day-after-spray was recorded with *Beauveria bassiana* -4511 (83.65%) followed by *Cordyceps javanica* CICR-RSS -0102 (81.78%) and Pyriproxyfen (2.5ml/L) (Sain *et al.* 2021). These treatments were significantly superior to Diafenthiuron 50% WP (1. g/L), Neem oil (300 ppm) and commercial formulation of *Lecanicillium lecanii* (0.1% WP) (Fig. 4).

Conclusion

Overall, the results of the studies demonstrated that for selecting and incorporating EPFs in a sustainable IPM program, a thorough bioefficacy and compatibility study must be conducted for biocontrol and chemical components. The NPBM proved better in terms of ease, less labour and time-consuming method for screening of large number of EPFs. Among a large pool, EPFs were found to be with better bioefficacy in terms of insect mortality along with mycelial growth and sporulation; their compatibility with chemical/botanical insecticides can cause increased stress, immunocompromise and alteration in insect physiology (mortality and fecundity). This would improve the performance of selected EPFs in an IPM program with a better biological component.

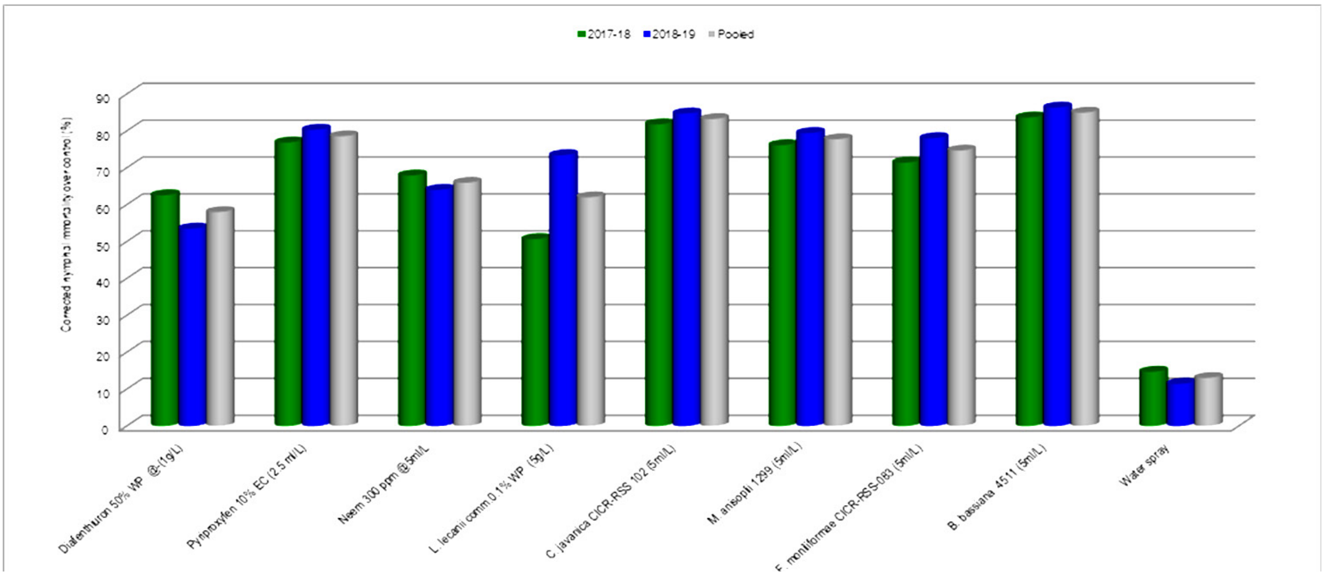

Fig.4. Effect of selected EPFs and pesticides on whitefly nymphal mortality under field conditions at CICR RS Sirsa (Pooled)

Acknowledgments

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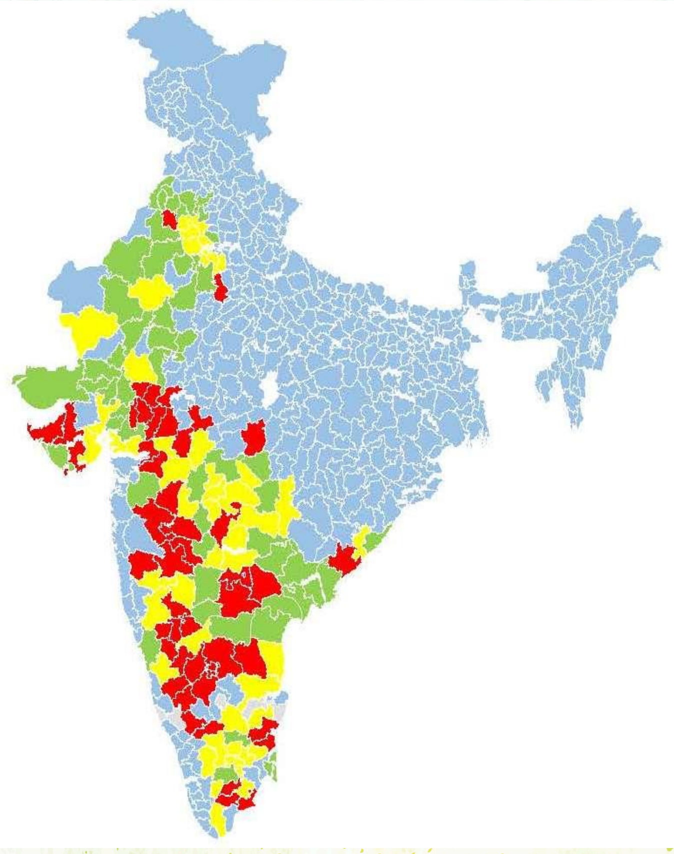
CURRENT STATUS OF HDPS COTTON CULTIVATION IN INDIA AND EVALUATION OF SUITABILITY OF HYBRIDS FOR HDPS

Nallathambi Kannan, K Ramya, P Karthik, R Arun Kumar, M Nagay Alli and M Ramasami
Cotton Breeding R D Centre, Rasi Seeds (P) Ltd.,
Attur, Salem, Tamil Nadu, India

Email: **kannan@rasiseeds.com, ramasami@rasi.in**

Introduction:

India is having the world's largest cotton production area of 13.4 million hectares which is more than one-third of the world's cotton area with a productivity of 473 kg/ha. India stands first in production whereas productivity-wise which is far below the world's productivity (766 kg/ha). About, 65 percent area is rainfed, mainly in the central and southern zones. Most of the rainfed area has soil with low water storage capacity, poor fertility, shallow and less accessibility to water resources for irrigation. As a result, 72 % of the cotton area comes under low (<300 Kg/ha) and medium productivity (370-455 Kg/ha) (Table 1 & Fig. 1). So it is important to focus on challenges in these areas to increase the yield. This is achieved by increasing the yield per unit area through enhancing the genetic base of genotypes and adopting improved agronomic practices. High-Density Planting System (HDPS) is one of the better agronomic approaches to increase yield. So it is necessary to alter the morphology of cotton hybrids to suit the HDPS.



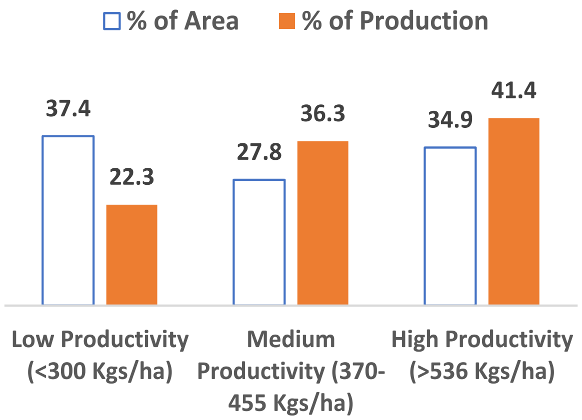


Fig. 1: District wise cotton productivity mapping in cotton-growing states

High-Density Planting System (HDPS)

Depending on the local conditions, hybrid cotton is planted at row spacing ranging from 90 to 120 cm and plant spacing ranging from 30 to 90 cm resulting in accommodation of 15000 to 25000 plants/ha. In HDPS, short duration, semi-compact cotton hybrids are planted at populations ranging from 75000 to 112000 plants /ha by planting at a distance of 80-90 cm between rows depending upon the soil type and growing conditions and 10 to 15 cm between plants in a row. It is aimed to establish around 6-7 plants/m row length. The objective is to achieve10-15 bolls/plant, maximize the number of bolls/unit area and realize a high yield in the shortest possible time. If the number of bolls/ plant is few, the fruiting window (or flowering period) is short (4-5 weeks) and the plant matures early, producing fibers with good quality.

Table 1: Cotton productivity mapping

Category	Area (%)	Production (%)
Low Productivity <300 Kg/ha	37.4	22.3
Medium Productivity 370-455 Kg/ha	34.9	41.4
High Productivity >536 Kg/ha	27.8	36.3

Source: Department of Agriculture, Cooperation & Farmer's welfare (2017-18)

The necessity of HDPS amenable hybrids

- High initial vigor of HDPS hybrids imparts tolerance to drought and better crop establishment in light and shallow/saline soil conditions
- Hybrids respond better to crop management practices (E.g. Fertilizer response)
- Combination of multiple traits like stress-tolerant, higher yield with better fiber quality.
- Comparatively better yields and wider adaptability than varieties under rainfed situations due to initial vigor and establishment.

Ideotype Concept

High-Density Planting System needs genotypes with suitable morphological characters (ideotype) for realizing higher yield. The selection criteria of suitable genotype for HDPS were described below.

Traits	Preferred Type
Duration	Early (140 days)-Early to medium (145-150 days)
Plant type	Compact & semi-compact, erect types along with semi-dwarf /medium tall
Plant height	80 cm - 120 cm
Plant width	≤ 60cm
Stem	Sparsely hairy to glabrous, Flexible but should not break
Leaf	Small size to medium with optimum foliage Angle- Upward/erect/wavy leaf margin Leaf trichome density- Sparse to Glabrous Others- Natural senescence
Bract size	Small or medium
Boll retention	High
Monopodial branches	0-1 (0 monopodia is highly preferred)
Sympodial arrangement	First, sympodia should be above 20 cm from the ground
Boll	Big boll (uniform boll size from bottom to top), with high locule retention and fluffy opening
Ginning percentage	>40% along with optimum seed index (10)
Response to PGR& defoliants	High response to PGR & defoliants
Pest tolerance	Jassid, Thrips, Whitefly and Bollworm complex
Disease tolerance	CLCuV (North Zone), TSVD Grey mildew, BLB, *Alternaria, Verticillium* Wilt, *Fusarium* Wilt, and Boll rot
Abiotic stress tolerance	Drought/Salinity, Para Wilt

Advantages of HDPS in India

- Early crop maturity and higher production/per unit area with short growing seasons.
- Suitability for rainfed crop production on shallow and medium-deep soils.
- Shorter window for protection against bollworms and therefore lower insecticide requirement and reduced production costs.
- Lesser chance of getting infected with Para wilt.

Challenges in adopting High-density planting system (HDPS)

- Availability of amenable HDPS genotypes.
- Cotton growers were less aware of

effective canopy management.

- Change in microclimate conditions increases pest and diseases such as Jassid, Whitefly, BLB, Alternaria leaf spot, and Grey mildew
- Uncertainty in rainfall pattern (In the north: September, in the south: October, November) during peak boll formation period resulting in the severe square, boll drop, boll rot, and poor bursting.

An attempt was made to evaluate hybrid and variety performance under HDPS and also to standardize proper canopy management practices.

Summer Trial during 2020:

A trial was conducted in 2020 (summer) at Sathyamangalam, Tamil Nadu to find out the optimum summer sowing window and to evaluate the performance of the hybrid and varieties to PGR application, monopodia removal, and undisturbed condition under HDPS and with farmer spacing. Sowing was done on the first day of February, March, April, and May as four different sowing windows. Subiksha (Non-Bt. variety) and RCH608BGII (hybrid) were used for this study. These genotypes were sown in two different spacing of 86*10cm (HDPS-1138080 plants/ha) and 86*60cm (Farmer practice-18968 plants/ha). To study the management of plant canopy area, two treatments namely PGR application and monopodia removal on 55th DAS were followed against undisturbed (control) conditions.

The results (Table 2) clearly showed that February and March sowing were more suitable for summer cotton. Hybrid RCH608BGII performed better than the variety Subiksha for seed cotton yield. Both hybrid RCH608BGII and variety Subiksha yielded higher in HDPS than farmers' spacing. Hybrid RCH608BGII possess a more stable seed cotton yield than variety Subiksha under different sowing windows. In canopy management treatment, there is only a narrow difference between removal of monopodia and PGR application in variety Subiksha but in hybrid RCH608BGII produced more seed cotton yield under PGR application than removal of monopodia. Both variety Subiksha and hybrid RCH608BGII under undisturbed conditions yielded more when compared to removal of monopodia and PGR application. This is because, in the summer season, excessive growth was not observed to warrant PGR application.

Table 2: Seed cotton yield (kg/acre) during the summer season of 2020 at Sathyamangalam, Tamil Nadu under HDPS and normal spacing at different sowing dates

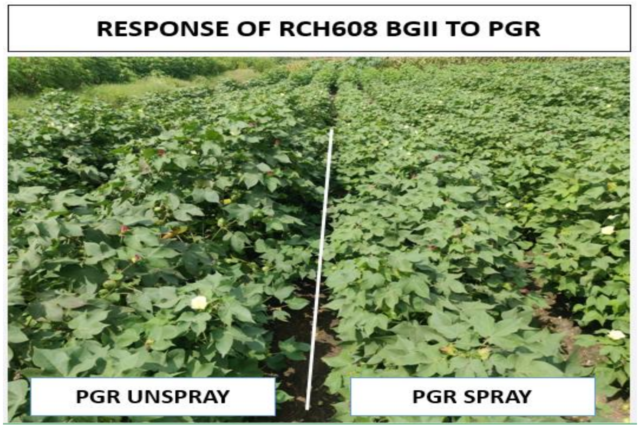
Treatment	Genotype	February 1 sowing		March 1 sowing		April 1 sowing		May 1 sowing	
		HDPS	FP	HDPS	FP	HDPS	FP	HDPS	FP
Monopodia Removed	Subiksha	500.1	363.9	467.9	313.7	143.4	120.1	143.4	116.5
	RCH608BGll	932.1	666.8	878.4	634.6	553.9	340.6	528.8	378.2
PGR (mepiquat chloride) Spray	Subiksha	419.5	372.9	523.4	308.3	163.1	104.0	170.3	123.7
	RCH608BGll	966.2	681.2	1005.6	788.7	803.1	577.2	634.6	553.9
Undisturbed	Subiksha	668.6	410.5	591.6	507.3	177.5	147.0	154.2	150.6
	RCH608BGll	1197.5	790.5	1369.5	984.1	985.9	638.2	812.0	677.6

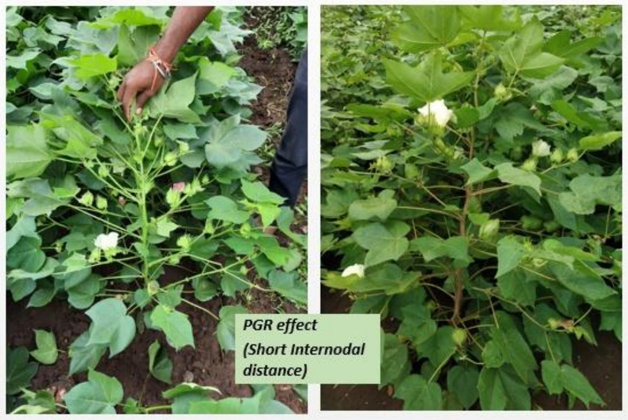
Summary Trial during 2021:

BG II Hybrids RCH 608 and RASI NEO were evaluated under HDPS and farmers' practice. Different canopy management options- Mechanical (removal of monopodia) and chemical (mepiquat chloride) applications were superimposed. The results are presented in Table 3. PGR was applied once for RCH608BGII at 55th DAS and twice for RASINEOBGII at 55th& 70th DAS based on vegetative growth rate. The hybrid RCH608BGII responded with one spray of PGR application to canopy management practice. The seed cotton yield of both hybrids in HDPS is more than farmer practices. HDPS hybrid RCH608BGII yielded better in PGR treatment than the other two treatments whereas the normal spacing hybrid RASINEOBGII in PGR treatment yielded less than undisturbed condition and better than treatment with monopodia removed. This result showed the need for the development of a hybrid for HDPS to maximize the yield.

Table 3: Seed cotton yield (kg/acre) in BG II hybrids in normal and HDPS under different canopy management regimes

Hybrid	Spacing *	Treatment	Yield per ac (kg)
RCH608BGII	HDPS	Monopodia Removed	1290.0
	Farmer Practise		730.0
	HDPS	PGR Spray (1 spray @ 55th DAS)	1590.0
	Farmer Practise		770.0
	HDPS	Undisturbed	1270.0
	Farmer Practise		740.0
RASINEOBGII	HDPS	Monopodia Removed	1170.0
	Farmer Practise		810.0
	HDPS	PGR Spray (2 spray @ 55th & 70th DAS)	1390.0
	Farmer Practise		870.0
	HDPS	Undisturbed	1440.0
	Farmer Practise		910.0





Summary

Based on the studies, the trial result showed the following inference;

1. Hybrid performed superior to a variety
2. Seed cotton yield was higher in HDPS than Farmer spacing
3. Seed cotton yield of hybrid under HDPS is higher than variety under HDPS
4. Better canopy management of hybrids in HDPS without yield compensation was achieved through precise application of PGR

Conclusion and way forward:

Hybrids under HDPS are a viable alternative for rainfed and low productivity regions to increase the yield. Developing genotypes to suit HDPS and standardized agronomic practices in HDPS will help in increasing productivity. Infusing technology along with HDPS such as amenable genotypes for mechanical harvesting, response to defoliation, uniform boll maturity of hybrids will pave way for mechanical harvest in near future. So, it is necessary to fasten the activities in the development and adaptation of HDPS hybrids as it is being projected by scientists, policymakers, NGOs, private stakeholders, and farmers as the next game-changer in cotton production in India.

INTEGRATED PEST MANAGEMENT PROGRAM- A STEP TOWARDS REVIVAL OF COTTON

Saqib Ali Ateel[1] and Haider Karar[2]

[1]Secretary Agriculture South Punjab,
Agriculture Secretariat-Multan, Pakistan
Email: saqibaliateel@gmail.com
[2]Deputy Secretary (Technical) South Punjab,
Agriculture Secretariat-Multan, Pakistan
Email: dstechnicalsp@gmail.com

Introduction:

Cotton is "White Gold", an important cash crop and the lifeline of Pakistan's textile industry. Its products account for 55 percent of all foreign exchange earnings of Pakistan. Nearly 26% growers cultivate cotton, and more than 15 percent of the total cultivated area is devoted to this crop. Approximately, 65 percent of Pakistan's cotton is grown in the province of Punjab, while 35 percent in Sindh, with a negligible area under cotton crop has been recorded in the Balochistan and Khyber Pakhtunkhwa provinces. Cotton production accounts for 4.5 percent of the value-added in AgGDP and 0.8 percent of GDP. It serves as the raw material for the textile industry, the country's largest agro-industrial sector, employs 17 percent, earns 60 percent of foreign exchange, and contributes 8.5 percent to GDP. Despite its importance, cotton productivity in Pakistan has been underwhelming. Pakistan now ranks 4th in terms of area and ranks 39th in cotton productivity per hectare. (Abdul Wajid Rana, et al., 2020). The cotton area, production and average yield per acre of last three years shown in Table 1.

Table 1: Cotton area, production and yield of South Punjab, during 2019-20, 2020-21 and 2021-22.

Indicators	**2019-2020**	**2020-2021**	**2021-2022**
Cotton area sown (Million acres)	4.199	3.579	2.976
Cotton production (Million bales)	5.714	4.662	4.870
Average Yield (Maunds/acre)	17.5	15.63	19.64

Source: Crop Reporting Services 2021-22

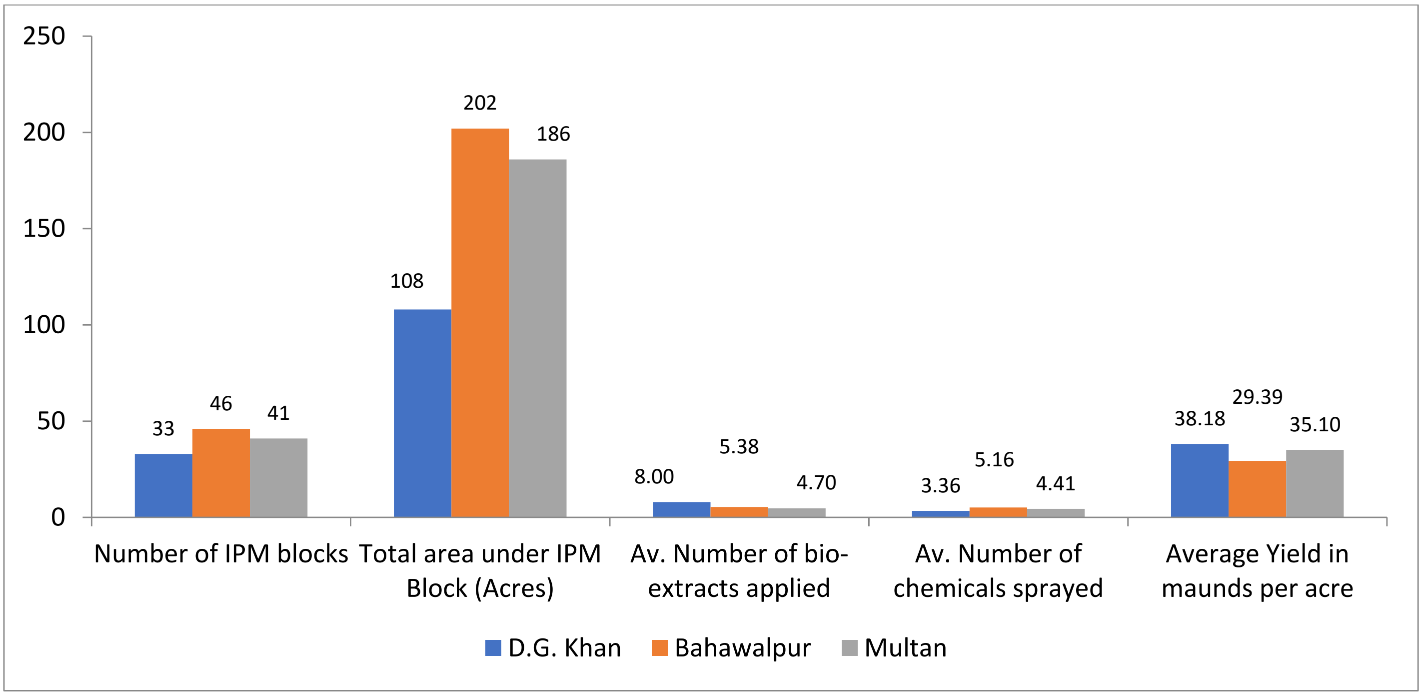
It is clear that the area, production, and average yield decreased significantly during the years 2019-20 and 2020-21 (Table 1). But during 2021-22, although the area under cotton decreased, the production, and yield per acre was increased (CRS-2021-22) significantly. There are so many factors of cotton decline in Pakistan i.e. non-availability of quality seed, low price, climate change (Anonymous, 2015), lack of tolerant varieties, high cost of production, low return, heavy attack of insect pests, and lack of proper pesticides etc. After the establishment of South Punjab Agri. Secretariat, it was challenge, for the newly established agri. department to revive the cotton with the consultation of stakeholders. The following step were taken for the revival of cotton

- Preparation of cotton calendar and its implementation
- Selection of Integrated Pest Management (IPM) plots
- Issuance of advisory services
- Creation of South Punjab Ext. and PWQC whatsApp group (for daily update of cotton situation) and
- Regular field visits of Secretariat staff

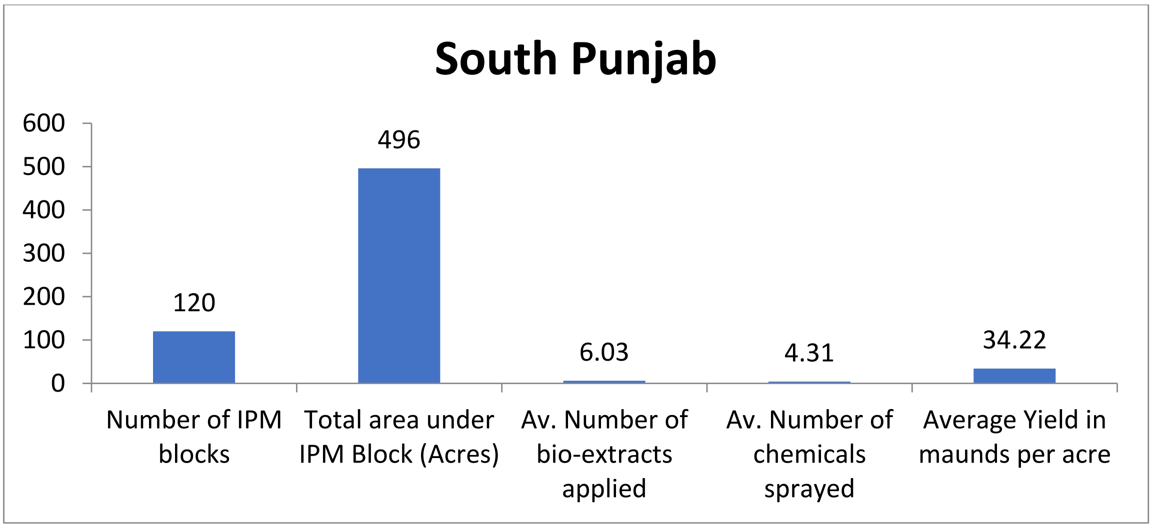
After the selection of IPM plots in South Punjab and then execution of IPM practices on these plots was at top priority. The IPM involves using all existing possible techniques for the management of pests populations with the aim of reducing the chemicals use while maintaining profitability, yield and fibre quality. It is a practice for improving the quality of the environment and the quality of an IPM programme depends on how environmentally friendly it is.

The IPM is not a new concept, but the practical execution was made during the cropping season of 2021-22. Total 120 IPM plots were maintained by field formation (Extension and Pest warning and Quality Control of Pesticides) with the willingness of cotton growers. These plots were monitored by the South Punjab Agriculture Secretariat, Officers regularly. On these plots different IPM techniques were applied to overcome the insect pests like botanicals extracts, installation of bio-cards (parasites and predators), pheromones traps, yellow sticky traps and chemicals etc. The chemicals were applied only when the insect pest population reached above the ETL. The advisories were prepared and issued for IPM blocks and cotton growers. Initially, the use of chemicals was delayed for the period of 90 days. During first three months, natural fauna played an important role in the suppression of pests. The growers welcomed advisories messages, in view of the last many years' experience of chemicals application. The messages were disseminated to the cotton growers through farmers gathering, field days, mass sweeping campaign, electronic media as well as individual contact with the growers. The overall impact of these activities resulted in average yield i.e. 34.22 maunds per acre (Saqib Ali Ateel, 2021) of these IPM plots. DAWN, 2 Jan.2022 article, reported that 57% reduction in pesticides was noticed on cotton farms during 2021-22 in Southern Punjab. Such type of IPM practices were highly appreciated by the cotton growers.

IPM Blocks: Among 120 IPM blocks, 33 were maintained in D.G.Khan, 46 in Bahawalpur and 41 in Multan Division, with an area of 108, 202 and 186 acres, respectivelly. A total of number of bio extracts i.e., 8.00, 5.38 and 4.70 were sprayed while 3.36, 5.16 and 4.41, number of chemicals were sprayed during the cropping season of 2021-22. Average yield in maunds per acre was 38.18, 29.39 and 35.10 as shown in graph below.



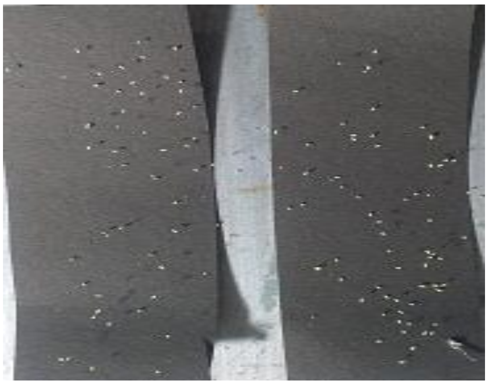
South Punjab IPM Blocks: In South Punjab, total area was 496 acres under IPM blocks. The average number of bio extracts and chemicals applied were 6.03 and 4.31, respectively. The yield remained 34.22 maunds per acre. The data of IPM blocks was compiled and graphically shown below.



IPM practices:

Bio-cards: Cards of 1x3 inch having eggs of Chrysoperla 16-60 per card and card of 2x3 inch for Trichogramma having 200-250 eggs per card. These cards @ 20 per acre were hanged in the cotton field fortnightly. These effectively control the sucking pests as well as bollworms.

***Trichogramma* eggs & parasite**



***Chrysoperla* eggs card**

Predators

Botanical Extracts: Kortumma, Neem, Akk and Tobacco @ 600 g dissolved in 100 liter water was used when the population of sucking insect pest recorded above ETL.

Kurtumma

Neem

Akk

Tobacco

Why do we need to develop IPM programs?

Cotton crop in Pakistan is heavily infested by Whitefly (*Bemesia tabaci*), Jassid (*Amrasca devastans*), Thrips (*Thrips tabaci*), Mealy bug (*Phencoccus solenapsis*) and Pink bollworm (*Pectinophora gossypiella*) which are considered as major insect pests. For the management of these pests, cotton growers depend upon the use of synthetic chemicals from growing up to harvesting of the crop. But due to over reliance on chemicals, many problems were appeared including resistance in insect pests, disruption of parasites and predators, outbreak of secondary pests and ecological consequences. So IPM program is considered safe for such type of consequences.

Jassid: It is also known as "leaf hopper". Both the young ones and adults suck the sap from leaves. In case of heavy attack, the leaves become red known as "hopper burn" that impair photosynthetic activity of plants. The 1st and 2nd instars of jassid feed near bases of the leaf veins, later instars get dispersed all over the leaves but feed chiefly on the under surface of leaves. The affected leaves curl downward positions. Severe incidence can lead to the stunting of a cotton plant. The fruiting capacity of the infested plants is affected badly and, in many cases, high infestation can cause the early mortality of cotton plants and leads to reduced yields.

Components of IPM:

- Sowing of tolerant varieties
- Sowing of cotton North-South Directions
- Thinning
- Judicious use of nitrogenous fertilizer
- Flonicamid @ 60 g per 100 liter of water was used (It was noted that less efficacy of bio-extracts against Jassid)

Jassid

Thrips: It is also major sucking pest of cotton crop. Both nymphs and adults suck the cell sap from the lower surfaces of leaves by lacerating the leaves tissue. Thrips also inject saliva during sucking the sap resulted in silvery appearance. Seedlings infested with thrips grow very slow and the leaves become wrinkled, curl upwards and distorted with white shiny patches. During the fruiting phase there is premature dropping of squares, and the crop maturity is delayed that ultimately leads to reduction in seed cotton yield.

Components of IPM:

- Tolerant varieties
- Sowing of cotton North-South Directions
- Thinning
- Breaking of ridge sown cotton beds
- Judicious use of nitrogenous fertilizer
- Chlorfenapyr @ 100ml per 100 liter of water was used (less efficacy was reported against thrips of bio-extracts)

Thrips

Pirate bugs

Cotton Mealy bug: The cotton mealy bug is a small sap-sucking insect, causes severe economic damage to cotton and other field crops including vegetables and horticultural plants. The young ones are tiny, small and fast-moving crawlers which fix themselves on plants parts. After fixing, mealy powder appears on the insects with the passage of time. In case of severe damage, the affected plant parts completely dried. Mealy bug attacks on almost all organs of cotton plant including main stem, branches and fruit, underdeveloped flowers, bolls of smaller size. The boll opening affected badly resulted in the reduction of yield. Excretion of honeydew by mealy bug attracts ants and also contributes to the development of black sooty mould on leaves as well as on lint. Infested cotton plant shows the symptoms like white fluffy mass on underside of leaves, near growing tips, along leaf veins and on stem, distorted or bushy shoots.

Components of IPM:

- Uprooted the infested parts or plants by covering them with polythene sheet
- Removed alternate host plants
- Encouraged the natural enemies
- Spot spray profenofos @ 70 ml + bleach 200 ml per 20 liter of water was done.

Cotton mealy bug female

Cotton mealy bug male

Predator, Parasite

Pink Bollworm (PBW): The PBW is one of the most destructive pest of cotton known as hidden pest. The young ones of PBW attack the buds and bolls after emerging from the eggs within 30 minutes. The opened flowers look like rosette type in appearance. The larvae feed inside the flowers on pollen grains. After 12-15 days, the larvae along with petals fall on the ground and pupate. The adults emerged after seven days. After mating female select squares, bolls and branches for egg lying. The second generation of larvae enters in 10-12 days old bolls and feed on the developing seeds. Stained lint around feeding areas will be seen in opened bolls. Improper boll opening with damaged seeds are obvious. Small round holes are seen on the septa between locules of open bolls. The infested lint is of inferior quality and known as “Yellow Spot”. PBW spend six months in double seed in left over bolls, until next cropping season. The number of generations of PBW produced in one year are four.

IPM: Plucking of rosette flowers: The rosette flowers were plucked regularly and buried in the soil during pest scouting.

Pheromones traps: Eight pheromones traps per acre were hanged for the monitoring & control of Pink Bollworm.

GRAZING: After the termination of cotton, the left over bolls were grazed by sheeps and goats or by cattles. This practice proved helpful for the management of PBW in next cropping season.

PBW

Pheromones

Grazing of Sheep & Goat

Rotavation of cotton sticks

Rosette flower

Alternate host plant: In Pakistan, Okra (lady finger) is recorded as second most important host plant of PBW after cotton (Karar *et al*. 2021). Thus sowing of "okra" was prohibited near cotton field.

Chemical & Botanical Spray:

- Mixture of Tobacco @ 600g+ Gamma-cyhalothrin @ 100ml or
- Tobacco @ 600g+Neem @ 600g+ Gamma-cyhalothrin @ 100ml was sprayed for the control of PBW (Karar, *et al.,* 2021).

Whitefly: This insect has become one of the major pests of cotton. It causes damage to cotton plants in two ways i.e. by sucking the cell sap and by excreting honey dew on which sooty mould grows which affects the photosynthetic activity badly and reduces the yield. Whereas, indirect damage is the lint contamination with honeydew and associated fungi occur during heavy infestations after the boll opening. Excessive/regular usage of pyrethroids against PBW plays an impotent role in the outbreak of whitefly.

Components of IPM:

- Tolerant varieties
- Sowing of cotton North-South Directions
- Thinning
- Judicious use of nitrogenous fertilizer or application of CAN
- Delayed chemical sprays (avoid use of pyrethroids)
- Spray of botanical extracts including Kurtumma, Neem, Akk and Tobacco @ 600 g per 100 liter of water were sprayed against whitefly and their young ones when whitefly population above ETL
- Yellow sticky traps**:** Eight yellow sticky traps per acre of size 7x11.5 inch treated with German glu were hanged for the control of Adult whitefly.

Whitefly

Yellow sticky traps

Parasite of whitefly

IPM and its role in crop production: IPM has evolved as an economical, environmental and eco-friendly approach to manage insects, diseases, physiological disorders, weeds and rodents that cause economic yield loss and limit the agriculture production (IPM Package for cotton, 2014).

- IPM aims at reducing farmer risks from pesticide poisoning and consumer risks from residues in food chain at community level, low production costs and greater yield savings at farm level, and increased biodiversity especially of productive biota and improved quality of natural resources such as soil and water quality at agricultural ecosystem level.
- IPM aims to reduce pest populations below ETL.
- IPM utilizes the various methods of pest suppression in a compatible manner towards sustainable crop production and eco-friendly environment.

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SALT FREE DYEING TECHNOLOGY FOR COTTON TEXTILES

A S M Raja & Sujata Saxena***
ICAR- Central Institute for Research on Cotton Technology
Mumbai-400019, Maharashtra, India
* Principal Scientist E.mail : asmraja16475@gmail.com
** Principal Scientist & Director (Acting)

Introduction

Reactive dyes are widely used to dye cotton materials due to their brilliant colours and overall good fastness properties. As the name suggests, these dyes chemically react with hydroxyl group of cotton and form covalent bond and constitute more than 80 % of the dyes used for cotton. While dyeing cotton with reactive dyes, a large quantity of salts such as sodium chloride or sodium sulphate are used for exhausting the dyes from dyebath.

Why salts are needed during dyeing of cotton?

When the cotton material is immersed in water, it acquires week negative charge due to ionization of hydroxyl groups present in its structure. Reactive dye is also anionic in nature and acquires negative charge when dissolved in water. So during dyeing, cotton and dye repel each other due to same charge on their surface. The addition of salt during dyeing neutralizes the weak negative charge developed on the cotton substrate and makes it positive so that dye can react with cotton and form covalent bond and secondly it also prevents unnecessary reaction of reactive dye with water that leads to the loss of covalent bond formation activity of the dye with cotton. If salt is not added to the dye bath, the dye tends to react more with water than with cotton and loses its dyeability. This phenomenon is explained in Fig.1.

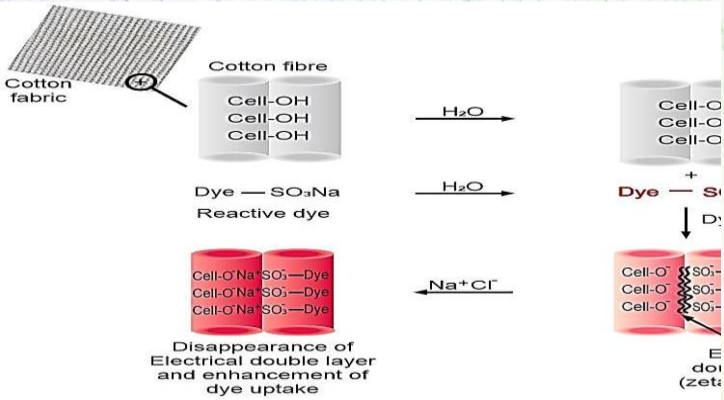

Fig 1: Interactions of cotton and dye in water and role of salt

Problem with the use of salt during dyeing

One kilogram of cotton fabric requires addition of approximately 0.2-0.8 kilogram of salt during reactive dyeing depending upon shade. Dark shades require addition of as much as 80 g/L of salt. The added salt is only an intermediate requirement to alter the surface charge of cotton for dyeing and once dyeing is over, the entire amount has to be removed along with unutilized dye during subsequent washing as effluent. The added salt drastically increases the total dissolved solid (TDS) load of the effluent. The TDS of the reactive dye bath will be around 60000 to 80000 ppm without dilution. This needs to be drastically reduced as the discharged effluent should not contain more than 2100 ppm of TDS according to the pollution control board norms, because the salt water can make the ground water saline and affect soil health and fertility.

The most commonly used method to remove the salt from the effluent is through Reverse Osmosis (RO) process and evaporation of RO rejects using Multi Effect Evaporator (MEE) to separate the salts. As both the processes are highly energy, time and cost intensive, several attempts have made to reduce the salt usage during reactive dyeing.

Salt free Dyeing Technology

Various attempts have been made to facilitate salt free dyeing of cotton through cationization process. Cationization is a pretreatment before dyeing in which cotton materials are treated with quaternary ammonium salts. A good amount of literature is available on methods for cationization of cotton materials and their performance (Hauser &Tabba (2001), Hashem *et al* (2003), Ramasamy & Kandasamy (2005), Montazer *et al* (2007), Ristic & Ristic (2012), Acharya *et al* (2014) and Arivithamani & Dev (2017)). Among the different cationization methods, 3-chloro-2-hydroxypropyltrimethylammonium chloride (CHPTAC) based method is widely studied for dyeing of cotton at industry level. CHPTC based cationization process though technically successful for salt free dyeing has some limitations like release of triethnolamine during storage, requirement of large addition of alkali, reduction in strength of fabric, issues related to fastness etc. Several attempts have been made to optimize the process to get better dyebility (Cotton Incorporated Technical Bulletin, 2017, Fu *et al* (2017) and Zhang *et al* (2021) and) however, large scale industrial adoption is not yet possible due to the above technical limitations.

ICAR-CIRCOT Salt Free Dyeing Technology

ICAR-CIRCOT initiated a project to develop salt free dyeing technology under Consortia Research Platform Project on Natural Fibres in 2014. Initially, attempt was made to optimize the CHPTC based process and afterwards, a polymer based new salt free dyeing technology was developed. By using the technology, cotton fabric could be dyed with both Chlorotriazine and vinyl sulphone based reactive dyes without salt and 50% less alkali. The newly developed process provided dyeing shades similar to those developed using CHPTAC. The advantage of new process is that the total organic carbon (TOC) and total nitrogen (TN) values of the effluent are significantly lower than CHPTAC process. In this technology, cotton in all forms such as fibre, yarn or fabric has to be pre-treated with cationising polymer before dyeing and it can then be dyed using reactive dyes without the use of salt. Using this salt free technology, 10 times reduction in the TDS of the effluent from 16000 to 1600 ppm, well below the pollution control board norms of 2100 ppm was observed (Fig.2). Due to lower TDS, minimum effluent treatment is required which can lead to cost effective ZLD process

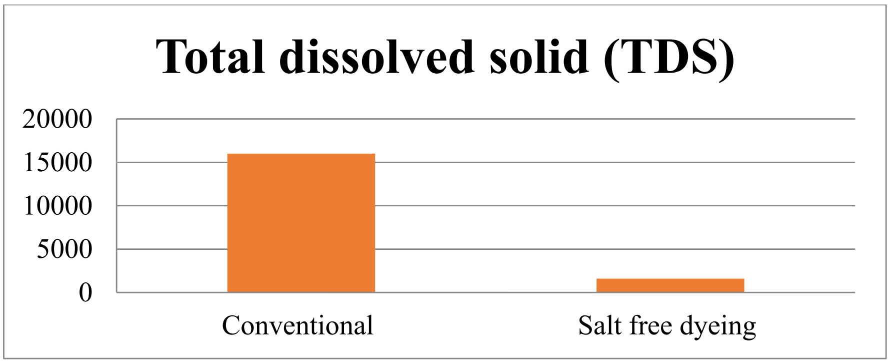

Fig 2: TDS values in conventional and salt free dyeing

ICAR-CIRCOT has completed three industrial level scale-up trials for dyeing of both woven and knitted cotton fabric using this technology producing cotton shirts and T-shirts. The developed process can be adopted at an industrial level without any modification of existing machinery sequence.

Salient features

- 80% reduction in the chemical use during dyeing
- Suitable for small scale dyeing industries – reduction in effluent treatment cost
- Reduction in pollution load leads to adoption of ZLD with less cost
- 20% more water recovery, 20% savings in time and energy make dyeing sustainable
- Comparable Dyeing Cost

Technology Commercialization

- Stake holder meetings were conducted at Boisar, Maharashtra and Tiruppur (Tamil Nadu) in collaboration with Industry Associations (TIMA) with participation from more than 170 cotton processing industries.
- MOU signed with M/S. SRG Apparels Ltd, Tirupur for commercialization

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PREPARATION OF ACTIVATED CARBON FROM COTTON STALKS

Sujata Saxena, T Senthilkumar, G Krishna Prasad, A S M Raja and Sujata R Kawlekar
ICAR-Central Institute for Research on Cotton Technology,
Mumbai – 400019, India
E-Mail: saxenasujata@gmail.com

Introduction

India is one of the major cotton cultivation countries globally, cultivating the cotton varieties viz. *Gossypium arboreum, G. hirsutum, G. herbaceum* and *G. barbadense* in addition to hybrids. Annually 26 million tonnes of cotton plant stalks are generated in India. On an average, cotton cultivation generates about 2 to 3 tons of cotton plant stalks per hectare. Cotton plant stalks are lignocellulosic in composition and contain about 69% holocellulose, 27% lignin and 7% ash (Shaikh *et al.,* 2010). High lignin content makes these resistant to degradation in soil. After harvesting the cotton crop, the stalks are burnt in the field itself after a small proportion has been used as domestic fuel. Burning of cotton stalks in the field results in air pollution and deteriorates soil fertility. An alternate approach for increasing farm income is to constructively utilize the by-products of crop cultivation. Cotton plant stalks being one of the essential by-products of the cotton crop, researchers are finding different ways and means for their better utilization to avoid burning of these in the field. Enhancing the value of cotton plant stalk by converting it into highly porous activated carbon is one of the best way to utilise this agro waste.

Activated carbon is predominantly an amorphous solid with a large surface area and pore volume, pore size distribution and varied surface reactivity. Due to their unique properties, activated carbon materials are used as very good adsorbents in many industrial applications. Agro biomass may be a cheaper alternative to coal, normally used for activated carbon preparation. The agricultural biomass which have been used to prepare activated carbons include *Cucumis sativa* fruit peel (Santhi & Manonmani, 2011), rice husk (Malik 2003), coconut shell (Yang *et al*., 2010), orange peel (Khaled), mango pit (Elizalde-Gonzalez & Hernandez-Montoya, 2007), oil palm fibre (Tan *et al.,* 2007), cotton fibre (Muxel *et al*., 2011), kenaf fibre (Aber & Sheydaei, 2011) etc.. Feasibility of the preparation of the activated carbon from the cotton stalk using a high-temperature fluidized bed reactor with steam as activating agent was explored. Activation parameters such as activation temperature, time and activating methods were optimized based on the generation of mesoporosity, microporosity and internal surface area.

Fig. 1: Methodology adopted for preparation of activated carbon from cotton stalk

Fig. 2: Fluidized Bed Reactor

Activation develops an extended surface area and a porous structure in the carbonized material. Chipped fine particles of cotton stalks were first washed in the stream of water, and then dried in the oven overnight, followed by carbonization. Optimum carbonization temperature was found to be 350ºC. The fluidizing column was then loaded with carbonized cotton stalk particles and fluidization was carried out at minimum fluidization velocity throughout the process using steam. Widening and deepening of existing pores and new pore development occurs at higher activation temperatures. Constant steam flow rate was maintained throughout the process and the char was activated at the desired temperature and time. Activation parameters such as activation temperature (600ºC), activation time (90mins) and steam pressure (0.25g/cm^2) were optimized. Activated carbon thus prepared was characterized in terms of micro porosity (Iodine number as per ASTM D4607) and meso porosity (Methylene Blue number as per BIS 877-1977). Maximum micro porosity and meso porosity was found to be 212mg/g and 640mg/g respectively. A comparison of micro and meso porosity of activated carbon prepared from cotton stalks by steam activation with other biomass based activated carbon is given in Fig 3. It can be inferred from the Fig. that activated carbon from cotton stalks compares well with activated carbon made from other sources and can be used for various adsorbent applications.

Conclusion

It is thus seen that the cotton plant stalks can be a potential source of low-cost activated carbon. The process protocol for producing activated carbon from cotton stalk micro particles has been optimized and the activated carbon thus produced can be used as an adsorbent in effluent treatment, filters, face masks, etc.

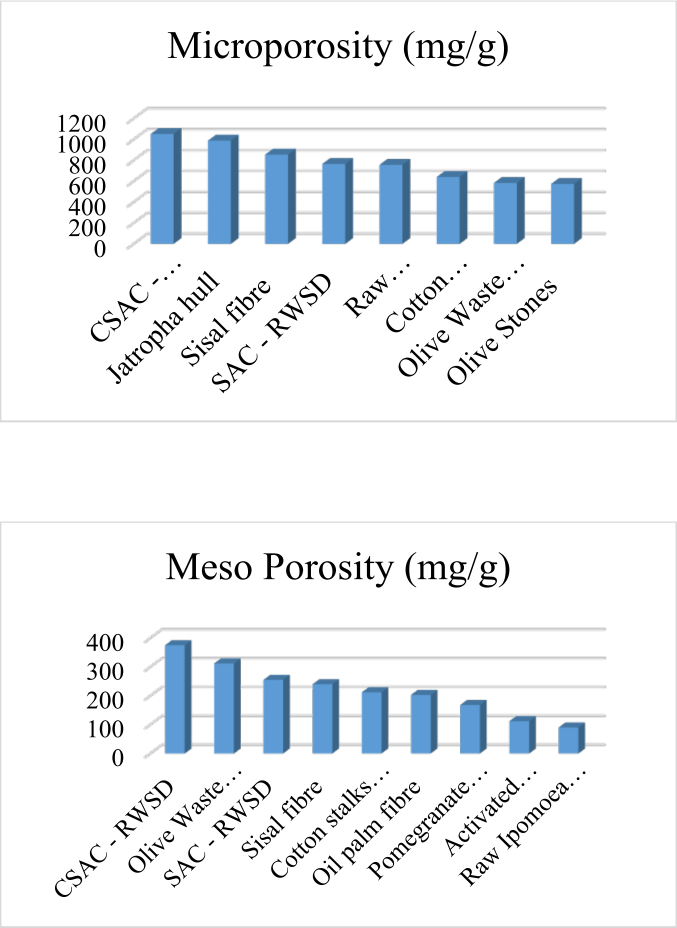

Fig.3: Comparison of micro and meso porosity of prepared activated carbon with other biomass sources

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