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Evaluation of different mass trapping and mating disruption tools against pink bollworm, *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae) in *Bt* cotton ecosystem

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Abstract
Pink bollworm is a serious pest of *Bt* cotton. Current techniques employed for PBW management have difficulty in bringing down its drastic damage levels. 'SPLAT' is a new strategy against this pest, in which males are confused by employing synthetic pheromone in higher concentration to mask the natural source. Trials were conducted using a wax based formulation, "Specialized Pheromone and Lure Application Technology" (SPLAT) to dispense and release the PBW sex pheromone. The field experiment was conducted at Kurudi village, Manvi taluk, Raichur district, Karnataka during *Kharif* 2017, with different treatments like sleeve trap and delta sticky trap at recommended dosage for mass trapping and SPLAT at three different doses of 500, 750 and 1250 g per acre, each treatment implemented in one acre area. Observation at weekly interval revealed that lowest rosette, green boll and locule damage of 6.38, 6.86 and 12.28 per cent was recorded in SPLAT @ 500 g per acre compared to 16.01, 19.41 and 40.83 per cent in farmers' practice. Considering its higher yield of 46.25q per hectare and greater B:C ratio of 2.48, compared to farmers' practice (24.55 q/ha and 1.23), SPLAT can be recommended for the management of PBW at 500 g per acre.

Keywords: Cotton, pink bollworm, *Pectinophora gossypiella* (Saunders), SPLAT

1. Introduction
Cotton (*Gossypium hirsutum* L.) is one of the most important fibre and cash crop of India and plays a dominant role in the industrial and agricultural economy of the country. By far, cotton is the most important natural fibre or vegetable wool has been in the cultivation commercially for domestic consumption and export needs in about 111 countries worldwide and hence called "King of fibres" or "White gold" [1]. The commercial cultivation of *Bt* transgenics from 2002, a shift from erstwhile conventional varieties and hybrids changed the paradigm of cotton cultivation in India. India has 105 lakh hectares under cotton cultivation with a production of 351 lakh bales and productivity of 568 kg per ha [2]. Approximately 65 per cent of India's cotton is produced on rain-fed areas [3].

Karnataka is the fourth largest producer of cotton in India during 2016-17 with an area of 4.64 lakh ha and production of 21 lakh bales and productivity of 769 kg [2]. In India over 160 species of insect pests have been reported to damage the crop, about dozens of pest causes economic damage as sap feeders and bollworms in different parts of the country. The sucking pests and bollworms on an average cause 50 to 60 per cent loss of seed cotton yield [4]. The cotton bollworms are real problematic and difficult to control, causing significant yield losses to the extent of 50 per cent [5]. Among the bollworms, the pink bollworm, *Pectinophora gossypiella* (Saunders) is considered one of the most destructive pests of cotton globally and is found in all cotton growing regions of the world and can cause locule damage to an extent of 55 per cent and reduction in seed cotton yield in the range of 35 to 90 per cent [6]. The countries loss due to this pest was estimated at 6525 metric tonnes of lint worth Rs 1216 million [7]. Off late, since three to four years or so, pink bollworm, *P. gossypiella* has aggravated as it has developed resistance to insecticides [8, 9] and to cry toxin of *Bt* cotton [10-15]. Under these circumstances and failure of mass trapping tools, farmers have left with no choice, either to leave the *Bt* cotton cultivation or to explore the possibility of novel, eco-friendly, long lasting tool which can overcome the above problems. Specialized Pheromone and Lure Application Technology (SPLAT) against PBW in *Bt* cotton ecosystem which has rain fastness

property, easy to apply, long lasting and cost effective. So, to assess its feasibility in *Bt* cotton ecosystem in comparison with other mass trapping (Sleeve trap and delta sticky trap) tools and overcome existing short falls the present investigation was planned.

2. Materials and Methods

The field studies were carried out in the farmers' fields (Sheshireddy and Venkatesh Reddy) of Kurudi village, Manvi taluk, Raichur district during *kharif* season 2017-18. The details of procedures adopted and the materials used for conducting this experiment are presented as under.

Popular *Bt* hybrid Jadoo was sown on 26th June, during the *kharif*, 2017-18, the mass trapping tools *viz*., delta sticky trap, sleeve trap and mating disruption tool *viz.*, Specialized Pheromone and Lure Application Technology (SPLAT-PBW) were evaluated for their efficacy. Agronomic practices to raise the crop were followed conventionally by the farmers including the plant protection measures to manage the sucking pests and other defoliators except for bollworms, mainly pink bollworm. The details pertaining to these tools are presented in detail below. The treatments were implemented when the crop was 35 to 40 days old. Delta sticky traps were installed at 10 per acre when the crop was 35 to 40 days old. Sleeve traps were installed at 10 per acre when the crop was 35 to 40 days old. Lure in the trap was replaced once in every twenty days.

Three different doses of SPLAT-PBW *viz*., 500 g, 750 g and 1250 g per acre were applied in 4 splits, first at 35 to 40 followed by 65 to 70, 95 to 100 and 125 to 130 days of crop growth with the help of a spoon hung onto the leaf petiole of top shoot. SPLAT was applied at 400 source points (Dollops) per acre in all the three treatments.

In each of the SPLAT-PBW treatments two sleeve traps were installed for monitoring so as to assess that how many male moths are normally caught compared to farmers practice, such observations were made at weekly interval. Details of the observations recorded are given below in detail.

2.1 Per cent rosette flowers

The observations on number of flowers showing rosette symptoms due to pink bollworm damage and total number of flowers per plant were recorded in the early stage before boll formation at an interval of one week on randomly selected 25 plants from each of the treatments. Such data was transformed to arc sine values prior to statistical analysis. The formula used to work out the per cent rosette is as follows

$$\textit{i.e.,}\ \text{Per cent rosette flowers} = \frac{\text{Number of rosette flowers}}{\text{Total number of flowers}} \times 100$$

2.2 Green boll damage

Similarly, the per cent green boll damage was recorded by collecting 25 green bolls randomly (destructive sampling) and were cut open to see the PBW larvae. By counting the number of damaged bolls out of total number of bolls, per cent green boll damage was worked out by using the formula mentioned below.

$$\textit{i.e.,}\ \text{Per cent green boll damage} = \frac{\text{Number of damaged bolls}}{\text{Total number of bolls}} \times 100$$

2.3 Locule damage

At every picking the locules damage was recorded from randomly selected 25 opened bolls in each treatment per application wherein, the total locules damaged among total bolls counted was worked out using the formula mentioned below.

$$\textit{i.e.,}\ \text{Per cent locules damage} = \frac{\text{Number of locules damaged}}{\text{Total number of locules}} \times 100$$

2.4 Moth trap catches

Number of male moths caught per trap in each of the treatments was counted every week and they were later discarded.

3. Experimental Results

The different types of pheromone trap *viz.*, sleeve trap and delta sticky trap and SPLAT were evaluated for their efficiency in mass trapping and mating disruption of the PBW moths and results are presented here (Table 1). The lowest mean seasonal rosette flower damage by pink bollworm was recorded in SPLAT treatments, *i.e.,* 3.88 per cent in SPLAT @ 1250 g/acre, 4.92 per cent in SPLAT @ 750 g per acre and 6.38 per cent in SPLAT @ 500 g per acre, which were all on par with each other. Rosette flowers of 12.41 per cent in sleeve trap and 13.87 per cent in delta sticky trap were recorded, which were on par with each other.

The moth trapping and mating disruption have rendered their influence over the pest populations and resulted in reducing the green boll damage. From table 1, it was evident that the green boll damage observed among the treatments was corresponding to their efficacy. In general significantly higher damage was noticed in farmer's field. The seasonal mean of all the weeks' observations on green boll damage indicated that, lowest green boll damage was recorded in SPLAT @ 1250 g per acre (3.67%), which was on par with its lower doses *i.e*., 5.71 per cent in SPLAT @ 750 g and 6.86 per cent in SPLAT @ 500 g per acre which were significantly better performer compared to mass trapping tools, followed by sleeve traps (11.75%) and delta sticky trap (13.79%).

The pooled data on the moth catches in two traps indicated that the sleeve trap with an average moth catches of 66.95 moths per trap was significantly effective over the delta sticky trap having an average of 15.45 moths per trap. Specialized pheromone and Lure Application Technology (SPLAT) being a mating disruptant technique it confused the male PBW moths hence the moth catches were very less in 1250 g applied (1.44/ trap) treatment. This treatment was non-significant with its lower dosages of 750 g (2.30/ trap) and 500 g (3.62/ trap) which doesn't mean that it is inferior instead it helped in avoiding the multiplication of the pest.

Considering the seasonal means of locule damage, SPLAT treatments were proven to be significantly superior than mass trapping tools, with SPLAT @ 1250 g standing first with record of lowest locule damage of 8.49 per cent, followed by its lower doses *i.e*., 10.01 per cent in SPLAT @ 750 g and 12.28 per cent in SPLAT @ 500 g. Mass trapping tools *viz*., sleeve trap and delta sticky trap had higher locule damage of 31.31 and 36.23 per cent respectively. The mean locule damage of 40.83 per cent was recorded in farmers' practice.

Among the treatments, highest yield was recorded in SPLAT @ 1250 g per acre (50 q/ha) that was significantly superior compared to the mass trapping tools *viz*., sleeve trap and delta

sticky trap, but was on par with its lower doses *i.e*., 48.5 q per ha in SPLAT @ 750 g and 46.25 q per ha in SPLAT @ 500 g per acre. Seed cotton harvested from mass trapping tools were significantly lower compared to SPLAT-PBW treatments, 30 q per ha in sleeve trap and 28.5 q per ha in delta sticky trap. A lower yield of 24.55 q per ha was recorded in farmers' field (Table 2).

In comparison to the mass trapping tools, SPLAT treatments recorded significantly higher net returns at the end of the season. Wherein, a highest net returns of Rs. 171500 ha^{-1} was recorded in SPLAT @ 750 g per acre with B:C ratio of 2.41, which was non-significant to other two doses *i.e*., Rs. 170000 ha^{-1} in SPLAT @ 1250 g (B:C ratio of 2.12) and Rs. 164750 ha^{-1} in SPLAT @ 500 g (B:C ratio of 2.48) per hectare (Table 2). Significantly lower gross net returns were obtained in sleeve trap (Rs. 94450 ha^{-1}) and delta sticky trap (Rs. 86950 ha^{-1}). Farmers practice was recorded with lowest net returns of Rs. 67750 ha^{-1}.

4. Discussion

Among the tested mass trapping and mating disruption tools, Specialized Pheromone and Lure Application Technology (SPLAT) treatments were found to be superior in bringing down the PBW incidence in the form of rosette flowers. Wherein, the lowest rosette flowers by pink bollworm were recorded in SPLAT treatment @ 1250 g per acre (3.88%) followed by 4.92 per cent in SPLAT @ 750 g per acre and 6.38 per cent in SPLAT @ 500 g per acre, and all the treatments were on par with each other.

Minimum per cent rosette flowers were observed in the fields treated with SPLAT-PBW @ 30 DAS, which might be due to saturation of entire *Bt* cotton field by the synthetic pheromone blend of pink bollworm before flowering stage, which masked the natural source of pheromone that was produced by the virgin females and confused the males that emerge earlier than females and reduced the probabilities of finding female by males and successfully interrupting their communication system and mating causing them to die without mating in their limited period of adulthood. Similar results were obtained by Harter *et al.* (2010) [16] wherein, the mating disruption technique led to the reduction of damage caused by oriental fruit moth, *Grapholita molesta* (Busck) in peach orchards, compared to orchards sprayed with insecticide, demonstrating the great advantage of using this method.

SPLAT-PBW treated at 1250 g per acre was found to be the best among all the treatments, with the lowest record of 3.67 per cent mean green boll damage, which was on par with its lower doses *i.e*., SPLAT @ 750 g (5.71%) and SPLAT @ 500 g (6.86%) per acre which were significantly superior in reducing boll damage as compared to mass trapping tools.

SPLAT treatments have recorded lowest green boll damage compared to the mass trapping tools, because of the successful suppression of pink boll worm population by the timely application at 30 DAS, which disrupted the communication between male and females among the pioneer populations that emerged first in the season. This initial suppression in combination with the timely application of subsequent doses of SPLAT has made, the SPLAT-PBW to stand foremost in bringing down the green boll damage by PBW. These results can be compared with the findings of Stelinski *et al.* (2009) [17], they achieved highest mating disruption (> 99%) using SPLAT against citrus leaf miner, *Phyllocnistis citrella* (Zeller) and reduced the damage to more than half, to which they account the inability of males to find females was the reason.

Sleeve trap was found to be superior over the delta sticky trap in the following field trial carried out, with the highest mean of adult moths caught per trap per week *i.e.*, 66.95, followed by delta sticky trap with the mean 15.45 male moths caught per trap per week (Fig. 1).

The significant success of sleeve trap over the delta sticky trap was that, sleeve trap employs a long polythene sleeve to catch the male moths that are attracted towards the pheromone source, which can hold a huge number of moths and there was no chance of escape. Whereas, the delta sticky trap depends on the sticky liner placed in the trap to catch moths, which soon gets covered easily with the non target insects and there are more chances of escape for the PBW moths with the minimal damages to their legs and wings which do not affect their flight. These results were in agreement with the findings of Attique *et al.* (2000) [18], who evaluated five trap designs *viz.*, yellow and white funnel, Delta red and white and universal trap for their catching efficiency against pink bollworm and came up with the results wherein, yellow funnel trap was found to be the best among all traps.

SPLAT treatments were proven to be significantly better than mass trapping tools in bringing down the locule damage in *Bt* cotton fields and increase the seed cotton yield. Wherein, SPLAT @ 1250 g stands foremost with the record of lowest locule damage of 8.49 per cent, followed by its lower doses *i.e*., 10.01 per cent in SPLAT @ 750 g and 12.28 per cent in SPLAT @ 500 g (Fig. 2). This reduced rosette flowers, green boll and locule damage by PBW in SPLAT treated field, altogether added can be attributed as the reason behind higher yields in *Bt* cotton fields. Compared to farmers' practice (24.55 q/ha), SPLAT treated fields recorded significantly higher yield of 50.0, 48.50 and 46.25 q per ha when treated at 1250, 750 and 500 g of SPLAT-PBW per acre respectively (Fig.3).

Lowest per cent locule damage and highest yield in SPLAT applied plots might be due to reduced pest populations by interfering with mate finding and consequently reducing the number of successful mating event. The artificial introduction of sex pheromones might have influenced on mating disruption and also resulted in the loss of fitness among females of the target species, as a consequence of delayed mating. Females have only a limited amount of time in which to reproduce and to select an appropriate site for oviposition. Similar results were obtained by Hristina *et al.* (2015) [19] in peach orchards, where there was great reduction of per cent shoot and fruit damage to zero per cent by Oriental fruit moth, *Cydia molesta* (Busck) in Isomate ®OFM treated orchards, compared to reference orchards where there was 25.4 per cent shoot damage and 4.9 per cent fruit damage.

In comparison to the mass trapping tools, SPLAT treatments gave significantly higher net returns at the end of the season. Wherein, a highest net returns of Rs. 171,500 $ha^{-1}$was recorded in SPLAT @ 750 g per acre with B:C ratio of 2.41, which was

non-significant to other two doses *i.e*., Rs. 170,000 ha^{-1} in SPLAT @ 1250 g (B:C ratio of 2.12) and Rs. 164,750 ha^{-1} in SPLAT @ 500 g (B:C ratio of 2.48) per acre. Significantly lower gross net returns were obtained in sleeve trap (Rs. 94,450 ha^{-1}) and delta sticky trap (Rs. 86,950 ha^{-1}). Farmers practice was recorded with the lowest net returns of Rs. 67,750 ha^{-1}.

5. Conclusion

Specialised pheromone lure application technology (SPLAT @ 500 g/ acre) proved significantly superior over rest of the treatments with less rosette flowers, green boll and locule damage and also recorded higher yield with more B: C ratio. SPLAT is environmentally viable, economically feasible, slow and sustained release formulation with trap free auto confusion technology for the management of pink bollworm. SPLAT is one of the best technology for the management of PBW in present scenario and suits well in the IPM programs.

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Table 1: Effect of different mass trapping and mating disruption tools on the incidence of pink bollworm on *Bt* cotton (pooled mean)

Treatment details	Pooled mean of pink bollworm incidence				
	Per cent Rosette flowers	Per cent Green boll damage	Per cent Locule damage	Adult moth catches/ trap /week	Cotton yield (q/ha)
T1: SPLAT- PBW@500g/acre	6.38 (14.64)^{ab}	6.86 (15.18)^{ab}	12.28 (20.52)^{a}	3.62 (2.14)^{a}	46.25
T2: SPLAT- PBW@750g/acre	4.92 (12.82)^{a}	5.71 (13.82)^{a}	10.01 (18.44)^{a}	2.30 (1.81)^{a}	48.50
T3: SPLAT- PBW@1250g/acre	3.88 (11.36)^{a}	3.67 (11.05)^{a}	8.49 (16.94)^{a}	1.44 (1.56)^{a}	50.00
T4: Sleeve traps@8/acre	12.41 (20.62)^{bc}	11.75 (20.04)^{bc}	31.31 (34.02)^{b}	66.95 (8.24)^{a}	30.00
T5: Delta sticky trap@ 10/ acre	13.87 (21.87)^{c}	13.79 (21.80)^{c}	36.23 (37.01)^{b}	15.45 (4.05)^{b}	28.50
T6: Farmers' practice	16.01 (23.59)^{c}	19.41 (26.14)^{d}	40.83 (39.71)^{b}	145.18 (12.09)^{c}	24.55
T7: Control	17.32 (24.59)^{c}	22.57 (36.06)^{d}	45.89 (42.64)^{b}	177.06 (13.34)^{d}	23.85
SE.m (±)	1.48	1.74	1.84	0.29	2.35
CD @ 5%	4.44	5.22	5.52	0.87	7.26
CV (%)	13.99	15.64	10.72	8.34	11.36

Table 2: Cost economics of different mass trapping and mating disruption tools for the management of pink bollworm on *Bt* cotton

Treatments	Cotton yield (q/ha)	Cost of cultivation (Rs./ha)	Cost of Treatment (Rs./ha)	Total Cost (Rs./ha)	Gross returns (Rs./ha)	Net Returns (Rs./ha)	B:C ratio
T_1 : SPLAT- PBW @ 500 g/acre	46.25	55,000	11,500	66,500	2,31,250	1,64,750	2.48
T_2 : SPLAT- PBW @ 750 g/acre	48.50	55,000	16,000	71,000	2,42,500	1,71,500	2.41
T_3 : SPLAT- PBW @ 1250g/acre	50.00	55,000	25,000	80,000	2,50,000	1,70,000	2.12
T_4: Sleeve traps @ 8/acre	30.00	55,000	550	55,5540	1,50,000	94,450	1.70
T_5 : Delta sticky trap @ 10/acre	28.50	55,000	550	55,550	1,42,500	86,950	1.56
T_6 : Farmers practice	24.55	55,000	-	55,000	1,22,750	67,750	1.23
T_7 : Control	23.85	55,000	-	55,000	1,19,250	64,250	1.17

Cotton price: Rs. 5000/q	Delta sticky trap: Rs. 35/ trap	Sleeve trap: Rs. 40/ trap	Lure: Rs. 15/ lure

Cost of SPLA T: Rs. 4600 (Rs. 900/application hence, for 4 applications it is 3600 plus cost of application Rs.1000 for four times)
Cost in farmers practice: Rs. 5000/acre (Rs. 4000 is chemical cost and Rs. 1000 for labour four times application)

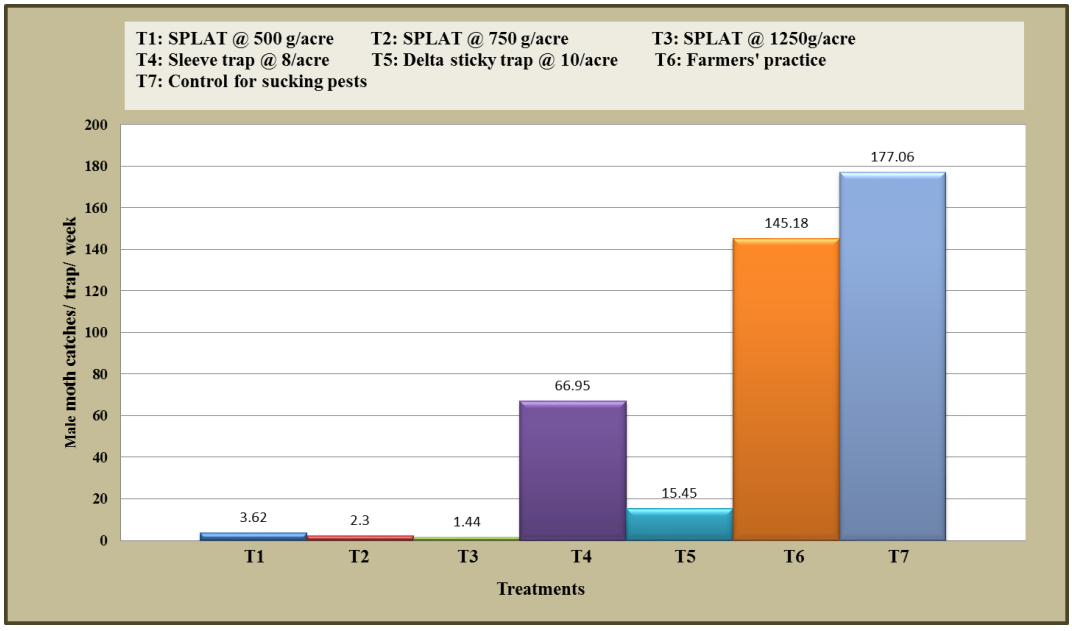

Fig 1: Influence of different mass trapping and mating disruption tools on the PBW male moth catches per trap per week in *Bt* cotton

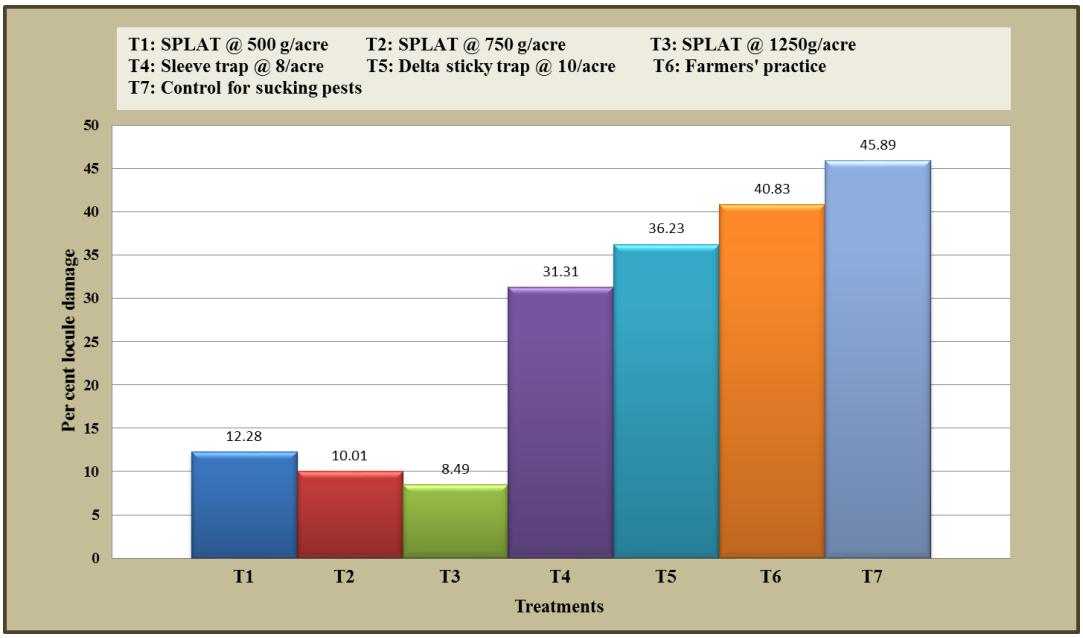

Fig 2: Influence of different mass trapping and mating disruption tools on the per cent locule damage caused by PBW on *Bt* cotton

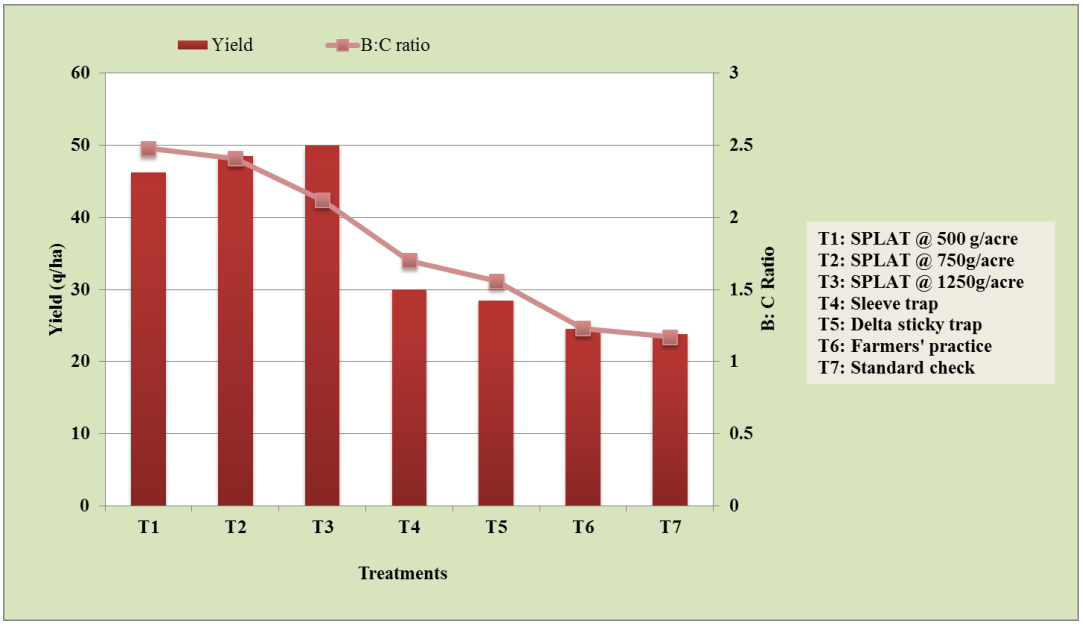

Fig 3: Influence of different mass trapping and mating disruption tools used for PBW management on yield and B: C of *Bt* cotton

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