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Removing Potential Sources of Off-season Survival of Pink Bollworm is the Key to Reducing its Carryover in Succeeding Cotton Crops in North India

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BACKGROUND

Cotton is an important commercial crop grown on 9.65 lakh ha of area in the North zone of India, encompassing states like Punjab, Haryana, and North-Western parts of Rajasthan with an annual production of 47.25 lakh bales and average productivity of 443.33 kg/ha (DES, 2023). Cotton production in a region is constrained by several biotic and abiotic factors, with the damage caused by sucking pests and bollworms at its forefront. Since the introduction of transgenic (Bt) cotton for commercial cultivation during 2002-2006, the cotton crop of the North zone was protected from ravages of bollworm complex, which included dreaded American bollworm *Helicoverpa armigera* (Hubner), spotted bollworm *Earias* sp. and pink bollworm *Pectinophora gossypiella* (Saunders). Despite relatively early breakdown of Bt resistance against pink bollworm leading to its heavy infestations on Bt cotton in Central and South cotton growing zones of the country, such reports on field level damage of pink bollworm to the Bt cotton were lacking from North zone until 2018. The reasons for the relatively delayed development of resistance in pink bollworm against Bt cotton in the North Zone might be the unique features of the region's cotton cropping system. In the northern cotton-growing zone of India, the cotton crop growing season typically spans a period of 165 to 180 days, from May to October, followed by the sowing of crops like wheat, chickpea, and mustard in Rabi season. The confined crop duration with a cotton-free period of > 6 months along with the management of residual cotton stalks helps in the destruction of surviving population of insects in leftover cotton stalks after harvest, limiting its carryover to the next season. Despite this, now pink bollworm infestation has started advancing gradually in cotton-growing areas of North Zone necessitating timely corrective measures

to manage its menace and to avoid economic crop damage. This article enlightens the possible reasons for the upsurge of pink bollworm in the North Zone and advocates an elimination of potential sources of off-season survival of the pest as an essential strategy for suppressing the pest populations in subsequent crop seasons.

KEY WORD: Cotton, ginneries, infested seed cotton, North zone, pink bollworm, Off-season management.

PROGRESSIVE SPREAD OF PINK BOLLWORM ON BT COTTON IN NORTH ZONE

During the cotton growing season of 2018 and 2019, the scientists of the ICAR-CICR, Regional Center, Sirsa (Haryana) have reported for the first time, the pink bollworm infestation on BG II hybrids in cotton fields of North India around ginning factories cum oil extraction units at Jind (Haryana) and Bathinda (Punjab) districts (Kumar et al., 2020). The primary cause of this occurrence was the inadvertent transportation of resistant pink bollworm larvae through infested cotton seeds brought from the central and southern zones for the purpose of oil extraction. Over the subsequent crop seasons of 2020 and 2021, the infestation gradually extended to nearby areas. The pest infestation advanced over subsequent seasons, accompanied by an escalation in its severity and preponement of onset of the pest occurrence. In the year 2020, initial infestation was noted during the 31st standard meteorological week (SMW). This shifted slightly earlier to the 29th - 31st SMW in 2021, further progressing to the 26th - 28th SMW in 2022, and the 24th - 25th SMW in 2023 (Figure 1).What began as a mild infestation in 2018-19 had now grown into a serious issue. A report by the State Government in November 2021 revealed that raw cotton yields in Punjab had suffered a 34% loss, with more than 54% of the total 3.0 lakh hectares of cotton fields being affected by pink bollworm (Hindustan Times, 2021). During the 2022 season, the infestation of pink bollworm remained relatively low, albeit with a few isolated pockets of higher infestation compared to the previous year (2021). However, in the 2023 season, there was a noticeable advancement in the occurrence of infestation, coupled with increased severity. This emphasized the need to recognize the off-season survival sources as a significant factor contributing to the persistence of pest infestations in the upcoming crop seasons.

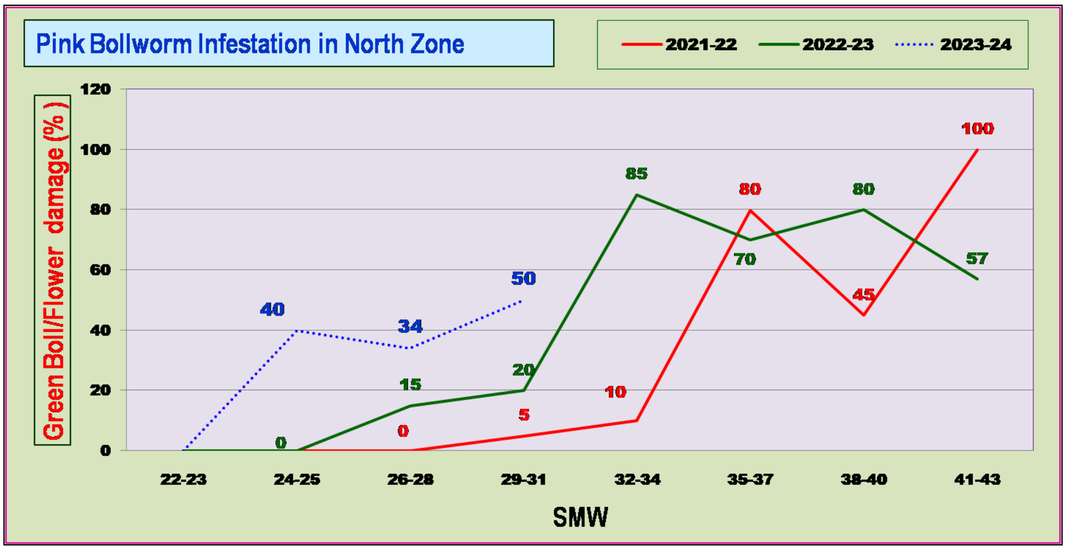

Figure 1. Gradual advancement of pink bollworm infestation on Bt cotton in North Zone

Conducting a survey spanning from 2021 to 2023, we aimed to gauge the extent of pink bollworm infestation in farmers' fields within the North zone, encompassing Haryana, Punjab, and Rajasthan. The state wise and year wise details of the number of locations surveyed and the range of pink bollworm infestation (flower or green boll damage) at mid-season (31st SMW), coinciding with July end to first week of August are provided in Table 1. The survey findings indicated a substantial pink bollworm infestation at farmers' field locations with notable low levels of infestation in locations surveyed in th4e state of Rajasthan.

Table 1. State wise Green boll/ Flower damage infested with PBW during 2021 to 2023

State	Districts covered	No. of locations surveyed			Green boll or flower damage (%)*		
		2021	2022	2023	2021	2022	2023
Haryana	Sirsa, Hisar	25	338	232	10-85	5-85	5-50
Punjab	Bathinda, Faridkot	15	417	216	10-100	5-50	5-34
Rajasthan	Hanumangarh, Sriganganagar	16	425	199	0-20	2-20	0-10

*Till 31st SMW (July end to first week of August)

PINK BOLLWORM LIFE CYCLE AND OFF-SEASON SURVIVAL

Comprehending the life cycle of pink bollworm is essential for implementing effective control measures. The life cycle of pink bollworm passes through four different developmental stages like egg, larva, pupa and adult (Figure 2). The larva is the main damaging stage of the pink bollworm which lasts for about 15-20 days and cause damage to flower buds (leading to formation of rosette flowers), and the seeds and lint of green bolls affecting the ling quality. The full grown larvae pupates either in the damaged seeds of bolls or fall on the ground to pupate in a plant debris on soil surface near the base of the plant. The entire life cycle is generally completed in about 35-37 days during cotton cropping season, enabling it to complete multiple generations of about 4-6 under north Indian conditions (Nath and Agarwal, 1982; Fand et al., 2021).

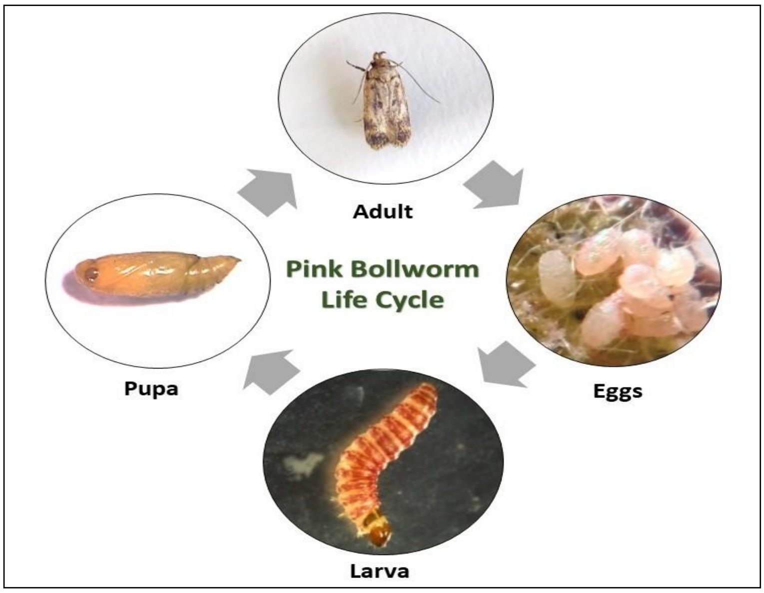

Figure 2. Life cycle of pink Bollworm on cotton (Photo credits: Dr Rishi Kumar, ICAR-CICR Regional Station Sirsa).

At the end of the crop season, due to absence of cotton as its major host, the pink bollworm population enters into overwintering phase. The infested crop residues enables the pink bollworm population to survive during these periods. The survivals of overwintering population can then propagate into the next season by spreading through damaged seeds and debris (Mallah et al., 2000; Kranthi, 2015).

During the overwintering phase, the pink bollworm assumes the form of a fully developed larva, typically in its fourth stage of growth. This phase is characterized by a suspended development state known as diapause. During diapause, the larva often constructs a loose, silken web or cocoon to encase itself, finding shelter in this state until late winter and spring seasons arrive. These overwintering larvae can be found within bolls nestled in the soil or on plants that remain undisturbed through the winter, and they may even persist as ratoon growth. Frequently, they seek refuge within the hollowed-out seeds of undamaged bolls. Alternatively, the larvae may be found directly within the soil, positioned either outside of seeds or bolls. The majority of overwintering occurs within the cotton field itself, although some instances occur wherever cotton remnants, such as stalks with unopened bolls, are stacked. The diapausing larvae in the North zone play a pivotal role in initiating infestations during the subsequent season. According to previous reports, various sources like seed cotton, stored cotton seeds in warehouses, ginneries, or oil extraction mills, as well as stacked cotton stalks, contribute to the survival of the pink bollworm during the off-season (Kranthi et al., 2015). Among these sources, cotton seeds stand out as a significant factor for pink bollworm survival. Therefore, understanding these potential infestation sources and the off-season persistence of the pest is vital for effective management. Interestingly, even though pink bollworm larvae can hibernate in a single cotton seed of adequate size, they often overwinters between two cotton seeds by joining them, leading to the formation of *double seeds*. This phenomenon serves as a major source of PBW survival (Figure 3).

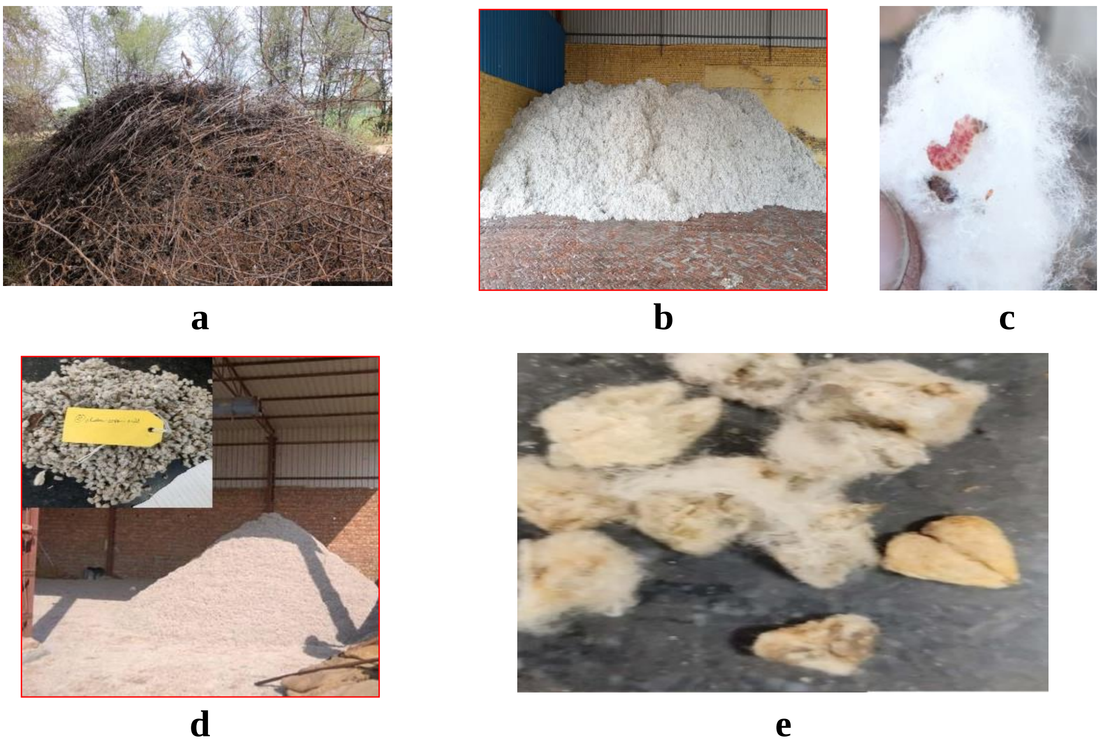

Figure 3. Potential sources of off season survival of pink bollworm. Leftover cotton stalks (a), seed cotton stored in ginning-cum-oil extraction mills (b), larvae of pink bollworm inside the infested cotton seeds (c), survival of pink bollworm in single seeds (d), and formation of double seed due to pink bollworm infestation (e)

OFF-SEASON SURVEYS IN GINNING-CUM-OIL EXTRACTION MILLS REVEALED COTTON SEEDS AS A POTENTIAL RESERVOIRS OF PINK BOLLWORM SURVIVAL

The comprehensive survey results across all three states revealed cotton seed as a major reservoir for PBW survival during the off-season, posing a potential threat to cotton growers in the North zone for the ensuing season. To assess the extent of pink bollworm survival within uncovered cotton seeds in ginneries cum oil extraction mills, the extensive surveys was carried out across North India from December 2021 to March 2022. A total of 64 mills were meticulously examined, comprising 28 in Haryana, 15 in Punjab and 21 in Rajasthan. This survey entailed the collection of 500-gram samples of cotton seeds drawn randomly from these mills. These samples were analyzed to determine the presence of larvae, pupae, damaged seeds, and double seeds. The larval count within each seed sample ranged between 2 to 10 larvae per sample in Haryana, 1 to 4 in Punjab and 1 to 3 in Rajasthan. Notably, the most extensive damage caused by pink bollworm was observed in Haryana, followed by Rajasthan and Punjab. The occurrence of double seeds was also most prevalent in samples from Haryana, particularly in the 'Jind' district. A separate investigation was conducted in Sirsa, with a focus on mills obtaining cotton seeds from the South zone. In these instances, significantly higher quantities of surviving larvae were discovered in the externally sourced seeds compared to locally obtain ones. The count of larvae per 500 grams of cotton seeds ranged from 15 to 22. For the externally sourced cotton seed samples from the South zone, the quantities of damaged seeds and double seeds ranged from 45.13 to 84.20 grams and 2.91 to 3.58 grams, respectively. The findings from the comprehensive surveys conducted across all three states underscored cotton seeds as a significant reservoir for pink bollworm survival during the off-season. This situation posed a potential threat to cotton growers in the North zone which witnessed severe infestations of pink bollworm in Bt cotton fields during following seasons

ELIMINATION OF SOURCES OF OFF-SEASON SURVIVAL FOR EFFECTIVE MANAGEMENT OF PINK BOLLWORM

Prior research work carried out in India has pinpointed crucial factors contributing to the endurance and spread of the pink bollworm, accounting for more than 85% of the pest population on new crops. These factors include ratooning practices in cotton cultivation, extended stacking of residual cotton stalks around fields, uncovered cotton seeds in ginneries or oil extraction mills, and the off-season survival of pink bollworms in double seeds (Kranthi, 2015; Naik et al., 2018; Fand et al., 2019). Considering the prevailing challenges facing Bollgard and Bollgard II cotton hybrids in combatting pink bollworm in various cotton-growing states, both in the northern, central, and southern regions, it has become imperative to proactively manage the sources of pink bollworm off-season survival (Kumar et al., 2020). Furthermore, strict adherence to Refugia as a part of Integrated Pest Management (IPM) for newly introduced events is crucial (Kranthi, 2015; Fand et al., 2019), even though Refuge-in-Bag strategies are being implemented. However, pink bollworm has already developed resistance and established its presence in all cotton-growing zones (Naik et al., 2018; Kumar et al., 2020; Prasad and Kumar, 2022).

Various integrated pest management strategies, applicable during both in-season and off-season periods, can be implemented to control pink bollworm. These strategies encompass diverse practices such as deep ploughing, crop rotation, adopting short-duration varieties/hybrids, timely sowing, utilizing pheromone traps for monitoring, proper nutrient management, clearing plant debris, controlled usage of synthetic pyrethroids, integrating biological control methods, and employing targeted insecticide application based on selectivity and timing (Kranthi, 2015; ICAR-CICR, 2019; Fand et al., 2019). However, as the sowing window expands over the years in the North zone (exceeding 60 days), the likelihood of suicidal emergence is diminishing due to the availability of fruiting bodies in early sown cotton genotypes exhibiting early fruiting behaviour, particularly during periods of water stress. Given that early-emerging adults from cotton stalks consistently play a crucial role in initiating infestations, managing the off-season sources of pink bollworm survival holds utmost importance for the upcoming season. Some important off-season management practices for pink bollworm are given in Table 2.

Table 2. Off-season management practices for effective management of pink bollworm

What to do?	Why to do?
A. Management of crop residues in and around the fields	
Destroy weeds/ alternate hosts growing near the irrigation channel/ canal and fallow lands during the off-season.	Though pink bollworm is a functional monophagous pests, some weed species like *Abutilon indicum* reported to support a low levels of pink bollworm infestations during off-season. Therefore, such weed hosts need to be removed at regular interval from the vicinity of cotton growing area those including non-cropped fallow lands.
Terminate the cotton crop season by the end of November for North zone by stopping the irrigation after September end.	Timely termination of cotton crop helps to reduce pink bollworm damage and its carryover to the next cropping season. Further, fields can be made ready for sowing of Rabi crops
Allow grazing of cattle, sheep and goats in the cotton field after final picking (Figure 4)	The grazing of animals helps to reduce the carryover of pink bollworm in infested bolls
Store the cotton stalks away from the fields. If possible shredding and incorporation of cotton stalks in soil should be done.	Stacking of cotton stalks near field bunds carries the pink bollworm infestation on new season's cotton crop. Shredding helps in destroying the dormant stages like larvae and pupae and thus helps in eliminating the source of infestation for next season.

Cover the stacks of uprooted cotton stalks using mesh nets, tarpaulin sheets or polythene sheets (Figure 5a)	Open stacking of infested cotton stalk or storage of damaged seed cotton in open area in the premises of ginning mills leads to escape of moths emerging from these sources which carries the pest infestation to cotton fields (Figure 5b)
B. Management of stored seed cotton and cotton seeds in ginneries and market premises	
Installation of pheromone traps and or light traps in the premises of cotton stalks storage areas, ginning mills and market yards for regular monitoring of off-season flushes of moths from infested sources.	The infested stalks either standing in the crop fields for longer periods or stacked along the field bunds, and the infested seeds from a cotton stored in the ginneries and market godowns serve as a reservoirs of pink bollworm survival during off-season. This serves as a primary source of pink bollworm infestation in adjoining cotton fields during next season. Therefore, installation of pheromone traps and or light traps in the premises of ginning mills and market yards is necessary for mass trapping of the pink bollworm moths emerged during off-season
Cover the stored seed cotton and damaged cotton seeds after ginning with the help of nylon nets, tarpaulin or polythene sheets (Figure 6a)	Prolonged storage of damaged seed cotton and seeds infested with pink bollworm in open area in the premises of ginning mills after ginning process is over leads to escape of moths emerging from these sources which carries the pest infestation to cotton fields (Figure 6b)
Complete the ginning process by March and remove all seed from the ginneries. Destroy all trash collected during the ginning process in ginneries, cotton seed oil extraction mills etc.	Do not prolong the ginning operation and do it at regular interval so as to clean the seeds contaminated with pink bollworm infestation.
Fumigate seed left uncrushed in the mills before end of April with Celphos /Phostoxin / Delicia @ one 3-g tablet per cubic metre space, giving an exposure of 48 hours or use two tablets with an exposure of 24 hours	Fumigation helps to kill the hibernating larvae inside the damaged cotton seeds. Do not apply fumigation in open stacked cotton seed or seed cotton
The seed cotton stored at farmers level in view of anticipated good market prices, should be stored in closed or covered spaces like gowdowns	Keeping the raw seed cotton with damaged seeds in open space at farmers' level may lead to pink bollworm carryover
Monitor the movement of sources	Movement of cotton seed or seed cotton from

of infestation from infested to uninfected areas	infested areas in South Zone to the Ginneries and oil extraction mills of North Zone lead to spread and upsurge of pink bollworm in the North cotton growing areas.
Stored cotton seed in ginning-cum-oil-extraction mills should be used till March, further storing should include acid delinting and further drying to destroy the carryovers	Storage of seed cotton and damaged seeds in open allows the escape of pink bollworm adults for egg laying in early sown cotton crop

Figure 4. Grazing of animals in harvested cotton fields to eliminate carryover of pink bollworm

a **b**

Figure 5. Covering the uprooted cotton stalks with nylon net (a), infested cotton stalks stored in open area (b)

a b

Figure 6. Covering the seed cotton and damaged seeds in ginning mill premises with tarpaulin sheets (a), and cotton seed stored in an open area (b)

CONCLUSION

Strategically eradicating the sources that facilitate pink bollworm survival during the off-season is a pivotal approach to suppressing pest populations and minimizing subsequent crop season damage. Stringently adhering to the prescribed sowing and harvesting windows, combined with extensive deployment of pheromone traps for monitoring and controlling pink bollworm infestations throughout both the in-season and off-season periods, along with the elimination of alternate hosts and proper disposal of infested remnants, both in fields and ginning mills, will definitely have a substantial positive impact on the effective management of pink bollworm, ensuring sustainable cotton production in the North Zone of India.

REFERENCES

DES. 2023. Agricultural Statistics at a Glance -2-22. Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare, New Delhi. Available online at: https://desagri.gov.in/document-report/agricultural-statistics-at-a-glance-2021/, Accessed on 15/08/2023.

Dhurua, S. and Gujar, G.T. 2011. Field-evolved resistance to Bt toxin Cry1Ac in the pink bollworm, *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae), from India. *Pest Management Science*, 67, pp. 898–903.

Fand, B.B., Nagrare, V.S., Bal, S.K., Naik, V.C.B., Naikwadi, B.V., Mahule, D.J., Gokte-Narkhedkar, N. and Waghmare, V.N. 2021. Degree day-based model predicts pink bollworm phenology across subtropics and semi-arid tropics of India. *Scientific Reports*, 11(436), pp. 1-18. https://doi.org/10.1038/s41598-(020-80184-6.

Fand, B.B., Nagrare, V.S., Gawande, S.P., Nagrale, D.T., Naikwadi, B.V., Deshmukh, V., Gokte-Narkhedkar, N. and Waghmare, V.N. 2019. Widespread infestation of pink bollworm, *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae) on Bt cotton in Central

India: a new threat and concerns for cotton production. *Phytoparasitica*, 47, pp. 313–325.

Hindustan Times, 2021. Pink bollworm attack: Punjab records 34% cotton crop loss https://www.hindustantimes.com/cities/chandigarh-news/pink-bollworm-attack-punjab.

ICAR-CICR. 2019. Technical Bulletin No 1/2019. Cotton: Integrated pest, disease and nematode management (English version). (Editors: Nagrare, V.S., Naik, V.C.B., Fand, B.B., Gawande, S.P., Nagrale, D.T., Gokte-Narkhedkar, N. and Waghmare, V.N.) ICAR-Central Institute for Cotton Research, Nagpur, Maharashtra, India. pp – 39.

Kranthi, K.R. 2015. Pink bollworm strikes *Bt* cotton. *Cotton Statistics News*, 35, pp. 1.

Kumar, R., Monga, D., Naik, V.C.B., Singh, P. and Waghmare, V.N. 2020. Incipient Infestations and Threat of Pink Bollworm *Pectinophora gossypiella* (Saunders) on Bollgard-II Cotton in the Northern Cotton-Growing Zone of India. *Current Science*, 118, pp. 1454-1456.

Mallah, G.H., Soomro, A.R., Soomro, A.W., Kourejo, A.K. and Kalhoro, A.D. 2000. Studies on the leftover standing cotton as carry–over sources of pink bollworm in Sindh. *Pakistan Journal of Biological Sciences*, 3 (1), pp. 147–149.

Naik, V.C.B., Kumbhare, S., Kranthi, S., Satija, U. and Kranthi, K.R. 2018. Field-evolved resistance of pink bollworm, *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae), to transgenic *Bacillus thuringiensis* (Bt) cotton expressing crystal 1Ac (Cry1Ac) and Cry2Ab in India. Pest Management Science, 7(75), pp. 2544-2553.

Nath, V. and Agarwal, R.A. 1982. Insect pests of crops and their control. Bharati Publications, Delhi 1, pp. 139.

Prasad, Y.G. and Kumar, R. 2022. Pink Bollworm in North Cotton Growing Zone of India– It Is Time For Coordinated Corrective Measures. *Cotton Statistics and News*, Weekly Publication of Cotton Association of India, 3, pp. 1-8.

Rotary Tubular Drum Dryer for Quarantine of Pink Bollworm Infested Cottonseeds in Indian Ginneries

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ABSTRACT

Pink bollworm is a dreaded pest that causes significant yield losses and adversely affects cotton fibre quality and income of cotton farmers and ginners. It has re-emerged as a major pest problem in Indian cotton production, due to development of resistance against transgenic cotton. Since last few years, concerns are being raised in India that cotton ginning industries serves as site for reintroduction of pink bollworm, as the live larvae gets escaped through cottonseed in the process of ginning and eventually the moths emerging from them spread into neighbourhood cotton growing areas causing damage. Currently, in India, there are no specific regulations or established devices and technologies for quarantining cottonseed infested with pink bollworm. To address this issue and disrupt the pest's life cycle, a prototype of a rotary tubular drum dryer was conceptualized, created, and assessed for use in quarantine of pink bollworm infested cottonseed obtained from Indian ginneries. The apparatus comprises several components, including a central drum, flights and lifters for movement, a steam joint, a piping assembly, a system for transporting moisture, a bucket elevator, and a seed bagging system. The process protocol for quarantining pink bollworm infested cottonseed was also formulated. The cottonseed is indirectly heated by circulating thermic fluid through the piping system, maintaining the desired temperature range of 65-68°C for approximately 5-6 minutes. Optimal results were achieved with incoming thermic fluid temperatures ranging between 180°C and 200°C. These conditions proved effective for quarantine of cottonseeds with initial moisture content ranging from 12% to 15% with corresponding dryer capacity of 500 and 600 kg/h respectively. The envisaged system holds significant promise in reducing the potential for pink bollworm spread from ginning mills. Thus, it could prove immensely valuable in both domestic and international quarantine initiatives aimed at containing the threat posed by this pest.

KEY WORDS: Gin trash treatment, Quarantine, Rotary tubular drum dryer, Seed cotton infestation.

CONCERNS FOR REINTRODUCTION OF PINK BOLLWORM FROM COTTON GINNERIES

Recent re-emergence of pink bollworm as a major threat to transgenic Bt cotton on account of development of resistance to Bt toxins placed the Indian cotton industry at its risk with increasing concerns for all the stakeholders. The pink bollworm infestation in cotton is higher generally towards the end of the season (Kranthi, 2015; Fand et al., 2019). The larvae of pink bollworm at flag end stage of crop season normally enters overwintering stage for the want of appropriate host stage to perpetuate, and can hibernate either in infested bolls on cotton stalks and or damaged seeds in the harvested seed cotton (Mallah et al., 2000; Kranthi et al., 2015). The larvae in hibernating stage remain live for longer period on the seed cotton, cottonseeds and gin trashes stored in cotton gins till the favourable conditions come. Once the signals received by the larvae about seasonal changes, mainly due receipt of light showers at the begging of monsoon season, they resume active growth, enters the pupation and emerge as moths to colonise the next season's crop in the adjoining areas of ginneries. Longer the storage of raw infested cotton, higher the inoculum load of the pest. Therefore, it becomes imperative to give a suitable treatment to the cottonseed to effectively quarantine the pink bollworm and disrupt its life cycle.

In the countries like US and Egypt, there are specific regulations in place especially to prevent the build-up and spread of the pink bollworm from ginneries. These regulations pertain to the treatment and movement of seed cotton, cotton lint, cottonseed, and related products within and from regulated areas. Cotton producers, ginners, and seed processors have to abide by these regulations. Hence, the impact of pink bollworm is minimal in these countries. The US has been declared recently as free from pink bollworm due to collective efforts through community approach involving IPM along with sterile insect release techniques (Tabashnik et al., 2020). However till recently, such regulations and treatment systems are seriously lacking from India.

In recent years, there have been growing concerns in India regarding the role of cotton ginning industries in the potential resurgence of the pink bollworm. This concern stems from the observation that pink bollworm infestations have occurred in areas surrounding cotton ginning mills (Kranthi, 2015; ICAR-CICR, 2023). The movement of seed cotton and cottonseed from infested regions or gins to non-infested ones has facilitated the rapid spread of the pest (Kumar et al., 2020). Notably, during the ginning process, there exists the possibility for pink bollworm to survive and bypass pre-cleaning and ginning machinery. The larvae of pink bollworm become embedded within cottonseed, lint, and gin residues (Huges et al., 1994), only to become active when favourable conditions arise (Kranthi, 2015; Fand, 2021; Fand et al., 2021). It is highly probable that both gin residues and cottonseeds harbour active or dormant stages of pink bollworm larvae and pupae. This raises concerns that ginning facilities might contribute to the build-up and lead to the expansion of the pink bollworm into unaffected regions. Incidents have been documented in various parts of the country, especially in the North zone where ginning-cum-oil extraction mills have been identified as a channel for the pink bollworm spread through gin residues and infested cottonseed (Kumar et al., 2020). In this context, it is therefore of paramount importance to curtail the dissemination of pink bollworm through the ginning process.

ICAR-Central Institute for Research on Cotton Technology (CIRCOT), Mumbai, India has recently developed gin trash treatment system to destroy pink bollworm larvae and pupae and prevent its dissemination from cotton ginneries (Arude et al., 2022). Besides, immediate post-ginning treatment of cottonseeds is crucial to effectively quarantine the pest as the pink bollworm larvae primarily remain concealed within the infested seeds,. Therefore, it is imperative to establish measures ensuring that all pink bollworm larvae entering the ginning process undergoes quarantine. Given the absence of suitable devices and technologies in India for treating pink bollworm infested cottonseed, a prototype of a rotary tubular drum dryer has been conceptualized, developed, and assessed. This innovation aims to isolate and contain pink bollworm infested cottonseed, thus mitigating the risk of its spread from ginneries.

DEVELOPMENT OF ROTARY TUBULAR DRUM DRYER (RTDD)

A continuous processing type Rotary Tubular Drum Dryer (RTDD) having a capacity of 1 tonne/hour was designed and developed at Ginning Training Centre (GTC) of ICAR-Central Institute for Research on Cotton Technology (HQ. Mumbai) located at Nagpur in the state of Maharashtra. In this system, cottonseed is quarantined by indirectly heating it to about 65-70 ^{o}C for 5-6 minutes using thermic fluid HYTHERM 500 as a heating medium. The inlet temperature of thermic fluid can be safely increased to 200 ^{o}C by controlling the boiler fuel feeding. In the developed dryer, wet cottonseed is introduced into the upper end of the dryer shell and the fed cottonseed progresses through it by virtue of rotation of tubing system and dried cottonseed is withdrawn at the lower end of the dryer.

The major sub-assemblies of the developed RTDD (Figure 1) are described briefly as follows:

i. Bucket elevator

It is developed for lifting of about 2 tonnes/h cottonseed vertically to about 2500 mm height and feeding same to the dryer inlet using a 2 HP electric motor. There are specially designed metallic cups attached over a vertical belt conveyor for lifting and feeding of cottonseed. A variable frequency drive (VFD) is provided to control the feeding rate. The length, width and height of the developed bucket elevator are 210 mm, 510 mm and 2800 mm, respectively.

ii. *Rotary joint*

It is one of the most critical components of indirect heating dryers. It is meant for supply of hot and cold thermic fluid to the dryer. In the developed system, a rotary joints having 75 mm and 90 mm diameter are selected for supply of hot and cold fluids, respectively into and out of the dryer.

iii. *Elliptical shell*

It is used for housing of metal tubes, which are installed longitudinally within its interior. The outer portion of the shell is insulated using glass wool. The height, diameter and length of the shell are 1042 mm, 600 mm and 2500 mm, respectively. Two heat resistant bearings are mounted on either side of the shell to support the tubing system.

iv. *Tubing system*

A bunch of well-designed metal tubes are used for transportation of hot and cold thermic fluids into the dryer. It consists of a main annulus central tube of 127 mm internal diameter and 7.6 mm thickness. It is mounted inside and at the centre of the elliptical shell over bearings. The hot fluid flows through the outer portion while the cold fluid flows through the inner portion of the central annulus tube. The central tube distributes the hot fluid to a bunch of 20 pipes (five tubes each are fitted longitudinally in four rows over the main pipe) having 50.8 mm internal diameter and 5 mm thickness through the four manifold pipes. The hot fluid circulated in these pipes supplies heat to cottonseeds and leaves the dryer through rotary joint via annulus space of the main central pipe. The whole tubing system is rotated using a VFD controlled 5 HP motor.

v. *Flights and lifters*

The wet cottonseeds fed into the dryer and subsequently elevated and guided into the drum by the combined action of flights and shovels, respectively. The pitch and shape of the flights and shovels influence the amount of material present in the rotary dryer. Flights and lifters are designed considering that the volume occupied by the load of solids in the rotary dryer shall be between 10 and 15% of the total dryer volume. Two-segment type flights have been used in the rotary drum dryer of present system.

vi. *Moisture transportation system*

It is designed and developed for removal of moisture evaporated during heating process from the dryer. It consists of a centrifugal fan and a 2D2D cyclone having 600 mm barrel diameter. An air damper has been provided at the fan inlet to control the rate of air flow of the moisture transportation system.

vii. *Cottonseed conveying and bagging system*

A belt conveyor system has been designed and developed for transportation and bagging of the dried cottonseed.

Figure 1. Components of Rotary Tubular Drum Dryer (RTDD) designed at GTC, (ICAR-CIRCOT), Nagpur for treatment of cotton seeds to quarantine the pink bollworm

PERFORMANCE EVALUATION OF RTDD SYSTEM

The developed RTTD was installed and evaluated for its performance at GTC (ICAR-CIRCOT), Nagpur. The variables studied were: incoming thermic fluid temperature range (180-200 ^{o}C), initial cottonseed moisture content of cottonseeds (12-18%) and tube rotational speeds (6-10 rpm) (Tables 1 and 2). The recorded room temperature and relative humidity were in the range of 25-28 ^{o}C and 35-40%, respectively. For quarantine of pink bollworm from cottonseeds, the desired temperature of cottonseed after 5-6 minutes of drying using indirect heating by steam or thermic fluid is 65-68 ^{o}C.

Initially, it was observed that cottonseed conveying rate was very high at 8-10 rpm leading to fast withdrawal of cottonseeds from the dryer in less than a minute resulting into minimal rising of cottonseed temperature by 10-20 ^{o}C with a removal of cottonseed moisture content merely by 0.5-1%. Hence the rotational speed of tubes was reduced to 2 rpm. At this speed it was observed that cottonseed was moving in lumps. Cottonseed was neither mixing properly nor coming into contacts of all peripheral tubes leading into insufficient heating of seeds resulting in poor moisture removal. It was learnt that optimum rotational speed of tubes is required for proper mixing of seeds for increasing its temperature and reducing moisture content. In order to address this issue, the shovels and lifters were modified to reduce the cottonseed transportation rate. The pitch of the lifters and flights was reduced to 100 mm from initial pitch of 500 mm. It resulted into proper mixing of cottonseeds at tubes rotational speed in the range of 6 to 10 rpm. Full-scale performance trials were conducted on the modified dryer by keeping incoming thermic fluid temperature at 180 ^{o}C and 200 ^{o}C, rotational speed in the range of 6 to 10 rpm, and cottonseed feed rate in the range of 400 to 600 kg/h. The initial cottonseed moisture content was kept in the range of 12 to 18%. The cottonseed temperature and moisture content after drying were recorded for different trials.

The initial cottonseed temperature was around 26 ^{o}C. The gauge pressures of incoming and outgoing thermic fluid were measured as 1 bar and 0.5 bar, respectively indicating a pressure drop of about 0.5 bar in the dryer.

The results of performance evaluation of the dryer at incoming thermic fluid temperature of 180 ^{o}C are presented in Table 1. For cottonseed with 12% initial moisture content, the desired cottonseed temperature (65-68 ^{o}C) for quarantine of pink bollworm after drying was achieved at rotational speed of 8 rpm and feed rate of 500 kg/h. The final moisture content found to reduce by around 5%. However, the effectiveness of the dryer was not up to the mark for quarantine of cottonseed having 15% and 18% moisture content as the maximum final cottonseed temperature achieved was lesser than required for quarantine purpose. The Table 2 presents the results of performance evaluation of the dryer at incoming thermic fluid temperature of 200 ^{o}C. For cottonseed with 12% initial moisture content, the desired cottonseed temperature (65-68 ^{o}C) for quarantine of pink bollworm after drying was achieved at rotational speed of 10 rpm and feed rate of 600 kg/h. For cottonseed with 15% initial moisture content, the desired cottonseed temperature (65-68 ^{o}C) for quarantine of pink bollworm after drying was achieved at rotational speed of 8 rpm and feed rate of 500 kg/h. However, the effectiveness of the dryer was not up to the mark for quarantine of cottonseed having 18% moisture content as the maximum final cottonseed temperature achieved was lesser than required for quarantine purpose.

Table 1: Performance evaluation of Rotary Tubular Drum Dryer for thermic fluid temperature of 180 ^{o}C

Rotational speed of Tubes (rpm)	Feed Rate/Capacity (kg/h)	Retention time (min)	Initial moisture content of cottonseed (%)	Temperature after drying (^{o}C)	Final moisture content of cottonseed after drying (%)
6	400	8	12	72	6.1
8	500	6		68	7.1
10	600	4		56	9.4
6	400	8	15	62	7.6
8	500	6		56	9.1
10	600	4		51	11.6
6	400	8	18	58	14.9
8	500	6		50	16.1
10	600	4		46	17.0

Table 2: Performance evaluation of Rotary Tubular Drum Dryer (Incoming Thermic Fluid Temperature of 200 ^{0}C)

Rotational speed of Tubes (rpm)	Feed Rate /Capacity (kg/h)	Retention time (min)	Initial moisture content of cottonseed (%)	Temperature after drying (°C)	Final cottonseed moisture content after drying (%)
6	400	8	12	78	5.5
8	500	6		70	6.2
10	600	4		68	8.9
6	400	8	15	72	6.5
8	500	6		68	8.3
10	600	4		60	10.6
6	400	8	18	59	13.2
8	500	6		54	14.6
10	600	4		49	16.0

CONCLUSIONS

A rotary tubular drum dryer (RTDD) designed and developed in present study was able to perform satisfactorily to quarantine the pink bollworm infested cottonseeds having initial moisture contents between 12 to 15% at the operating conditions of: incoming thermic fluid temperatures between 180 °C and 200 °C, retention time of 5 to 6 minutes and corresponding dryer capacity of 500 and 600 kg/h. At these conditions the indirect heating of cottonseed by circulating thermic fluid through piping system resulted in attainment of desired temperature range (65-68 °C) and moisture content (≤6%) of cottonseed after drying process.

REFERENCES

Arude, V. G., Shukla, S.K. and Naik, V.C.B. 2022. Mechanical gin trash treatment system to prevent transmission of pink bollworm from cotton ginneries. *Journal of Cotton Research and Development*, 36(1), pp. 111-119.

Fand, B. B. 2021. Seasonal dynamics of pink bollworm in cotton ecosystems of India and key ecological aspects for its management. ICAC Recorder 39 (1), pp. 29-32.

Fand, B. B., Nagrare, V. S., Bal, S. K., Naik, V. C. B., Naikwadi, B. V., Mahule, D.J., Gokte-Narkhedkar, N. and Waghmare, V. N. 2021. Degree day-based model predicts pink bollworm phenology across subtropics and semi-arid tropics of India. *Scientific Reports*, 11(436), pp. 1-18. https://doi.org/10.1038/s41598-(020-80184-6.

Fand, B. B., Nagrare, V.S., Gawande, S. P., Nagrale, D. T., Naikwadi, B. V., Deshmukh, V., Gokte-Narkhedkar, N. and Waghmare, V. N. 2019. Widespread infestation of pink bollworm, *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechidae) on Bt cotton in Central

India: a new threat and concerns for cotton production. *Phytoparasitica*, 47, pp. 313–332.

Huges, S., Marvis, E. and Gillium, N. 1994. Pink bollworm control in gins. (In: Antony, W., Williams, S. and Mayfield, D. (Eds.), Cotton Ginners Handbook). United States Department of Agriculture (USDA), Washington DC, USA, 503, pp. 315-322.

ICAR-CICR. 2023. Cotton Pest and Disease Management Strategies 2023-24. ICAR-Central Institute for Cotton Research, Nagpur. Pp. 1-7. Avaliable online at: https://cicr.org.in/wp-content/uploads/Pest-and-disease-management-2023-24.pdf. Accessed on 15/08/2023.

Kranthi, K.R. 2015. Pink bollworm strikes *Bt* cotton. *Cotton Statistics News*, 35, pp. 1.

Kumar, R., Monga, D., Naik, V.C.B., Singh, P. and Waghmare, V.N. 2020. Incipient Infestations and Threat of Pink Bollworm *Pectinophora gossypiella* (Saunders) on Bollgard-II Cotton in the Northern Cotton-Growing Zone of India. *Current Science*, 118, pp. 1454-1456.

Mallah, G.H., Soomro, A.R., Soomro, A.W., Kourejo, A.K. and Kalhoro, A.D. 2000. Studies on the leftover standing cotton as carry–over sources of pink bollworm in Sindh. *Pakistan Journal of Biological Sciences*, 3 (1), pp. 147–149.

Tabashnik, B.E., Leighton, R. L., Ellsworth, P.C. and Carrière, Y. 2020. Transgenic cotton and sterile insect releases synergize eradication of pink bollworm a century after it invaded the United States. PNAS, 118(1), e2019115118, pp. 1-5. https://doi.org/10.1073/pnas.2019115118.

Vennila, S., Biradkar, V.K. and Khadi, B.M. 2007. Know your cotton inset pest pink bollworm. Cotton Protection Folder Series: 7 of 11, Central Institute for Cotton Research, Nagpur, India, pp. 1-2.