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Effects of repeated application of contact insecticides on lac insect survival across different landraces of *Cajanus cajan* (L.) Millsp

[1]Dhruv Kumar Patel, [2]Moni Thomas, [1]R.S. Marabi, [3]Deepak Singh[*1]Dipali Samridhi, [1]Jitendra Patel Kurmi, [1]Dwarka

(Ph.D., Research Scholar);
(Director of Institute of Agri Business Management);
(Assistant Professor);
(Ph.D.), Department of Fruit Science;
(Ph.D., Research Scholar);
(M.Sc.);
(Ph.D.)
[1,2]Department of Entomology, [1,2,3]College of Agriculture, Jabalpur, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh, India- 482004.
***Corresponding Author E-mail: dsingh.horticulture@gmail.com**

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Abstract

A field trial was conducted at Jawahar Model Farm, JNKVV, Jabalpur, from June 2022 to June 2023 to assess the impact of insecticides on lac insect survival across six *Cajanus cajan* landraces. Using a Split Plot Design, the trial evaluated three treatments: chlorantraniliprole followed by emamectin benzoate, emamectin benzoate followed by emamectin benzoate and a control (water spray), revealing significant differences in insect survival based on insecticide use and landrace variation. This study investigates the impact of different insecticide combinations on mean number of live lac insect (MNL) of *Cajanus cajan* across multiple time points: 30th, 60th, 90th, 120th, 150th, and 180th days after brood lac inoculation (BLI). Results show that chlorantraniliprole followed by emamectin benzoate (M_1) consistently achieved the highest MNL values and significantly reduced lac insect losses compared to emamectin benzoate alone (M_2) and water spray (M_3). On the 30th day post-BLI, MNL ranged from 161.89 (M_1S_4) to 178.11 (M_3S_5), with $M_3 + S_5$ producing the highest MNL. At 60 days, MNL was highest with M_1S_1 (175.72), followed closely by M_3S_5 (168.46), and M_1 also resulted in the lowest lac insect loss (1.10%). By 90 days, predator activity had increased, leading to MNL losses peaking at 22.52% with the control (M_3). Chlorantraniliprole (M_1) and emamectin benzoate (M_2) treatments reduced this loss to 14.06% and 14.37%, respectively. The MNL trends continued at 120, 150, and 180 days, with the $M_1 + S_1$ and $M_1 + S_5$ combinations consistently outperforming other treatments. At 180 days, MNL declines were lowest in treated landraces, highlighting the critical role of insecticides in protecting lac insects from natural enemies and minimizing economic losses.

Key words: Lac survival, *Cajanus cajan*, Chlorantraniliprole and Landraces.

1. Introduction

The survival of lac insects (*Kerria lacca*), critical for lac production in many regions, can be significantly affected by the application of contact insecticides (Janghel *et al.,* 2014). This research investigates the effects of such insecticides on lac insect populations, particularly in relation to their interaction with landraces of pigeon pea (*Cajanus cajan* L.) Jethu (2022). Pigeon pea is a major pulse crop with diverse landraces, each exhibiting varying degrees of pest resistance (Khichi *et al.,* 2021). By employing a treadmill application method, which ensures uniform and consistent insecticide coverage (Gross *et al.,* 2011), this study aims to assess the impact of different contact insecticides on the survival rates of lac insects on these landraces. Understanding these interactions is crucial for developing effective pest management strategies while preserving crop health and productivity (Kakade *et al*.,2020). This research not only contributes to sustainable agriculture practices but also supports the optimization of lac production, a valuable commodity in various industries.

2. Materials and Methods

2.1 Experimental details

The impact of contact insecticides on the survival of lac insects across different landraces of *Cajanus cajan* (L.) Millsp. was assessed through a field trial conducted at the Jawahar Model farm, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh. The trial spanned from June 2022 to June 2023 and utilized a Split Plot Design. The main plots consisted of three insecticide treatments: M_1 - Chlorantraniliprole 18.5% SC followed by E. benzoate 5% SG, M_2 - E. benzoate 5% SG applied twice, and M_3 - Control. Within these main plots, six sub-plots were dedicated to different landraces of *Cajanus cajan*: S_1 - Korsar 1, S_2 - Korsar 2, S_3 - Amarkantak 3, S_4 - Burhanpur 1, S_5 - Lakhnadon 1, and S_6 - TDN 1 (Plate 2). The experiment was carried out during the Kharif-Rabi season of 2022-23 to evaluate the effectiveness of insecticide treatments and the influence of crop landraces on lac insect survival.

2.2 Layout of the main field

The experimental layout in the main field was designed to accommodate 54 *Cajanus cajan* plants. Each plant was spaced six feet apart, both within rows and between rows. To ensure proper spacing between replications, a distance of 10 feet was maintained. This arrangement follows the guidelines outlined by Khichi *et al.,* (2021).

2.3 Poly propylene bag (PPB)

Each empty PPB, sourced from a local manufacturer, initially weighed 85 grams and measured 95 cm by 55 cm. The substrate, consisting of a 2:1 mix of 30 kg Kapu and 15 kg FYM, was added to the PPBs using a *tasala*. The bags were shaken continuously to ensure the substrate settled and compacted effectively. After filling, the PPBs, now containing a total of 45 kg of substrate, had a final dimension of 40 cm in height and 120 cm in circumference. The filled PPBs were then placed in their designated positions within the experimental layout and were to remain undisturbed thereafter (Kakade *et al.*, 2020).

3.3 Treatment of the substrate

The PPBs containing the substrate were subsequently inoculated with soil microbes specifically *Trichoderma viride*, *Rhizobium*, and PSB sourced from the microbe production unit at JNKVV, Jabalpur, Madhya Pradesh, India.

Table 1: Pesticides spray schedule days after BLI

Dates	M_1	M_2	M_3
(28th day)	Chlorantraniliprole	Emamectin benzoate	Water spray
(58th day)	Emamectin benzoate	Emamectin benzoate	Water spray
(88th day)	Chlorantraniliprole	Emamectin benzoate	Water spray
(118th day)	Emamectin benzoate	Emamectin benzoate	Water spray
(148th day)	Chlorantraniliprole	Emamectin benzoate	Water spray
(178th day)	Emamectin benzoate	Emamectin benzoate	Water spray

3.4 Brood lac inoculation on *C.cajan* plants

On October 22, 2022, *Rangeeni* brood lac (also known as *Baishakhi* lac) was purchased from Adarsh Lac Samiti in Jamankhari village, Tehsil Barghat, District Seoni, M.P. The brood lac was carefully transported from Seoni to Jabalpur. Upon arrival, it was sorted to ensure predator-free quality. On the same day, a brood lac stick weighing 15-20 grams was attached to the main stem of each *C. cajan* plant in the PPBs. The stick was placed approximately one foot above the plant base and secured with twine, in accordance with the treatment protocol. *Phunki* was carefully removed from the *C. cajan* plants on November 12, 2022, ensuring that the lac insect colonies remained undamaged. The number of lac insects was counted in a 2.5 cm^2 area (2.5 cm length and 1.0 cm width) on the branches.

3.5 Marking of slots of 2.5cm^2

After 30 days, the majority of the crawlers emerge from the BLI and settle on various branches of the plant. At this stage, two well-settled branches are selected. A 2.5cm^2 slot is then created on each of these branches, resulting in a total of four slots, labeled P_1, P_2, P_3, and P_4. Before making the slots, the borders are carefully outlined with thread, and any lac insects settled on these borders are gently removed by hand (Patil *et al.*, 2021).

3.6 Digital recording

Initially, the lac insect crawlers measure just 0.5 mm, making it very challenging to count them within a small 2.5 cm^2 area, referred to as a slot. Increasing the slot size would only add to the difficulty of accurately counting the lac insects both per slot and per plant. To address this issue, the branches with slots are photographed using a Digital Single-Lens Reflex (DSLR) camera equipped with a 100mm macro lens, set to ISO 400, manual mode, and a shutter speed of 4.5 to 6 seconds. Multiple photographs are taken to ensure clarity, and the clearest images are selected for analysis (Kakade *et al.,* 2020).

3.7 Digital counting

Using a memory card reader, the best digital images captured by the DSLR camera were transferred to a laptop. The images were then opened in the "Paint 3D" application from the Microsoft Office 11 suite. After enlarging the image on the laptop screen, the "*Brush tool*" was selected from the Paint 3D toolbar. The Calligraphy pen was chosen with a thickness adjusted from 1 to 18 times its original size, along with a contrasting color for the Brush tool. By hovering the mouse pointer over a specific lac insect in the image and left-clicking, a dot of the selected thickness and color was applied to the insect in the image. This process was repeated until every lac insect in the slot was marked with a dot. Once all the dots were counted and recorded, the image was renamed and saved in a designated folder for future reference (Patent Application No. 201921007852A) (Kakade *et al.*, 2020).

3.8 Frequency of lac insect count

The lac insect populations within the slots were counted on the 30th, 60th, 90th, 120th, and 150th days after BLI during the 2022-23 period (Plate 1).

4. Results and Discussion

4.1 Effect of insecticide application and *Cajanus cajan* landraces on lac insect survival

The incidence of predators and parasitoids affecting lac insects is well-documented (Janghel *et al.,* 2013). Insecticides are commonly used to protect lac insects from these natural enemies (Janghel *et al.,* 2014). Therefore, selecting an insecticide that is safe for lac insects is crucial (Khichi *et al.,* 2021) (Table-1).

4.2 Mean number of live lac insects per 2.5 cm^2 (MNL)

At 30 days after BLI and 158 DAS, the MNL ranged from 161.89 (M_1S_4) to 178.11 (M_3S_5). The MNL was notably higher in the combination of water (M_3) + S_5, but it was comparable to that of chlorantraniliprole (M_2) + S_1. This suggests that chlorantraniliprole is relatively safer than the other options. Jethu (2022) reported MNL on *C. cajan* ranging from 153.56 to 182.08, while Patil *et al.* (2021) reported a range of 164.61 to 213.94.

On the 60th day after BLI and 188 DAS, the combination of chlorantraniliprole followed by emamectin benzoate (M_1) with S1 (Korsar 1) achieved the highest MNL (175.72), nearly matching the MNL (168.46) observed with water spray and S_5 (Lakhnadon 1). This suggests that chlorantraniliprole followed by emamectin benzoate (M_1) effectively protects lac insects from their natural enemies. The M_1 + S_1 (Korsar 1) combination also resulted in the lowest lac insect loss (1.10%), indicating its efficacy. Conversely, the combination of emamectin benzoate followed by emamectin benzoate (M_2) with S_3 (landrace) recorded the highest lac insect loss (9.23%) at 60 days after BLI. A decline in MNL was observed at 60 days after BLI compared to the 30-day mark. Similar declines were reported by Kakade *et al.* (2020) with a 10.45% reduction, Vishal *et al.* (2020) with a 15.34% reduction, and Khichi *et al.* (2021) with a 9.23% reduction.

On the 90th day after BLI and 208 DAS, the data indicates that predator activity on lac insects began between 30 and 60 days after BLI, but significantly increased after the 60-day mark. At 30 days after BLI, the highest MNL loss recorded was 7.54%. However, between the 60th and 90th days, the loss peaked at 22.52% with the water spray treatment. In contrast, MNL losses were lower with chlorantraniliprole followed by emamectin benzoate (M_1) at 14.06%, and with emamectin benzoate followed by emamectin benzoate (M_2) at 14.37%. This data underscores the critical importance of predator management using insecticides, especially considering the 22.52% loss of lac insects in the control treatment (M_3). It appears that chlorantraniliprole followed by emamectin benzoate (M_1) acts more rapidly, while emamectin benzoate followed by emamectin benzoate (M_2) requires three sprays to achieve the effectiveness of the M_1 treatment.

The landrace S_1 (Korsar 1), when combined with both insecticides, proved to be the most efficient, yielding the highest MNL. In contrast, the landrace S_6 (TDN 1) had the lowest MNL, though its performance improved when combined with both insecticides (M_1S_6 and M_2S_6). The reduction in MNL at 90 days BLI compared to 60 days BLI was the lowest (12.17%) in the M_2S_3 treatment and the highest (23.89%) in the M_3S_3 treatment. This clearly highlights the role of insecticides in mitigating lac insect losses caused by natural enemies. A similar decline in MNL at 90 days BLI has been reported by earlier researchers, with Janghel *et al.* (2013) noting a 21.17% reduction, Namdev *et al.* (2014) reporting an 18.99% decline, and Patil *et al.* (2021) observing a 17.83% decrease.

On the 120th day of BLI and 238 DAS, the combinations of insecticides with landrace S_1 (M_1S_1 and M_2S_1) exhibited the highest and most effective MNL values compared to other combinations. Although landrace S6 initially had the lowest MNL, its MNL increased when treated with insecticides (125.22 for M_1S_6 and 121.20 for M_2S_6) compared to the untreated control (99.73 for M_3S_6). This indicates that the combination of chlorantraniliprole followed by emamectin benzoate (M_1) is particularly effective in achieving the highest MNL. Furthermore, at later stages of lac insect growth, emamectin benzoate followed by emamectin benzoate (M_2) also proves to be effective. The observed decline in MNL at 120 days BLI has been supported by earlier studies, with reported declines of 20.54% by Patidar *et al.* (2019), 19.23% by Jethu (2022), and 16.48% by Khichi *et al.* (2021).

On the 150th day of BLI and 268 DAS, the fifth application of insecticides was conducted on March 21, 2022, with MNL observations recorded on March 23, 2023, which was two days after the fifth spray and 150 days after BLI. The MNL values for *C. cajan* were 104.01 for M_1, 92.88 for M_2, and 88.16 for M_3. The MNL for M_1 was significantly higher compared to M_3. The combination of chlorantraniliprole followed by emamectin benzoate (M_1) with both S_1 (Korsar 1) and S_5 resulted in the highest MNL values. The percentage reduction in MNL from 120 to 150 days BLI was the lowest (20.48%) for M_1S_5 and the highest (38.50%) for M_2S_2. This decline in MNL at 150 days BLI is consistent with findings from earlier studies, which reported reductions of 23.21% by Namdev *et al.* (2014), 20.91% by Janghel *et al.* (2013), and 18.33% by Patil *et al.* (2021).

On the 180th day of BLI and 298 DAS, the combination of chlorantraniliprole followed by emamectin benzoate (M_1) with S_5 (Lakhnadon 1) and S_6 (TDN 1) showed the highest MNL at 180 days (Table 02). This indicates that this sequence of insecticides is more effective than using emamectin benzoate followed by emamectin benzoate (M_2). However, when considering the percent reduction in MNL at 180 days compared to 150 days, M_2S_2 exhibited the lowest reduction at 15.82%, while the highest losses were 40.42% and 40.96% in M_3S_2 and M_3S_5, respectively. This suggests that without insecticides, there is a significant economic loss of lac insects.

Nevertheless, if S_5 is used in combination with chlorantraniliprole followed by emamectin benzoate (M_1S_5) or even with emamectin benzoate followed by emamectin benzoate (M_2S_5), the percent reduction in MNL at 180 days compared to 150 days BLI was 25.39% and 30.04%, respectively, compared to a 40.96% reduction without insecticide application. A decline in MNL at 180 days BLI has also been reported by previous studies: a 27.32% decrease by Khichi *et al.* (2021), 24.99% by Kakade et al. (2020), 19.52% by Jethu (2022), 18.63% by Namdev *et al.* (2013), and 17.88% by Patil *et al.* (2021).

4.3 Overall survival percent in MNL on 2.5 cm^2

The survival of lac insects from BLI to crop harvest is a crucial factor for maximizing lac yield (Janghel *et al.*, 2014). In addition to abiotic factors (Jethu, 2022), biotic factors (Vishal *et al.*, 2020) also play a significant role in the survival of lac insects. To manage biotic factors, such as parasitoids and predators of lac insects, contact insecticides are applied at specific intervals 30 days after BLI and then at 30-day intervals thereafter (Shah *et al.,* 2018; Khichi *et al.,* 2021). Insecticide application on lac crops is not very common among lac growers (Khichi *et al.,* 2021). Most lac crops are managed by small and marginal farmers (Kumar *et al.,* 2017). Among these farmers, it is a common practice to use leftover insecticides from previous purchases for subsequent applications (Glass *et al.,* 2009). This practice is referred to as the "treadmill effect" (Gross *et al.,* 2011). A decline in MNL from BLI to the harvest of lac crops has been documented by several researchers (Khichi *et al.,* 2021; Vishal *et al.,* 2020; Janghel *et al.,* 2014; Jethu, 2022), particularly on *C. cajan* (Kakade *et al.,* 2020). The use of emamectin benzoate for managing predators of lac insects has been reported by Janghel *et al.* (2014), while chlorantraniliprole is commonly used on food crops for insect pest protection (Chawan *et al.*, 2020). However, its application in lac crops is relatively rare. Emamectin benzoate application on lac crops resulted in MNL survival rates over 30 BLI ranging from 24.91% to 38.13% (Khichi *et al.*, 2021), 31.72% to 41.83% (Kakade *et al.*, 2020) and 20.47% to 23.52% (Shah *et al.*, 2018).

The survival percentage of lac insects from 30 BLI to 180 days BLI was highest with M_1 (50.17%), followed by M_2 (44.86%) and M_3 (38.32%) (Figure 1). This suggests that without predator management, there can be significant losses in live lac insects. M_2 exhibited a treadmill phenomenon, where repeated application of the same insecticides at short intervals can lead to diminishing effectiveness. The drawbacks of such treadmill practices have been discussed by Gross *et al.* (2011) and Williamson *et al.* (2015). M_1 involves the application of chlorantraniliprole followed by emamectin benzoate in a specific sequence. Several researchers have recommended using a variety of insecticides for effective pest management (Das *et al.*, 2015; Janghel *et al.*, 2014; Khichi *et al.*, 2021). The survival percentage of lac insects from 30 to 180 days after BLI was highest in Korsar-1 at 45.20% among all six landraces, followed closely by Burhanpur-1 at 45.12%. Various studies have reported differing survival percentages of lac insects on different *C. cajan* landraces, ranging from 52.13% to 81.53% (Vajpayee *et al.*, 2019) and 19.63% to 20.58% (Namdev *et al.*, 2015). The impact of treatment interactions on the survival or mortality of lac insects is widely recognized (Vishal *et al.*, 2020).

5. Conclusion

The study on the effect of insecticide application and *C. cajan* landraces on the survival percentage of lac insects indicates that using insecticides in an alternating sequence is beneficial for lac production. Among all landraces, the M_1 treatment (chlorantraniliprole followed by emamectin benzoate) resulted in a higher percentage of lac insect survival compared to the M_2 treatment (emamectin benzoate followed by emamectin benzoate), which is considered a treadmill approach, and the control (water spray). Specifically, the landrace S_2 (Korsar 2) exhibited the lowest survival rate at 43.45% under general conditions. However, with the M_1 treatment (M_1S_2), the survival rate improved to 49.43%.

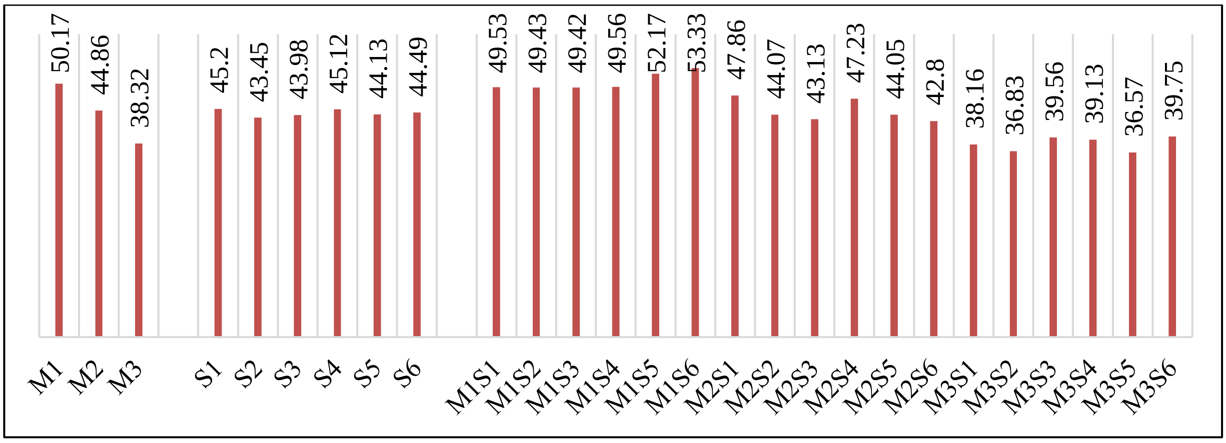


Figure 1. Overall survival percent in MNL on 2.5 cm^2

Plate 1. Mean number of live lac insects per 2.5 cm^2 (MNL)

30th day

60thday

90th day

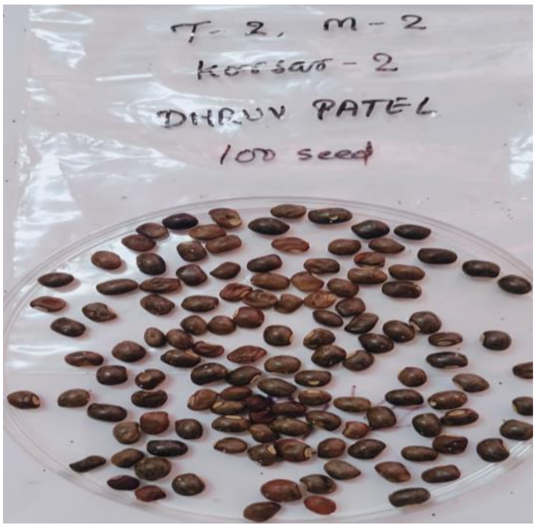
120th day

150th day

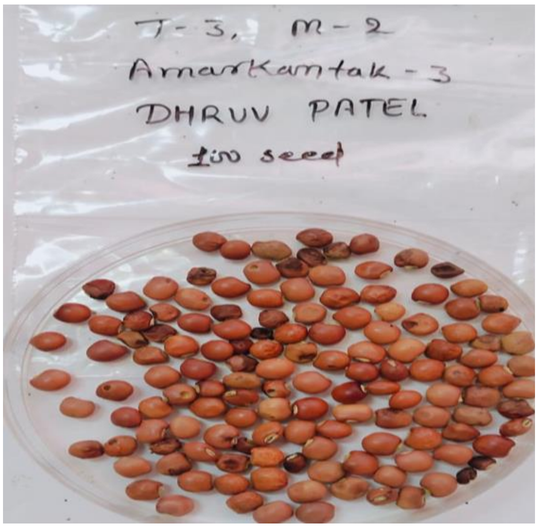
180th day

Plate 2. Seeds of different landraces

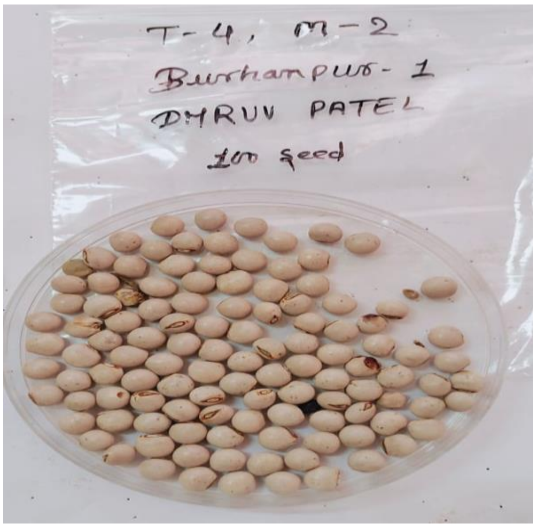
Korsar-1



Korsar-2



Amarkantak - 3



Burhanpur-1

Lakhnadon-1

TDN - 1

Table 2: MNL lac insect per 2.5 cm^2 during lac crop growth period (Days afterBLI)

Mean number of live lac insect count per 2.5 cm^2 on						
Treatments	**Days after BLI**					
	30th day 23-11-22	**60th day 23-12-22**	**90th day 22-01-23**	**120th day21-02-23**	**150th day23-03-23**	**180thday 22-04-23**
Main plot treatments (contact insecticides)						
M_1 (Chlorantraniliprole followed by	167.89 (12.95)	159.95 (12.64)	140.23 (11.84)	127.73 (11.30)	104.01 (10.19)	84.23 (9.18)

Emamectin benzoate)						
M_2 (Emamectin benzoate followed by Emamectin benzoate)	169.39 (13.01)	157.50 (12.55)	137.71 (11.74)	122.15 (11.05)	92.88 (9.63)	75.98 (8.71)
M_3 (Water spray)	172.40 (13.13)	162.14 (12.73)	132.33 (11.50)	108.16 (10.40)	88.16 (9.39)	66.05 (8.12)
SEm (±)	**0.06**	**0.05**	**0.04**	**0.03**	**0.07**	**0.11**
CD (5%)	**0.24**	**0.19**	**0.16**	**0.11**	**0.28**	**0.44**
Sub plot treatments (landraces of *C. cajan*)						
S_1 (Korsar 1)	175.86 (13.26)	167.20 (12.93)	143.80 (11.99)	129.47 (11.36)	101.13 (10.04)	79.48 (8.90)
S_2 (Korsar 2)	170.74 (13.06)	160.52 (12.67)	136.16 (11.67)	117.82 (10.85)	91.82 (9.58)	74.17 (8.60)
S_3 (Amarkantak 3)	166.58 (12.89)	155.18 (12.46)	133.40 (11.55)	113.62 (10.65)	89.06 (9.43)	73.25 (8.55)
S_4 (Burhanpur 1)	167.52 (12.94)	157.75 (12.56)	135.63 (11.65)	117.07 (10.82)	95.18 (9.75)	75.58 (8.68)
S_5 (Lakhnadon 1)	172.42 (13.13)	161.98 (12.72)	138.39 (11.76)	122.72 (11.07)	99.95 (9.99)	76.08 (8.70)
S_6 (TDN 1)	166.23 (12.89)	156.55 (12.51)	133.16 (11.53)	115.38 (10.73)	92.94 (9.63)	73.94 (8.58)
SEm (±)	**0.06**	**0.05**	**0.04**	**0.05**	**0.07**	**0.09**
CD (5%)	**0.19**	**0.15**	**0.12**	**0.13**	**0.19**	**0.27**

Figures in the parenthesis are √+0.5 transformed values

Interactions (insecticides × landraces)						
M_1S_1	177.72 (13.33)	175.72 (13.25)	153.87 (12.40)	141.54 (11.90)	113.54 (10.65)	88.01 (9.38)
M_1S_2	169.64 (13.02)	158.98 (12.61)	137.81 (11.74)	122.14 (11.05)	99.47 (9.97)	83.85 (9.16)
M_1S_3	163.74 (12.76)	155.13 (12.45)	136.87 (11.70)	122.54 (11.07)	98.54 (9.93)	80.93 (9.00)
M_1S_4	161.89 (12.72)	153.56 (12.39)	133.98 (11.57)	121.64 (11.03)	99.31 (9.97)	80.23 (8.96)
M_1S_5	169.14 (13.00)	160.08 (12.65)	140.98 (11.87)	133.32 (11.55)	110.65 (10.52)	88.24 (9.40)
M_1S_6	165.20 (12.85)	156.20 (12.50)	137.89 (11.74)	125.22 (11.19)	102.56 (10.13)	88.10 (9.17)
M_2S_1	174.77 (13.22)	162.43 (12.74)	142.75 (11.95)	135.42 (11.64)	100.75 (10.04)	83.63 (9.15)
M_2S_2	172.64 (13.14)	162.30 (12.74)	138.45 (11.76)	122.45 (11.07)	88.12 (9.38)	76.08 (8.72)
M_2S_3	165.52 (12.86)	151.52 (12.31)	135.08 (11.62)	115.74 (10.76)	85.41 (9.24)	71.38 (8.44)
M_2S_4	163.34 (12.78)	153.34 (12.38)	135.06 (11.62)	115.39 (10.74)	91.73 (9.58)	77.13 (8.78)
M_2S_5	170.02 (13.04)	157.38 (12.54)	137.38 (11.72)	122.71 (11.08)	97.38 (9.87)	74.88 (8.64)
M_2S_6	170.04 (13.04)	158.04 (12.57)	137.54 (11.73)	121.20 (11.01)	93.87 (9.68)	72.77 (8.53)
M_3S_1	175.10 (13.23)	163.44 (12.78)	134.77 (11.61)	111.44 (10.56)	89.11 (9.44)	66.81 (8.17)
M_3S_2	169.95 (13.03)	160.28 (12.66)	132.22 (11.50)	108.88 (10.44)	87.88 (9.37)	62.58 (7.91)
M_3S_3	170.48 (13.06)	158.88 (12.61)	128.24 (11.32)	102.57 (10.13)	83.24 (9.12)	67.44 (8.21)
	177.34	166.34	137.85	114.18	94.51	69.38

M_3S_4	(13.31)	(12.90)	(11.74)	(10.68)	(9.72)	(8.31)
M_3S_5	178.11 (13.34)	168.46 (12.98)	136.81 (11.70)	112.15 (10.59)	91.81 (9.58)	65.13 (8.07)
M_3S_6	163.44 (12.78)	155.40 (12.46)	124.06 (11.14)	99.73 (9.99)	82.39 (9.08)	64.96 (8.04)
SEm (±)	**0.15**	**0.15**	**0.16**	**0.29**	**0.27**	**0.32**
CD (5%)	**0.43**	**0.44**	**0.46**	**0.83**	**0.78**	**0.91**

Figures in the parenthesis are √+0.5 transformed values

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