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EVALUATION OF DIFFERENT IPM MODULES AGAINST SUCKING INSECTS IN *Bt* COTTON UNDER SOUTH-WESTERN PUNJAB CONDITIONS

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ABSTRACT

Experiments were conducted to evaluate the IPM modules in *Bt* cotton against the whitefly *Bemisia tabaci* (Gennadius), jassid *Amrasca biguttula biguttula* Ishida and thrips *Thrips tabaci* Lindeman during the summers of 2019 and 2020. The modules included homemade neem extract, neem oil, sesame oil, microbials and insecticides. The data from the experiment revealed a significant maximum reduction in whitefly (60.44%), jassid (64.18%) and thrips (60.15%) population in the plots treated with module M6 and was followed by module M5 which resulted in 46.64, 52.74 and 41.46 per cent reduction in whitefly, jassid and thrips population, respectively, when compared to untreated control. Seed cotton yield was significantly higher in treated plots than untreated check, however it was found to be maximum in module M6 (22.54 q/ha) but was statistically at par with modules M4 (19.61 q/ha), M5 (18.96 q/ha) and M3 (18.79 q/ha). Moreover, the highest (ICBR) incremental cost benefit ratio was obtained from the application of module M6 (1:3.55) and M5 (1:3.28). It can be concluded that application of initial homemade neem extract and need based use of new chemistry insecticides and microbials will play an important role to curtail sucking pests incidence in Bt cotton.

Keywords: Botanicals, Cotton, IPM modules, Insecticides, Microbials

Cotton (*Gossypium* spp.) commonly known as 'White gold' is an important cash crop of India. It significantly contributes to the national economy by providing the raw material to allied sectors like ginning, fabric production, textile processing and garment manufacture, etc. In Punjab, cotton is grown as major *kharif* crop after rice and mainly cultivated in South-western districts of Punjab *i.e.* Bathinda, Mansa, Sri Muktsar Sahib and Fazilka. During 2019-20, American cotton was grown on an area of 2.45 lakh hectares with an average yield of 8.29 quintals lint per hectare (3.35 quintals lint per acre) in Punjab (Anonymous, 2021). Because of the luxuriant growth, hot and humid weather prevalent during the summers, the cotton crop is vulnerable to the infestation of insect-pests and diseases right from germination till harvesting (Pathania *et al.,* 2020a). In India a total of 162 species of insects was recorded to be associated with cotton crop, 24 species of which have attained the status of pest and nine species became major pests in different cotton growing zones (Sundramurthy and Chitra,1992; Dhawan, 2000). Among different pest threats, sucking insects viz. whitefly, jassids and thrips made Bt cotton cultivation problematic compared to desi cotton (*Gossypium arborium*) (Nath *et al.,* 2000) and the incidence of these insects gained importance in Bt cotton after 2015 under Punjab conditions (Dhillon and Sidhu, 2016; Kumar *et a*l., 2020).Because of wide host range, these pests are capable of producing many generations during the year due to which they may exist in the fields around the year in varying amounts (Pathania *et al*., 2020a). Adults and nymphs of whitefly suck sap from underside of leaves and excrete honeydew which encourages sooty mould growth, thereby, adversely affecting the process of photosynthesis. Besides lint discoloration, this pest also vectored cotton leaf curl virus disease. Similarly, being sap feeders, both nymphs and adults of jassid are damaging to cotton leaves and capable of injecting its toxic saliva in to the leaves, whereas, thrips can lacerate the leaf tissue and feed on the oozing cell sap resulting in silver streaks around the midrib and veins andlater itbecomes severe and slight to extreme cupping of the leaves can be observed. The incidence of whitefly, jassids and thrips when uncontrolled resulted in about 60, 11.6 and 50-60 per cent reduction in seed cotton yield, respectively (Dhillon and Sidhu, 2016; Dhawan *et al*., 1988 ; Mohan and Nandini, 2011). Approximately 28.30 per cent avoidable losses in cotton crop observed by Chavan *et al.* (2010) were because of the sucking insect's incidence. The major incidence of sucking pests in cotton was observed during the months of July-August (Pathania *et al*., 2020a and 2020b). Because of increased incidence of sucking pests in cotton during this period, farmers have to rely heavily on repeated applications of chemical insecticides. Due to use of readymade insecticidal mixtures, synthetic pyrethroids and repeated use of insecticides with similar mode of action, there are chances of development of resistance in these pests, loss of biodiversity, accumulation of pesticide residue and also results in reduced efficacy

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of the insecticides. This further adds to increased cost of production. According to an estimate 36-50 per cent of the total pesticide consumption among different cultivated crops is in cotton crop in India (Bhardwaj and Sharma 2013; Devi 2010; Wavdhane et al. 2020). So, there is a need to evaluate the different biopesticides, microbials, and green chemistry insecticides in an integrated manner as a module to reduce the cost of production and to achieve desired pest control. Keeping in view these, the present study was planned to evaluate different IPM modules for their effectiveness in controlling sucking pests of cotton.

MATERIALS AND METHODS

Study environment

The experiments were conducted during the summers of 2019 and 2020, at the experimental farm of the Punjab Agricultural University Regional Research Station, Bathinda, India located 211 meter above mean sea level (Lattitude 30°17'N and Longitude 74°58'E). The study region lies in the extreme south west of Punjab. The area receives about 400 mm of annual rainfall more than 80 per cent of which occurs between July to September months. Climate of the region is semi-arid and characterized as hot and humid summers and cool winters. The soils of the experimental area are loamy sand to sandy loam in texture, low in nitrogen, medium in phosphorus and high in potassium. The variations in the meteorological factors during the experimental period were recorded from the Agrometeorology Observatory installed at Regional Research Station, Bathinda and presented in Fig. 1.

Experiment details

Experimental site was having long history of cotton-wheat cropping system. The experiment was laid out in Randomized Block Design (RBD) where each treatment was replicated thrice. The plot size was 4 x 4m. Seed of recommended Bt cotton hybrid, RCH 776 @ 2.25 kg^{-ha} was sown at 67.5 cm row to row and 75 cm plant to plant spacing. The crop was raised as per the recommended practices of Punjab Agricultural University (Anonymous, 2019) except for insect management. The detail of different treatments/modules is given in Table 1. The different standard formulations of insecticides, microbials, biopesticides and oils used in the study were procured from local market.The different formulations used were flonicamid (Ulala 50WG, United Phosphorus Limited), Pyriproxyfen (Lano 10% EC, Sumitoma India Pvt. Ltd.), Dinotefuran (Osheen 20% SG, PI Industries Pvt. Ltd.), Diafenthiuron(Polo 50%WP, Syngenta Crop Protection), *Verticillium lecanii* (Bio-Catch 1.15% WP, T Stanes & Company Limited), *Beauveria bassiana*(Bio-Power 1.15% WP, T Stanes& Company Limited), *Metarhizium anisopliae* (Bio-Magic 1.15% WP, T Stanes & Company Limited), Neem oil (Procured from local market), homemade neem extract (Prepared by taking 4 kg of terminal parts of shoots of neem trees including leaves, green branches and fruits and boiling in 10 litres of water for 30 minutes and then were filtered through muslin cloth). Homemade neem extract has also been reported effective even against other sucking insect-pests in the region (Taggar *et al.,* 2022).

In each module, there were four spray applications of different treatments done at 15 days interval starting from mid-July to end-August which was considered to be the major activity period of sucking pests of cotton (Pathania *et al*., 2020a). Spray application of insecticides/biopesticides was done with battery operated, calibrated shoulder mounted knapsack sprayer. The spray was done in the morning/ evening hours. Data on the incidence of whitefly, jassids and thrips was recorded at the weekly interval from SMW 24 to SMW 43 (Standard Meteorological Week). The number of whiteflies, jassids and thirps was counted

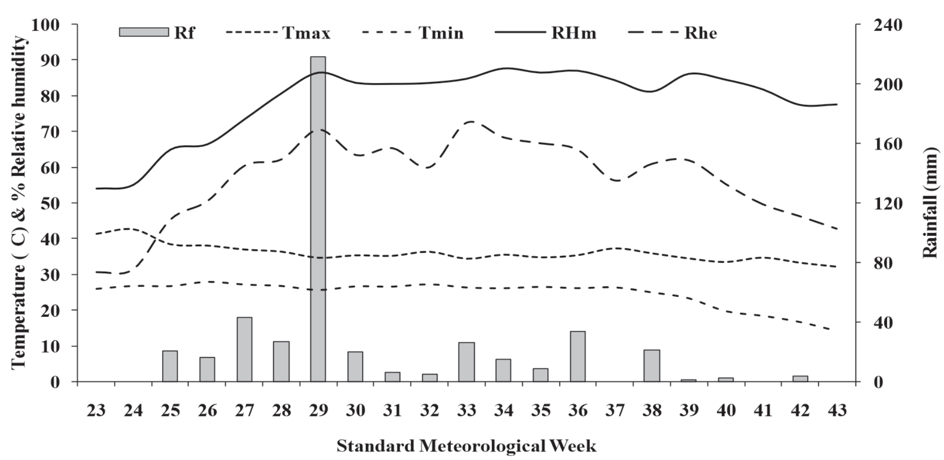

Fig. 1. Meteorological observations of the study site during the experimental period (pooled 2019 & 2020)

from 15 randomly selected plants (5 plants/ replication). For counting whitefly adults, from each plant, 3 leaves were selected (one leaf from the upper canopy, the 2nd leaf from the middle canopy and 3rd leaf from lower canopy of the plant), however, in case of jassid and thrips the counts were taken from three fully formed leaves from the upper canopy of the plant. The count of predator's *viz*. chrysopids, spiders etc. was also recorded on per plant basis. The cost benefit ratio of different modules was also worked out. At the harvest, seed cotton yield was recorded and Per cent increase in yield over untreated control worked as per the formula:

$$\text{Per cent increase in yield over control} = \frac{\text{yield of treatment - yield of control}}{\text{Yield of treatment}} \times 100$$

Statistical analyses

There were two experiments conducted each with three replications with an idea to distinguish the treatment results with confidence. The pest population data was subjected to square root transformation for statistical analyses. The data generated from two trials was pooled and subjected to analysis of variance to evaluate the treatment effects and the means were separated using Least Significant Difference (LSD) at p=0.05.

RESULTS AND DISCUSSION

Incidence of sucking pests in cotton

The pooled data for the year of 2019 and 2020 with respect to whitefly, jassid and thrips incidence in cotton (cv. *RCH 776 BGII*) is presented in Fig. 2. During the experiment, we recorded weekly observations of sucking pests in cotton from SMW 24 to 43. It was observed that whitefly and thrips infestation started in cotton started with the germination of the plant and these insects suck/ lacerate the sap from the tender leaves. The population of whitefly on cotton plants ranged from 0.77 – 32.97 ± 1.13 adults/ 3 leaves (mean ± SE; N=15) during the study period *i.e.* from SMW (Standard Meteorological Week) 24 to SMW 43 (Fig. 2). There were two peaks of whitefly incidence in cotton observed (28th to 34th SMW and 37th to 41st SMW; Fig. 2) and the maximum incidence was observed during 31st SMW (Fig. 2). Jassid appearance on leaves started from the second fortnight of June and the incidence was peaked during 33rd SMW (10.85± 1.01 jassids / 3 leaves; mean ± SE; N=15) and the insect remain active in the cotton canopy till 43rd SMW (Fig. 2). The favourable time span for infestation of thrips in cotton ranged between 26th SMW to 34th (Fig. 2) and the population peaked during 31st SMW (50.12 ± 1.56 thrips /3 leaves).

Table 1. Details of different treatments in the respective IPM Module

Module No.	Treatment details
M_1	I: Homemade neem extract @ 3 litre/ha II: Neem oil @ 2.5 l/ha III: Homemade neem extract @ 3 litre/ha IV: Neem oil @ 2.5 l/ha
M_2	I:*Beauveria bassiana* (1 x 10^8cfu/ml)@ 2.5 l/ha II:*Metarhizium anisopliae* (1 x 10^8cfu/ml)@ 2.5 l/ha III:*Verticillium lecani* (1 x 10^8cfu/ml)@ 2.5 l/ha IV:*Beauveriabassiana* (1 x 10^8cfu/ml)@ 2.5 l/ha
M_3	I: Homemade neem extract @ 3 litre/ha II:*Beauveria bassiana* (1 x 10^8cfu/ml)@ 2.5 l/ha III: Homemade neem extract @ 3 litre/ha IV:*Verticillium lecani* (1 x 10^8cfu/ml)@ 2.5 l/ha
M_4	I:*Beauveria bassiana* (1 x 10^8cfu/ml)@ 2.5 l/ha + neem oil @ 1.25l/ha II:*Verticillium lecani* (1 x 10^8cfu/ml) @ 2.5 l/ha + sesame oil @ 1.25l/ha III: *Beauveria bassiana* (1 x 10^8cfu/ml)@ 2.5 l/ha + sesame oil @ 1.25l/ha IV:*Verticillium lecani* (1 x 10^8cfu/ml) @ 2.5 l/ha + neem oil @ 1.25l/ha
M_5	I: Homemade neem extract @ 3 litre/ha II: Ulala 50WG (flonicamid) @ 200 g/ha III: *Beauveria bassiana* (1 x 10^8cfu/ml)@ 2.5 l/ha IV: Osheen 20 SG (dinotefuran) @ 150 g/ha
M_6	I: Ulala 50WG (flonicamid) @ 200 g/ha II: Lano 10 EC (pyriproxyfen) @ 1250 ml/ha III: Delegate 11.7 SC (Spinetoram) @ 425 ml/ha IV: Polo 50 WP (diafenthiuron) @ 500 g/ha
M_7	Untreated check

*I: First spray; II: second spray; III: Third spray; IV: Fourth spray

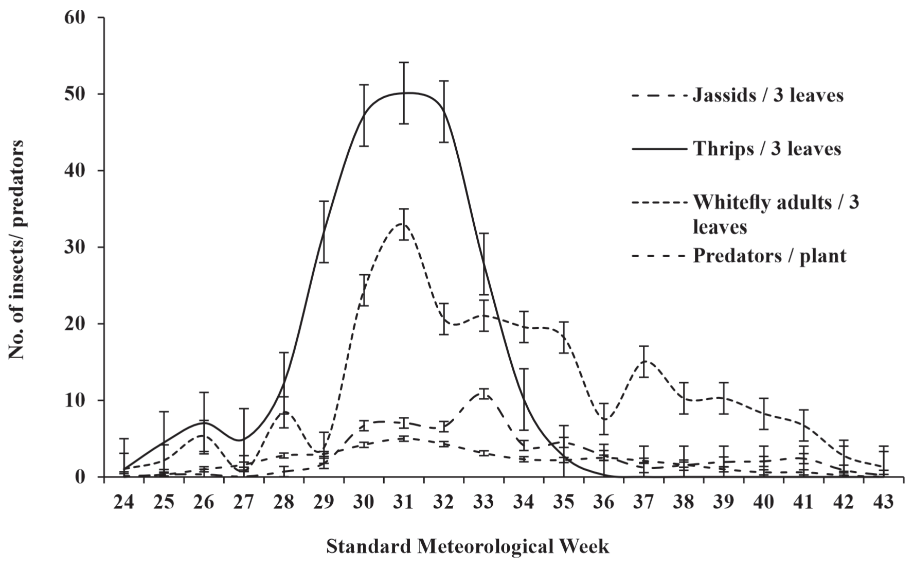

Fig. 2. Incidence of sucking insects and predators during the experiment (pooled 2019 & 2020)

It was depicted from the population dynamics data and corresponding weather variables that a typical optimum range of temperature (Tmax 34.29 °C – 42.54 °C; Tmin 25.46 °C – 27.76 °C) and humidity (RHm 55.07 % – 86.50 %; RHe 31.57 % – 70.50 %) were found favourable for the build-up of thrips's population (Fig. 2). The incidence and population build-up of whitefly was peaked between SMW 26 to 39 which signifies the favourable temperature range of 33.37 - 37.99°C of maximum and 18.27 - 27.76°C of minimum temperature for its development, whereas the same for the jassid ranged between 34.29 – 36.26°C and 25.46 - 27.06 °C of maximum and minimum temperature, respectively, as its population buildup was maximum between SMW 28 to 35 (Fig.1 & 2).

Management of sucking insects

The population of sucking insect pests viz. whitefly, jassid and thrips was recorded at weekly intervals during the cropping season and was presented as average population in different treatments. The pooled data of two trials conducted during 2019 and 2020 on the efficacy of different modules against sucking insect's viz. whitefly, jassid and thrips in cotton is presented in Table 2. All the modules were found effective in reducing pest infestation as compared to untreated control. Significant differences between different modules for the management of whitefly ($F_{6,2}$ = 19.81, p < 0.01), jassid ($F_{7,21}$ = 9.37, p < 0.01) and thrips ($F_{6,2}$ = 119.58, p < 0.01) was recorded over the time. The average population of whitefly in different modules during the experiment varied from 3.24 to 8.19 adults/ 3 leaves (Table 2). The incidence of whitefly in different modules crossed the Economic Threshold level (ETL) during the SMW 30 to 35 (18.22 – 32.97 whitefly adults / 3 leaves) and remained below ETL rest of the season. The module M6 was found significantly superior in causing 60 per cent reduction in average whitefly population in cotton during the cropping season, and statistically at par with M5 (Table 2). Insecticides with new chemistry and alternation with neembicidine and microbials resulted in effective management of *B. tabaci* in Bt cotton during the season. The initial spray of neem oil followed by need based sprays of flonicamid 50 WG and pyriproxyfen 10 EC during the season resulted in 80-85 per cent reduction in *B. tabaci* adult population in cotton was reported by Singh *et al*. (2020) which are in confirmation of our findings. Hence, integration of new chemistry insecticides, botanicals and microbials in the form of module will result in effective management of whitefly in cotton. The average seasonal incidence of jassid in different modules varied from 0.72 – 1.28 jassids/ 3 leaves as compared to 2.01 jassids /3 leaves in the untreated control (Table 2). The incidence of jassids in different modules crossed the Economic Threshold level (ETL) during the SMW 30 to 34 (6.70 – 10.85 jassids / 3 leaves) and remained below ETL rest of the season. Again the module M6 was found most effective in reducing jassid population in cotton during the season and was statistically at par with M5, M1 and M2 (Table 2). Sharma and Summarwar (2017) observed 21.76 per cent lesser population of jassid in IPM treated cotton plots as compared to control plots also substantiate our findings. Spray application of new chemistry insecticides viz. flonicanid and dinotefuran were effective in controlling jassids population percent in Bt cotton was also supported by the findings of Halder *et al.* (2018) and Sanghi *et al.* (2019) who also advocated the better efficacy of these insecticides against cotton jassid. Seasonal incidence of thrips in

Table 2. Bioefficacy of different modules against sucking insects in cotton (pooled 2019& 2020)

Modules	Avg. incidence of sucking insects/ 3 leaves during the season			No. of sprays during the season	Seed cotton yield q/ ha	Additional produce (q/ha)	% increase in yield over control	Increased income over control (Rs/ ha)	Net gain (Rs./ ha)	Incremental Cost benefit ratio (ICBR)
	Whitefly	Jassids	Thrips							
M_1	5.76 (3.96)	1.05 (1.46)	16.39 (4.23)	4	16.75	2.11	12.60	6580	2280	1:0.53
M_2	6.21 (4.33)	1.09 (1.73)	14.61 (3.72)	4	17.72	3.08	17.38	11624	5724	1:0.97
M_3	6.27 (4.50)	1.28 (1.76)	16.79 (4.25)	4	18.79	4.15	22.09	17188	11588	1:2.07
M_4	6.55 (4.78)	0.97 (1.56)	11.49 (3.34)	4	19.61	4.97	25.34	21452	14122	1:1.93
M_5	4.37 (3.59)	0.95 (1.71)	12.69 (3.43)	4	18.96	4.32	22.78	18072	12522	1:2.26
M_6	3.24 (2.37)	0.72 (1.14)	8.64 (2.54)	4	22.54	7.90	35.05	36688	27138	1:2.84
Control	8.19 (6.25)	2.01 (3.57)	21.68 (10.98)		14.64					
CD (p=0.05)	0.97	0.46	0.97		4.35					

*Cost of insecticidal treatment = Cost of insecticide +Labour charges @ Rs 300/- for spraying 1 ha of crop
** Rates of insecticides: Neembicidine 300 ppm = Rs. 480/L; *Beauveria bassiana* = Rs. 540/l; *Verticillium lecani* = 540/l; *Metarhizium anisopliae* = Rs. 540/l; Ulala 50 WG= 8000/kg; Lano = Rs. 1250/l; Polo = Rs. 1250/l; Osheen = Rs. 6000/kg; Delegate = Rs. 11050/l; Neem oil = Rs. 280/l; Sesame oil = Rs. 170/l
*** Market price of seed cotton @ Rs 5200/q

cotton was recorded to be highest in untreated control (21.68 thrips/ 3 leaves). All the modules were found effective in reducing thrips population to varying extent (Table 2). The incidence of thrips in different modules crossed the Economic Threshold level (ETL) during the SMW 29 to 33 (32.01 – 50.12 thrips / 3 leaves) and remained below ETL rest of the season. The incidence of thrips found to be lowest in M6 and was statistically at par with M4 and M5 (Table 2). Overall, the module M6 was found most effective with 60.44, 64.18 and 60.15 per cent reduction in whitefly, jassids and thrips population, respectively (Fig. 3) followed by M5 which contributed 46.64 and 52.89 per cent reduction of whitefly and jassids incidence in cotton (Fig.3). In case of thrips module M4 was proved to be the second best treatment and reduced thrips population by 46.99 per cent and was at par with M5 (41.45% reduction) when compared to untreated control. The results of the experiment suggested that if the spray schedule in cotton is focused on the alternations of new chemistry insecticides as well as biopesticides during the major activity period of sucking insects i.e. July and August, it will definitely result in appreciable control of sucking insects in cotton. In line with our findings, Sharma and Summarwar (2017) also reported that adoption of IPM modules resulted in 32.76, 21.76 and 27.22 per cent reduction of whitefly, jassid and thrips population as compared to non IPM plots in Bt cotton. The treatments with microbials alone as well as in combination with botanical oils also resulted in appreciable reduction in sucking pest's population yet the combination/ alternation of new chemistry insecticides was most effective in Bt cotton which is in confirmation with the findings of Khajuria *et al.*(2020), Kumar *et al.* (2019); Jindal and Kumar (2018) and Bharpoda *et al.* (2016) which advocated that IPM modules comprising of insecticides and microbials are effective in cotton pests management.

Effect of different treatments on seed cotton yield and cost benefit ratio

The data on the economics of different insecticide treatments was depicted in Table 2. All the modules exhibited higher seed cotton yield as compared to control (14.64 to 22.54 q/ha). The maximum (35.05%) increase in seed cotton yield was obtained in plots with module M6 followed by M4 and M5 (25.34 and 22.78 per cent increase, respectively) as compared to untreated control (Table 2). However, when we have taken into consideration the cost of pesticides treatment and labour involved in getting incremental grain yield over control, the maximum benefit (Rs 27138/ha) was obtained from plots treated with module M6 followed by M4 (Rs 14122/ha). Moreover, the highest incremental Cost Benefit Ration (ICBR) of actual cost incurred in pesticides treatment was obtained with M6 (1:3.55)

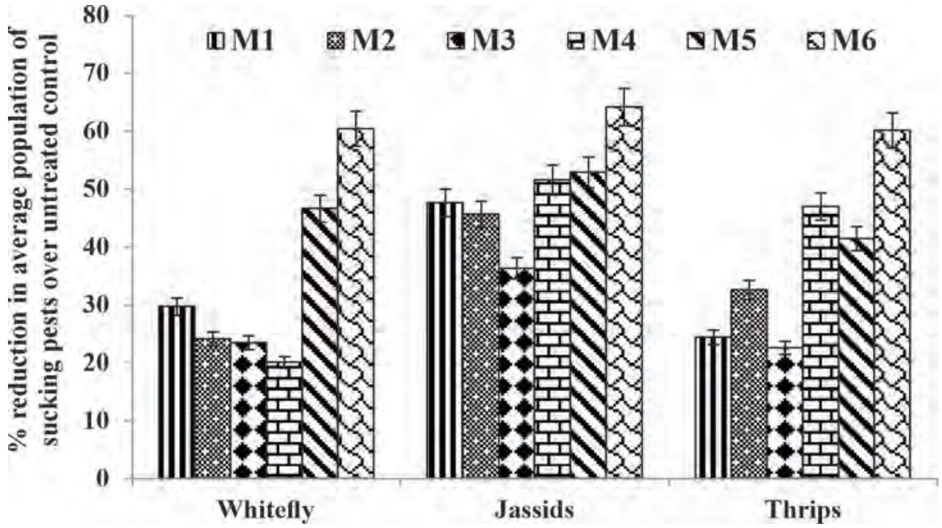

Fig. 3. Reduction in incidence of whitefly, jassid and thrips population in different modules over untreated control (pooled 2019 & 2020)

followed by M5 (1:3.28) and M3 (1:3.08) due to low cost of insect management during the experimental period, respectively (Table 2). The different IPM modules proved beneficial in respect of enhancing yield and economics of cotton was also advocated by Jindal and Kumar (2018), Singh *et al.* (2020) and Kumar *et al.* (2020).

It can be concluded from the study that the activity of sucking pests viz. whitefly, jassid and thrips in cotton was maximum during the months of July and August which should be targeted for the planning and implementation of IPM strategies against these pests for sustainable cotton production. It is imperative from the results that planning management strategies in the form of modules either solely based on new chemistry insecticides viz. Ulala 50 WG (flonicamid) @ 200 g/ha, Osheen 20 SG (dinotefuran) @ 150 g/ha, Lano 10 EC (Pyriproxyfen) @ 1250ml/ha and Polo 50 WP (diafenthiuron) @ 500g/ha, which are effective at low dosages or integration/ alternation of these insecticides with botanicals and microbials is effective in managing sucking pests in *Bt* cotton and enhancing seed cotton yield.

Authors' contribution

Conceptualization and designing of the research work (MP); Execution of field experiments and data collection (JK, MP); Analyses of data and interpretation of results (JK, MP); Preparation of manuscript (JK, MP).

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