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Management of Capsule Borer *Conogethes punctiferalis* (Guenee) on *Castor Ricinus communis* L. Using Some Plants Oil

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The insecticides were tested under field conditions on the basis of percentage of capsule bore *Conogethes punctiferalis* (Guenee) infestation noticed under field condition. The capsule borer *C. punctiferalis* (Guenee) damage goes on decreasing among the chemical and plant based insecticidal treatments at first and second week after spraying. Among the eight treatments, the lowest capsule borer damage/plant recorded by T5 Mahua oil 2% with 43.55% reduction over

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control followed by T6 neem oil 2% recorded 36.05% reduction over control recorded during 1st week after spray. The percentage of capsule borer *C. punctiferalis* (Guenee) damage per plant was highest recorded by T1 treatment it was mainly due to, this treatment did not receive any insecticidal spray either chemical or plant based insecticides throughout the experimental period. Same trend was noticed after 2nd week after spray. During 2nd week after spray highest percent of reduction over control recorded by T6 neem oil 2% recorded 80.27% reduction over control followed by T7 pongamia oil 2% recorded 79.09% reduction over control. Lowest percentage of castor capsule borer *C. punctiferalis* (Guenee) per plant recorded by T6 neem oil 2%, T7 pongamia oil 2% and T5 mahua oil 2% which were statistically at par with throughout the observation. The T6 neem oil 2% and T7 pongamia oil 2% recorded as best treatments over rest of the treatments. The grain yield in the treatment significantly highest grain yield @3730.00 kg and 3627.63 kg recorded by T6 Neem oil 2% and T7 Pongamia oil 2% followed by T5 Mahuva oil recorded yield @ 3283.30kg. However, the chemical treatments viz., T3 Profenophos 50 EC @0.03% and T4 quinolphos 25 EC @ 0.05% recorded yield @ 2956.66 and 2936.00 kg/ha both at par with each other. Whereas untreated control recorded the lowest yield @2426.03 kg/ha.

Keywords: Conogethes punctiferalis; Castor Ricinus communis; insecticides; plant physiology.

1. INTRODUCTION

Castor is one of the industrially important non-edible oil seed crops of the world. India ranks first among the major castor producing countries [Brazil and China] in the world occupying 68% of area and 85% of castor seed production [1]. In India, castor area was reported in the year 2021-22 was 1.484 lakh ha (3.67 lakh acres) as against 1.732 lakh ha (4.28 lakh acres) during the same period in 2020-21. Among different states, Gujarat is leading state with 1.022 lakh ha (2.52 lakh acres) in castor followed by Rajasthan 0.254 lakh ha (0.63 lakh acres), Andhra Pradesh 0.075 lakh ha (0.19 lakh acres) and Telangana 0.036 lakh ha (0.09 lakh acres). According to 3rd advance estimates, all India castor production in 2020-21 is at 17.74 lakh tones (DES, 2021 & Castor outlook, 2021) [2]. During the year 2018-19, the global major castor producing countries are India (18.42 lakh tons), Mozambique (0.85 lakh tons), China (0.27 lakh tons), Brazil (0.14 lakh tons) and Myanmar (0.12 lakh tons) [3].

In India, more than 107 species of insects and six species of mites recorded on castor at different phenological stages of the crop. Among them, castor semilooper, *Achaea janata* L., castor shoot and capsule borer, *Conogethes punctiferalis* Guen.*, Dichocrocis punctiferalis* [Guenee], tobacco caterpillar, *Spodoptera litura* [Fabricius], leafhopper, *Empoasca flavescens* [Fabricius] and white fly, *Trialeurodes ricini* [Misra] are of greater economic importance. In addition, serpentine leaf miner, *Liriomyza trifoli* [Burgess], several hairy caterpillars, *Spilarctia oblique* [Walker], *Euproctis* spp., *Pericallia ricini*, Fabricius, *Amsacta albistriga* Walker, *A. moorei* Butl. and castor slug caterpillar, *Parasa lepida* C. are also becoming serious pests on the crop [4]. As many as 20 species of insect pests were associated with castor, but many of them were highly irregular in nature of incidence and their occurrence over the years, distributed in patches with less infestation causing no remarkable damage to the crop. Only 10 species belonging to Lepidoptera, Hemiptera, Othoptera and Thysanoptera showed variable economic importance and of these, five species were regular with high degree of severity as major pests. Most of the insect pests were either defoliators or sucking pests. The magnitude of insect pest damage and problem arises from them is quite high in southern part of India where castor is grown mainly as rainfed crop, resulting in lower seed yield. The pest problem in castor include defoliators namely semilooper, *A. janata*, tobacco caterpillar, *S. litura*, capsule borer, *C. punctiferalis* [5]. Insect pests such as defoliators*viz*., red hairy caterpillar, *A. moorei*, semilooper, *A. janata*, tobacco caterpillar, *S. litura* and shoot and capsule borer *C. punctiferalis* were reportd as major pests of castor and apart from that serpentine leaf miner *L. trifoli* has become a serious pest [6]. Highly resistant and polyphagous pest, *Helicoverpa armigera* Hubner also causes considerable damage to castor crop by feeding foliage at vegetative stage and boring into the castor capsules at later stage [7]. Remarkable yield losses occur in cultivated castor due to severe pest outbreak including leafhoppers, whiteflies, semiloopers, cutworms, hairy/slug caterpillars, capsule borers, etc. [8].

In recent years, use of synthetic insecticides in crop protection program resulted in adverse effect on the environment, noticing pesticide

residues in the crop produce, pest resurgence and pest resistance in the existing pest population, etc. This lead to increased importance of naturally occurring plants associated with rich traditional knowledge base available with the highly diverse indigenous communities in India, as it is an environmental friendly agricultural technology for ensuring food safety and food security [9].

The chemical control of insect pests is often expensive and prohibitive to majority of the farmers. Use of resistant varieties is the most economical approaches and would become inexpensive in the long run. However, in India, some of the bio-pesticides like Bt, NPV and and plant based neem, pongamia and mahua bio-pesticides; *Trichderma*, etc. have already been registered and are also being practiced. There are many locally available plants like beshram, neem, garlic, *etc.* which can be easily processed and used for the management of many of the hard-core insect pests of crops [10]. Hence, management of capsule borer *Conogethes punctiferalis* (Guenee) through integrated/eco-friendly approach is of prime importance to keep the pest population below the level of economic injury.

In the castor ecosystem, insect pests are also having good number of natural enemies and attack at different growth stages, among them; the egg parasitoid, *Trichogramma chilonis* Ishii; larval parasitoid, *Microplitis maculipennis* Szepligate, insect predators, insectivorous birds and some of the microbial agents exert greater biological resistance in the succession of the pest complex of castor [7].

2. MATERIALS AND METHODS

The DCH-177 variety of castor seeds were sown at 90 x 60 cm spacing in plots of 5.0 x 5.0 m adopting Randomized Complete Block Design [RCBD] with three replications at Zonal Agricultural Research Station, University of Agricultural Sciences [UAS], Gandhi Krishi Vigyan Kendra [GKVK], Bengaluru during 2018-19 and 2019-20. Before sowing, the seeds were soaked in cold water to smoothen the seed coat that makes easy for the germination. Two seeds were dibbled at each spot. Sprouting of seeds was observed after one week. The newly germinated seedlings were allowed to grow for few days, later thinning was done. Among the two seedlings in each spot, healthy seedling was allowed to grow and weak and slow growing seedlings were removed. This technique was followed for maintaining optimum population in the field. The crop was raised by following recommended package of practices [except for plant protection measures] developed for rainfed condition with protective irrigation as and when required for better crop stand and to maintain required population in the field [1]. Treatments imposed immediately after capsule borer *Conogethes punctiferalis* (Guenee) damage noticed above the threshold level. Second spray was under taken at 25th days after first spray.

The observations of capsule borer *Conogethes punctiferalis* (Guenee) damage recorded from 6 randomly selected plants from each treatment at one day before imposition of treatment and 1st and 2nd week after imposition of treatments. Simultaneously natural enemies like coccinellids, green lacewings, damselfly and other natural enemies' populations were also recorded along with capsule borer *Conogethes punctiferalis* (Guenee) damage. Data collected from the experimental plot before and after the treatments imposition subjected to statistical analysis.

3. RESULTS AND DISCUSSION

The insecticides were tested under field conditions on the basis of percentage of capsule bore *Conogethes punctiferalis* (Guenee) infestation noticed under field condition. It is clear from the result that the percentage of capsule borer C. *punctiferalis* (Guenee) did not vary significantly among the treatments before application of insecticides. The capsule borer *C. punctiferalis* (Guenee) damage goes on decreasing among the chemical and plant based insecticidal treatments at first and second week after spraying. Capsule borer *C. punctiferalis* (Guenee) damage percentage/plant maintained under normal limit. Among the eight treatments, the lowest capsule borer damage/plant recorded by T5 Mahua oil 2% with 43.55% reduction over control followed by T6 neem oil 2% recorded 36.05% reduction over control recorded during 1st week after spray. The percentage of capsule borer *C. punctiferalis* (Guenee) damage per plant was highest recorded by T1 treatment it was mainly due to, this treatment did not receive any insecticidal spray either chemical or plant based insecticides throughout the experimental period. Same trend was noticed after 2nd week after spray. During 2nd week after spray highest percent of reduction over control recorded by T6 neem oil 2% recorded 80.27% reduction over control followed by T7 pongamia oil 2% recorded

79.09% reduction over control. In both the spraying the percentage of capsule borer *C. punctiferalis* (Guenee) of castor was considerably reduced after first week after spraying and continued even after second week after spray. Lowest percentage of castor capsule borer *C. punctiferalis* (Guenee) per plant recorded by T6 neem oil 2%, T7 pongamia oil 2% and T5 mahua oil 2% which were statistically at par with throughout the observation. The T6 neem oil 2% and T7 pongamia oil 2% recorded as best treatments over rest of the treatments. The grain yield in the treatment significantly highest grain yield @3730.00 kg and 3627.63 kg recorded by T6 Neem oil 2% and T7 Pongamia oil 2% followed by T5 Mahuva oil recorded yield @ 3283.30kg. However, the chemical treatments viz., T3 Profenophos 50 EC @0.03% and T4 quinolphos 25 EC @ 0.05% recorded yield @ 2956.66 and 2936.00 kg/ha both at par with each other. Whereas untreated control recorded the lowest yield @2426.03 kg/ha.

3.1 Efficacy IPM Modules on Natural Enemies' Populations at Different days after Imposition of Treatments

3.1.1 Coccinellids

First week after imposition of treatments: The population of coccinellids did not vary significantly [F-value=0.763^{NS}] when they were recorded at first week after imposition of integrated management practices on castor. However, their number ranged between 0.700/plant [T2: Fenvalerate 20 EC @ 0.02%] and 0.967/plant [T6: Neem oil @ 2%].

Second week after imposition of treatments: The population of coccinellids found non-significant [F-value=0.570^{NS}] at second week after imposition of integrated pest management practices on castor. However, their number varied from 4.250/plant [T4: Quinalphos 25 EC @ 0.05%] to 5.817/plant [T7: Pongamia oil @ 2%].

Third week after imposition of treatments: The population of coccinellids did not vary significantly [F-value=0.561^{NS}] among the treatments at third week after imposition of integrated management practices on castor. However, number of coccinellids ranged between 4.607/plant [T4: Quinalphos 25 EC @ 0.05%] and 6.102/plant [T7: Pongamia oil @ 2%].

Fourth week after imposition of treatments: Highly significant difference [*p≤0.01*; F-value=45.30**] with respect to coccinellid population was observed among the treatments at fourth week after their imposition. Among the treatments, T0 [Control] recorded highest number of coccinellids [7.567/plant] followed by T6 [Neem oil @2 %] recorded coccinellid population of 7.417/plant. Whereas T1 [Cucumber+*T.chilonis* @2 lakh eggs/ha @30 days] and T5 [Mahua oil @ 2%] recorded coccinellid population of 6.533 and 6.433/plant, respectively. Three treatments, namely T3 [Profenophos 50 EC @ 0.03%], T4 [Quinalphos 25 EC @ 0.05%] and T2 [Fenvalerate 20 EC @ 0.02%] recorded coccinellid population of @ 3.617, 3.533 and 3.283/plant, respectively with later being the lowest among the treatments.

3.1.2 Green lacewings

First week after imposition of treatments: Population of green lacewings also found non-significant [F-value=0.917^{NS}] among the eight treatments at first week after imposition of selective integrated management practices. Further, the number of green lacewings vary from 0.450/plant [T6: Neem oil @ 2%] to 0.667/plant [T3: Profenophos 50 EC @ 0.03% and T5: Mahuva oil @ 2%].

Second week after imposition of treatments: Population of green lace wings did not vary significantly [F-value=1.842^{NS}] when they were recorded at second week after imposition of integrated management practices on castor. However, number of green lacewings vary from 2.783/plant [T2: Fenvalerate 20 EC @ 0.02%] to 4.533/plant [T7: Pongamia oil @ 2%].

Third week after imposition of treatments: Population of green lacewings too found non-significant [F-value=1.795^{NS}] among the eight treatments at third week after imposition of selective integrated management practices. Further, the number of green lacewings vary from 3.069/plant [T2: Fenvalerate 20 EC @ 0.02%] to 4.902/plant [T7: Pongamia oil @ 2%].

Fourth week after imposition of treatments: Population of green lacewings also found non-significant [F-value=2.571^{NS}] among the eight treatments at third week after imposition of selective integrated management practices on castor. Further, number of green lacewings vary from 2.717/plant [T2: Fenvalerate 20 EC @ 0.02%] to 5.733/plant [T6: Neem oil @ 2%].

Table 1. Effect of integrated pest management modules against capsule borer in castor during Kharif 2017-18

Integrated management practices	First spray				Second spray				Yield kg/ha
	% Capsule damage Before	1st week after	2nd week after	%ROC	% Capsule damage Before	1st week after	2nd week after	%ROC	
T0:Control	25.65 (30.41)	30.60 (33.56)	32.24 (34.57)	----	34.45 (35.92)	36.20 (36.95)	38.25 (38.18)	-----	2426.03
T1: Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS	25.35 (30.21)	28.11 (31.98)	31.45 (34.00)	2.46	32.24 (34.58)	33.10 35.09	36.15 (36.93)	5.50	2730.03
T2: Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Fenvalerate 20 EC @ 0.02%	25.00 (29.97)	24.56 (29.70)	21.15 (27.36)	34.40	19.64 (26.29)	16.24 (23.73)	10.45 (18.84)	72.68	2793.36
T3: Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Profenophos 50 EC 0.03%	24.89 (29.91)	22.89 (28.57)	22.82 (28.52)	29.22	21.48 (27.59)	17.45 (24.67)	9.54 (17.94)	75.06	2956.66
T4: Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Quinalphos 25 EC @ 0.05%	24.95 (29.95)	22.84 (28.53)	22.15 (28.04)	3130	20.84 (27.14)	17.15 (24.45)	8.66 (17.08)	77.36	2936.00
T5: Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Mahua oil@ 2%	25.70 (30.43)	22.00 (27.96)	18.20 (25.23)	43.55	16.74 (24.13)	13.74 (21.72)	8.05 (16.45)	78.96	3283.30
T6: Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Neem oil@ 2%	25.25 (30.14)	21.78 (27.80)	20.62 (26.99)	36.05	17.84 (24.97)	14.05 (22.00)	7.55 (15.93)	80.27	3730.00
T7: Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Pongamia oil @ 2%	25.55 (30.34)	21.68 (27.73)	20.78 (27.10)	35.55	17.55 (24.75)	13.94 (21.91)	8.00 (16.33)	79.09	3627.63
Sem ±	0.83	0.84	1.56		0.54	1.22	0.82		91.66
CD	NS	2.57	4.78	----	1.67	3.75	1.16	---	275.00
CV	5.68	6.00	11.43		4.18	10.50	9.03		13.10

Values in parenthesis are angular transformed values

3.1.3 Damselfly

First week after imposition of treatments: Selective integrated management practices adopted against capsule borer damage on on castor did not influence [F-value=1.285^{NS}] much on the population of damselfly when they were recorded at first week after imposition. Number of damselfly ranged between 0.317/plant [T4: Quinalphos 25 EC @ 0.05%] and 0.733/plant [T1: Cucumber + *T. chelonis* @ 2 lakh eggs/ha at 30 DAS].

Second week after imposition of treatments: Integrated management practices followed against castor capsule borer of castor did not vary significantly [F-value=0.547^{NS}] on the population of damselfly at second week after their imposition. The number of damselfly ranged between 2.900/plant [T7:Pongamia oil @ 2%] to 4.183/plant [T5:Mahuva oil @ 2%].

Third week after imposition of treatments: Selective integrated management practices adopted against castor capsule borer of castor did not differ significantly [F-value=0.538^{NS}] with respect to population of damselfly when recorded during third week after imposition. The number of damselfly ranged between 3.269/plant [T7: Pongamia oil @ 2%] and 4.552/plant [T5: Mahuva oil @ 2%].

Fourth week after imposition of treatments: Integrated management practices adopted against castor capsule borer of castor did not vary significantly [F-value=2.151^{NS}] at fourth week after their imposition. The number damselfly ranged from 1.617/plant [T2: Fenvalerate 20 EC @0.02%]to4.117/plant [T6:Neem oil @ 2%].

3.1.4 Other natural enemies

First week after imposition of treatments: The population of other natural enemies vary statistically [*p≤0.01*; F-value=7.264**] when they were recorded at first week after imposition of selective integrated management practices. Significantly highest population of other natural enemies was recorded in T1 [Cucumber + *T. chelonis* @ 2 lakh eggs/ha at 30 DAS] [4.270/plant] and it was on par with T0 [Control] [4.170/plant]. The population of other natural enemies recorded two plant based pesticide treatments namely T7 [Pongamia oil @ 2%] and T6 [Neem oil @2%] were found on par with each other by recording population of 3.787 and 3.287/plant, respectively. Further, the treatments T5 [Mahuva oil @ 2%], T2 [Fenvalerate 20EC @ 0.02%] and T3 [Profenophos 50 EC @ 0.03%] recorded other natural enemies population of 2.603, 2.570 and 2.020/plant, respectively. Notably, lowest population of other natural enemies was recorded in T4 [Quinalphos 25 EC @ 0.05%] [1.037/plant].

Second week after imposition of treatments: Highly significant difference [*p≤0.01*; F-value=7.284**]in population of other natural enemies was observed among the integrated management practices at second week after their imposition. Significantly highest population of other natural enemies was recorded in T1 [Cucumber + *T. chelonis* @ 2 lakh eggs/ha at 30 DAS] [4.700/plant] followed by T0 [Control] [4.600/plant] and were on par with T7 [Pongamia oil @ 2%] where it registered other natural enemies population of 4.217/plant. However, three treatments *viz.*, T6 [Neem oil @2%], T2 [Fenvalerate 20 EC @ 0.02%] and T5 [Mahuva oil @ 2%] showed parity among them in respect of other natural enemies population [3.717, 3.033 and 3.000/plant, respectively]. Rest of the two treatments namely T3 [Profenophos 50 EC @ 0.03%] and T4 [Quinalphos 25 EC @ 0.05%] recorded significantly lowest population of other natural enemies [2.450 and 1.467/plant, respectively].

Third week after imposition of treatments: Highly significant difference [*p≤0.01*; F-value=7.207**] in other natural enemies population was observed among the eight treatments at third week after their imposition. Among all the treatments, T1 [Cucumber + *T. chelonis* @ 2 lakh eggs/ha at 30 DAS] recorded significantly highest population [4.576/plant] followed by T6 [Neem oil @ 2%] [4.476/plant] and was on par with T7 [Pongamia oil @ 2%] [4.093/plant]. Whereas, three treatments namely T0 [Control], T2 [Fenvalerate 20 EC @ 0.02%] and T5 [Mahuva oil @ 2%] are in close association with each other by recording population of 3.593, 2.910 and 2.876/plant, respectively. Futher, T3 [Profenophos 50 EC @ 0.02%] [2.326/plant] and T4 [Quinalphos 25 EC @ 0.05%] [1.343/plant] were least with respect to population of other natural enemies.

Table 2. Population of natural enemies - coccinellid at different weeks after imposition of selective integrated management practices on castor

Integrated management practice	First week	Second week	Third week	Fourth week
T_0 =Control	0.900 ± 0.115	4.550 ± 1.290	4.907 ± 1.130	7.567 ± 0.289
T_1 = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS	0.900 ± 0.05 [0.000]	4.917 ± 0.289 [8.066]	5.274 ± 0.129 [7.472]	6.533 ± 0.262 [-13.67]
T_2 = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Fenvalerate 20 EC @ 0.02%	0.700 ± 0.764 [-22.22]	4.617 ± 0.717 [1.363]	4.974 ± 0.557 [1.359]	3.283 ± 0.148 [-65.58]
T_3 = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Profenophos 50 EC 0.03%	0.817 ± 0.136 [-9.222]	5.167 ± 0.629 [12.55]	5.524 ± 0.469 [12.57]	3.617 ± 0.167 [-60.46]
T_4 = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Quinalphos 25 EC @ 0.05%	0.767 ± 0.044 [-14.78]	4.250 ± 0.351 [-6.101]	4.607 ± 0.191 [-6.114]	3.533 ± 0.262 [-61.75]
T_5 = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Mahua oil @ 2%	0.850 ± 0.104 [-5.556]	5.067 ± 0.955 [10.51]	5.424 ± 0.795 [10.53]	6.433 ± 0.277 [-17.36]
T_6 = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Neem oil @ 2%	0.967 ± 0.088 [7.444]	5.617 ± 0.338 [21.70]	5.974 ± 0.178 [21.74]	7.417 ± 0.438 [-2.296]
T_7 = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Pongamia oil @ 2%	0.883 ± 0.117 [-1.889]	5.817 ± 0.448 [25.77]	6.102 ± 0.289 [24.36]	5.750 ± 0.150 [-27.81]
Mean	0.848 ± 0.033	5.000 ± 0.233	5.348 ± 0.073	5.517 ± 0.357
F - value	0.763^{NS}	0.570^{NS}	0.561^{NS}	45.30^{**}

*DAS : Days after sowing, **: p≤ 0.01, NS: Non-significant, [ ] : Per cent change over control*

Table 3. Population of natural enemies - green lacewing at different weeks after imposition of selective integrated management practices on castor

Integrated management practice	First week	Second week	Third week	Fourth week
T_0 =Control	0.633 ± 0.060	4.367 ± 0.819	4.652 ± 0.659	4.683 ± 0.601
T_1 = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS	0.583 ± 0.060 [-7.899]	3.817 ± 0.606 [-12.59]	4.102 ± 0.447 [-11.82]	5.383 ± 1.053 [14.95]
T_2 = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Fenvalerate 20 EC @ 0.02%	0.517 ± 0.017 [-19.90]	2.783 ± 0.289 [-41.50]	3.069 ± 0.129 [-34.03]	2.717 ± 0.159 [-36.52]
T_3 = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Profenophos 50 EC 0.03%	0.667 ± 0.093 [5.832]	3.167 ± 0.344 [-31.44]	3.452 ± 0.185 [-25.79]	2.800 ± 0.881 [-34.98]
T_4 = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Quinalphos 25 EC @ 0.05%	0.617 ± 0.073 [-2.744]	4.367 ± 0.347 [0.000]	4.652 ± 0.187 [0.000]	3.667 ± 0.848 [-18.87]
T_5 = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Mahua oil @ 2%	0.667 ± 0.088 [5.832]	3.067 ± 0.760 [-34.06]	3.352 ± 0.600 [-27.94]	4.817 ± 0.291 [2.489]
T_6 = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Neem oil @ 2%	0.450 ± 0.126 [-31.39]	2.883 ± 0.438 [-38.88]	3.252 ± 0.278 [-30.09]	5.733 ± 0.738 [19.51]
T_7 = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Pongamia oil @ 2%	0.550 ± 0.076 [-14.24]	4.533 ± 0.438 [4.349]	4.902 ± 0.278 [5.373]	5.017 ± 0.716 [6.205]
Mean	0.585 ± 0.028	3.623 ± 0.213	3.929 ± 0.054	4.352 ± 0.309
F - value	0.917^{NS}	1.842^{NS}	1.795^{NS}	2.571^{NS}

DAS : Days after sowing, NS : Non-significant, [ ] : Per cent change over control

Table 4. Population of natural enemies - damselfly at different weeks after imposition of selective integrated management practices on castor

Integrated management practice	First week	Second week	Third week	Fourth week
T_0 =Control	0.567 ± 0.033	3.817 ± 0.819	4.186 ± 0.659	3.450 ± 0.350
T_1 = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS	0.733 ± 0.067 [29.28]	3.450 ± 0.351 [-9.615]	3.819 ± 0.191 [-8.760]	3.617 ± 0.467 [4.841]
T_2 = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Fenvalerate 20 EC @ 0.02%	0.683 ± 0.220 [15.83]	3.150 ± 0.653 [-19.33]	3.519 ± 0.493 [-15.93]	1.617 ± 0.192 [-50.68]
T_3 = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Profenophos 50 EC 0.03%	0.683 ± 0.159 [15.83]	3.117 ± 0.661 [-20.29]	3.486 ± 0.501 [-16.72]	3.067 ± 0.725 [-10.59]
T_4 = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Quinalphos 25 EC @ 0.05%	0.317 ± 0.130 [-34.11]	3.400 ± 0.407 [-12.09]	3.769 ± 0.247 [-9.955]	2.950 ± 0.907 [-13.82]
T_5 = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Mahua oil @ 2%	0.500 ± 0.100 [-9.141]	4.183 ± 0.169 [10.61]	4.552 ± 0.009 [8.760]	4.100 ± 0.300 [17.97]
T_6 = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Neem oil @ 2%	0.533 ± 0.088 [-4.638]	3.250 ± 0.275 [-16.44]	3.619 ± 0.116 [-13.54]	4.117 ± 0.585 [18.44]
T_7 = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Pongamia oil @ 2%	0.433 ± 0.101 [-18.28]	2.900 ± 0.769 [-26.58]	3.269 ± 0.609 [-21.90]	3.900 ± 0.617 [12.44]
Mean	0.556 ± 0.046	3.408 ± 0.184	3.777 ± 0.024	3.352 ± 0.231
F - value	1.285^{NS}	0.547^{NS}	0.538^{NS}	2.151^{NS}

DAS: Days after sowing, NS : Non-significant, [ ] : Per cent change over control

Table 5. Population of other natural enemies at different weeks after imposition of selective integrated management practices on castor

Integrated management practice	First week	Second week	Third week	Fourth week
T_0 =Control	4.170 ± 0.202	4.600 ± 0.202	3.593 ± 0.187	4.383 ± 0.753
T_1 = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS	4.270 ± 0.150 [2.398]	4.700 ± 0.150 [2.174]	4.576 ± 0.075 [27.37]	3.583 ± 0.421 [-18.252]
T_2 = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Fenvalerate 20 EC @ 0.02%	2.570 ± 0.482 [-37.47]	3.033 ± 0.413 [-33.34]	2.910 ± 0.337 [-19.02]	1.400 ± 0.225 [-83.25]
T_3 = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Profenophos 50 EC 0.03%	2.020 ± 0.638 [-50.35]	2.450 ± 0.638 [-45.75]	2.326 ± 0.563 [-35.25]	1.217 ± 0.606 [-88.36]
T_4 = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Quinalphos 25 EC @ 0.05%	1.037 ± 0.192 [-73.37]	1.467 ± 0.192 [-66.66]	1.343 ± 0.117 [-62.62]	1.233 ± 0.318 [-87.92]
T_5 = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Mahua oil @ 2%	2.603 ± 0.413 [-36.70]	3.000 ± 0.482 [-34.04]	2.876 ± 0.407 [-19.95]	2.967 ± 0.388 [-39.52]
T_6 = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Neem oil @ 2%	3.287 ± 0.262 [-20.68]	3.717 ± 0.262 [-18.79]	4.476 ± 0.127 [24.58]	4.433 ± 0.318 [1.395]
T_7 = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Pongamia oil @ 2%	3.787 ± 0.641 [-8.970]	4.217 ± 0.641 [-8.149]	4.093 ± 0.565 [13.92]	4.000 ± 0.161 [-10.69]
Mean	2.968 ± 0.251	3.398 ± 0.251	3.274 ± 0.176	2.902 ± 0.306
F - value	7.264**	7.284**	7.207**	10.45**

*DAS: Days after sowing, **: p≤ 0.01, [ ] : Per cent change over control*

Fourth week after imposition of treatments: Highly significant difference [*p≤0.01*; F-value=10.45**] with respect to other natural enemies population was observed among the treatments at fourth week after their imposition. Significantly highest population of other natural enemies was recorded in T6 [Neem oil @2%] [4.433/plant] followed by T0 [Control] [4.383/plant] and was closely followed by T7 [Pongamia oil @2%] [4.000/plant]. Whereas T1 [Cucumber + *T. chelonis* @ 2 lakh eggs/ha at 30 DAS] and T5 [Mahua oil@2%] were at par with each other by recording a population of 3.583 and 2.967/plant, respectively. Significantly least number of other natural enemies was recorded by rest of the three treatments namely T2 [Fenvalerate 20 EC @ 0.02%], T4 [Quinalphos 25 EC @ 0.05%] and T3 [Profenophos 50 EC @ 0.03%] where they recorded other natural enemies population of 1.400, 1.233 and 1.217/plant, respectively.

4. CONCLUSION

The chemical control of insect pests is often expensive and prohibitive to majority of the farmers. Use of resistant varieties is the most economical approaches and would become inexpensive in the long run. Most of the insect pests were either defoliators or sucking pests. The magnitude of insect pest damage and problem arises from them is quite high in southern part of India where castor is grown mainly as rainfed crop, resulting in lower seed yield.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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