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# Evaluation of Integrated Pest Management Modules for the Management of Leafhopper *Empoasca flavescent* (Fab.) on Castor *Ricinus communis*

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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

Castor is an important oilseed crop. The castor bean contains about 50-55% oil. Among vegetable oils, castor oil is distinguished by its high content (over 85%) of ricinoleic acid. No other vegetable oil contains so high proportion of fatty hydroxyl acids. Castor oil's unsaturated bond, high molecular weight (298), low melting point (5°C) and very low solidification point (-12°C to -18°C) makes it

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industrially useful, most of all for the highest and most stable viscosity of any vegetable oil. The castor plant has a substantial taproot with many lateral branches which can reach a great depth enabling them to withstand drought and most harsh weather conditions. Leaves of castor plants are large, glossy and green with pointed lobes and prominent veins; however, the castor leaf for many years has often been attacked by the leafhopper and in most cases leads to the destruction of the plant. The leafhopper causes hopper-burn which renders the attacked leaves dry, uneven, curl downward in the shape of an inverted boat, margins turn brown and eventually death of the plant. Among the eight treatments, the lowest leafhopper/plant recorded by the T4 quinolphos and T6 Neem oil 2% recorded as best treatments over rest of the treatments. Significantly highest grain yield at 3730.00 Kg./ha and 3627.63 Kg./ha recorded by T6 Neem oil 2% and T7 Pongamia oil 2% followed by T5 Mahuva oil recorded yield at 3283.30 Kg./ha However the chemical treatments viz., T3 Profenophos 50 EC at 0.03% and T4 quinolphos 25 EC at 0.05% recorded yield at 2956.66 and 2936.00 Kg./ha both at par with each other. While, untreated control recorded the lowest yield at 2426.03 Kg./ha.

*Keywords: Castor (Ricinus communis); hopper-burn; leafhopper (Empoasca flavescens); wax bloom.*

## 1. INTRODUCTION

In Integrated Pest Management (IPM) farmers follow suitable techniques and different methods in order to maintain pest population below economically unacceptable level, so that damage by pests [1]. In present era of modern farming, IPM has globally perceived as one of the best controlling strategy to mitigate pest and natural enemy loss, it also helps farming community to yield better profits for the investments. However, during the transaction period of farm converting conventional farms to IPM farms farmers may face initial years decline in yield [2]. On the other hand, the crop yield loss caused by disease, nematode, weeds and Insect Pest accounts for 0.9 to 1.4 lakhs crore rupees in India [3]. Hence, looking to the present condition of resources and changing dynamics of environment it is essential to adopted management practices which are naturally good in resource and pest management and yields better results without affecting environment.

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 [4]. In India, castor production of 10.82 lakh MT during 2019-20 and is grown in an area of 9.92 lakh ha and mainly cultivated in Gujarat, Rajasthan, Andhra Pradesh and Karnataka. Gujarat occupies about 65% of the total share in area and contributes 75% share in production, while Karnataka occupies 9,527 ha in area with a production of 4,722 MT [5].

Although there are about 20 species of insect pests were associated with castor in reality extremely irregular in nature of incidence and their occurrence over the years, distributed in patches with less infestation causing no remarkable damage to the crop. Around 10 species belonging to Othoptera, Lepidoptera, Hemiptera, and Thysanoptera showed variable economic significance and five species were observed as high degree of severity and regular in nature as major pests affecting crop production by either defoliators or sucking pests. In southern part of India, the order of magnitude of insect pest and its damage and problem arises to quite high, where it is grown mainly as rainfed crop, resulting in lower seed yield. The pest problem in castor include defoliators namely *A. janata*, tobacco caterpillar, semilooper, *S. litura*, capsule borer, *C. punctiferalis* [6]. The sucking pests namely *flavescens* Fab., leafhopper, *E.* , thrips, *Retithrips syniacus* Mayet and white fly, *T. ricini*also cause considerable damage to crop [7].

Apart from defoliators such as borers sap feeders have great regional importance and quite sporadic in nature, these pests *viz*., castor gallfly,spiny caterpillar, *Ergollis merione* C. *Aspondylia ricini* M. red spider mite, *Tetranychus telarius* L. In Gujarat, castor inflorescence thrips [*Scirtothrips dorsalis* Hood] also attained a pest status by infesting the crop causing considerable loss to the crop in the flowering stage. 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 [8].

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 [9].

Due to severe pest outbreak such as leafhoppers, semiloopers, cutworms, whiteflies, hairy/slug caterpillars, capsule borers, etc. remarkable yield losses occur in cultivated castor [10]. Basic inputs like fertilizers and pesticides greatly helps in enhancing the production and productivity of crops. Indiscriminate use of chemical pesticides and fertilizers have drastic impact on environment by affecting soil fertility, development of insect resistance, genetic variation in plants, increasing toxic residue through food chain water hardness, and animal feed thus increasing health problems and many more. This necessitates to introduce measures that can harness challenges arise due to chemical pesticides. Thus, use of bio-pesticides and bio-fertilizers can play a major role in dealing with these challenges in a sustainable way [11].

In recent years, the application of synthetic insecticides in crop protection program resulted in adverse effect on the environment, pest resurgence and pest resistance in the existing pest population and noticing pesticide residues in the crop main products and its bi-products. On the other end, especially in agriculture residue of crops in the open field has become a evident concern both at regional and national level, which leads to change in climate and many government and line departments are taking initiative efforts to mitigation efforts worldwide. Crop residue practice leads to deteriorating air quality, haze, smog, heat waves, and other health problems. This actions can be controlled by adopting sustainable crop residue management practices and enabling farmers to engage in management activities [12]. At micro level, analyzing effects on health at the household level is important problem and finding a solution. 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 [13]. India is in a possession of vast potential use of bio-pesticides. Some bio-pesticides currently developed may be excellent alternative to chemical pesticides. Bio-pesticides being target pest specific presumed to be relatively safe to non-target organism including humans, live-stocks and water bodies. However, in India, some of the bio-pesticides like Bt, NPV and plant based Neem, mahua bio-pesticides such as *Trichderma*, pongamia canola oil. and have already been registered and are also being practiced. There are many locally available plants like beshram, neem, garlic and other locally avaiable plant products. which can be easy processed and used for the management of many of the hard-core insect pests of crops [14]. Keeping the above information and literature pertaining to the current investigation in view, it is evident that, castor is being majorly affected by the lepidopteran defoliators and sucking pests. Hence, management of defoliators as well as sucking pests through integrated/eco-friendly approach is of prime importance to keep the pest population below the level of economic injury. In this context, current investigation has been undertaken by adopting integrated approaches for the management of sucking pest leafhopper *Empoasca flaviscens* on castor.

## 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 smoother 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 rain-fed condition with protective irrigation as and when required for better crop stand and to maintain required population in the field [15]. Treatments imposed immediately after the leafhopper population reached above the threshold level. Second spray was under taken at 25$^{th}$ day after first spray. Table 1 representing the types, names and formulations of the tested pesticide used in this study.

**Table 1. Test pesticides used in the study**

| No. | Common name | Trade name | Formulation | Dosage [ml/litre] | Source of supply |
|---|---|---|---|---|---|
| 1 | Fenvalerate | Rocket | 20 EC | 1.00 | TATA (Rallys) Mumbai |
| 2 | Profenophos | Prahar | 50 EC | 0.75 | Biostadt (India) Ltd., Mumbai |
| 3 | Quinalphos | Ekalux | 25 EC | 1.50 | Bayer (India) Ltd., Mumbai |
| 4 | Mahuva oil | - | - | - | M/S Venkateshwara Oil Manufacturers, Hoskote Taluk, Bengaluru Rural District |
| 5 | Neem oil | - | - | - | |
| 6 | Pongamia oil | - | - | - | |

The observations of leafhopper *Empoasca flaviscens* recorded from 6 randomly selected plants from each treatment at one day before imposition of treatment and 3,7,11 and 15 days after imposition of treatments. Simultaneously natural enemies like green lace wings, damselfly and other natural enemies' populations were also recorded along with leafhopper population. 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 number of leafhopper per plant. It is clear from the result that the leafhopper population did not vary significantly among the treatments before application of insecticides at 3 days after spraying the population of leafhopper/plant goes on decreasing among the chemical and plant based insecticidal treatments up to 15 days after spraying leafhopper/plant maintained under normal limit. Among the eight treatments, the lowest leafhopper/plant recorded by T6 Neem oil 2% with 59.60% reduction over control followed by T5 Mahuva oil 2% recorded 57.53% reduction over control recorded during 1$^{st}$ spray. The population of leafhopper 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 2$^{nd}$ spray also. During 2$^{nd}$ spray highest percent of reduction over control recorded by T4 QUINOLPHOS 25 EC at 0.05% recorded 89.64% reduction over control followed by T6 Neem oil 2% recorded 85.60% reduction over control. In both the spraying population of leafhopper considerably reduced after 3 days after spraying and continued even after 15 days. Lowest population of leafhopper per plant recorded by T4 Quinolphos 25 EC at 0.05% and T6 Neem oil 2% which were statistically at par with throughout the observation. The T4 quinolphos and T6 Neem oil 2% recorded as best treatments over rest of the treatments.The grain yield in the treatment. Significantly highest grain yield at 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 at 3283.30 Kg. However the chemical treatments viz., T3 Profenophos 50 EC at 0.03% and T4 quinolphos 25 EC at 0.05% recorded yield at 2956.66 and 2936.00 Kg/ha both at par with each other.While, untreated control recorded the lowest yield at 2426.03 Kg/ha.

### 3.1 Efficacy of IPM Modules on natural enemies' populations at different days after imposition of treatments

#### 3.1.1 Green lacewings

Selective integrated management practices adopted against leafhopper on castor showed non-significant variations with respect to green lacewing population on a day before their imposition. On the other hand, their number varied significantly at 3$^{rd}$, 7$^{th}$, 11$^{th}$ and 15$^{th}$ days after the imposition of treatments. Considerable reduction in population of green lacewings was noticed when selective integrated management practices consists of chemical used for the management of leafhopper on castor. At 3$^{rd}$ day, T0 (Control) showed (1.247/plant) and T1 (Cucumber + *T. chelonis* at 2 lakh eggs/ha at 30 DAS) gave (1.143/plant) and recorded significantly highest population of green lacewings as these two treatments did not receive insecticidal spray and similar trend was noticed at 7$^{th}$ (1.100 and 1.023/plant), 11$^{th}$ (1.000 and 0.830/plant) and 15$^{th}$ days (1.143 and 0.867/plant) after imposition of treatments, respectively. Among the chemical and plant based treatments, at 3$^{rd}$ day, T3 [Profenophos 50 EC at 0.03%] recorded the highest population of 0.843/plant with a reduction of -35.35% population over control, while at 7$^{th}$ day, T7 (Pongamia oil at 2%) recorded a green lacewing population of 1.023/plant with a major

**Table 2. Effect of chemical and plant based pesticides on leafhopper *Empoasca flaviscens* on castor 2018-19**

| No | Integrated management practices | Pre treatment | Leafhopper /plant 2018-19 | | | | | | | | | | Yield kg/ha |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 3 DAS (1st spray) | 7DAS | 11 DAS | 15 DAS | % ROC | 3 DAS ( 2nd spray) | 7DAS | 11 DAS | 15 DAS | % ROC | |
| 1 | T0 control | 30.66 (33.62) | 32.20 (35.18) | 33.10 (35.12) | 34.78 (36.14) | 36.21 (36.99) | ------ | 37.46 (37.74) | 39.20 (38.76) | 42.43 (40.64) | 43.03 (40.99) | ------ | 2426.03 |
| | T1 cucumber +release of *T. chelonis* 2 lakhs eggs/ha @30 DAS | 31.38 (34.07) | 31.94 (34.41) | 30.20 (33.33) | 29.36 (32.81) | 27.43 (31.58) | 24.25 | 30.76 (33.68) | 25.43 (30.31) | 20.08 (26.62) | 18.81 (25.70) | 56.29 | 2730.03 |
| 2 | T2 release of *T. chelonis* 2 lakhs eggs/ha @30 DAS +Fenvalerate20EC@0.02% | 31.22 (33.96) | 26.89 (31.23) | 23.16 (28.76) | 19.00 (25.81) | 17.40 (24.65) | 51.95 | 19.70 (26.34) | 16.35 (23.84) | 14.13 (22.08) | 11.93 (20.20) | 72.28 | 2793.36 |
| 3 | T3 release of *T. chelonis* 2 lakhs eggs/ha @30 DAS + Profenophos 0EC@0.03% | 31.05 (33.86) | 25.22 (30.17) | 21.76 (27.80) | 20.16 (26.67) | 18.45 (25.43) | 49.05 | 20.50 (26.91) | 17.18 (24.48) | 12.26 (20.48) | 6.71 (15.00) | 84.41 | 2956.66 |
| 4 | T4 release of *T. chelonis* 2 lakhs eggs/ha @30 DAS + Qinolphos 25EC@0.05% | 30.99 (33.83) | 23.44 (28.95) | 20.30 (26.77) | 17.77 (24.93) | 15.90 (23.49) | 56.09 | 17.56 (24.77) | 15.03 (22.81) | 9.45 (17.89) | 4.46 (12.13) | 89.64 | 2936.00 |
| 5 | T5 release of *T. chelonis* 2 lakhs eggs/ha @30 DAS +Mahuva oil 2% | 30.83 (33.72) | 22.77 (28.49) | 21.10 (27.34) | 17.96 (25.06) | 15.38 (23.08) | 57.53 | 16.25 (23.76) | 14.80 (22.62) | 13.55 (21.59) | 7.13 (15.42) | 83.44 | 3283.30 |
| 6 | T6 release of *T.chelonis* 2 lakhs eggs/ha @30 DAS + Neem oil 2% | 30.79 (33.69) | 21.53 (27.64) | 20.18 (26.69) | 16.95 (24.31) | 14.63 (22.48) | 59.60 | 15.62 (23.28) | 13.16 (21.27) | 9.50 (17.92) | 6.20 (14.39) | 85.60 | 3730.00 |
| 7 | T7 release of *T.chelonis* 2 lakhs eggs/ha @30 DAS + Pongamia oil 2% | 31.05 (33.86) | 21.03 (27.29) | 20.11 (26.64) | 17.95 (25.06) | 16.10 (23.65) | 55.54 | 17.20 (24.50) | 15.50 (23.18) | 13.08 (21.18) | 7.60 (15.99) | 82.34 | 3627.63 |
| Sem± | | 0.16 | 0.58 | 0.49 | 0.69 | 0.40 | | 0.37 | 0.47 | 0.57 | 0.59 | | 91.66 |
| CD | | NS | 1.71 | 1.49 | 2.08 | 1.22 | | 1.11 | 1.41 | 1.71 | 1.79 | | 275.00 |
| CV | | ----- | 3.79 | 3.59 | 5.46 | 3.46 | | 3.89 | 4.12 | 5.83 | 7.72 | | 13.10 |

*Values in parentheses are Arc sign transformed values*

**Table 3. Efficacy of selective integrated management practices on natural enemies green lacewing at different days after imposition of treatment on castor 2018-19**

| Integrated management practice | Day before imposition | Third day | Seventh day | Eleventh day | Fifteenth day |
|---|---|---|---|---|---|
| $T_0$ =Control | 1.023 ± 0.053 | 1.247 ± 0.153 | 1.100 ± 0.085 | 1.000 ± 0.017 | 1.143 ± 0.030 |
| $T_1$ = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS | 0.933 ± 0.071 [-8.798] | 1.143 ± 0.057 [-8.340] | 1.023 ± 0.039 [-7.000] | 0.830 ± 0.100 [-22.16] | 0.867 ± 0.082 [-24.15] |
| $T_2$ = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Fenvalerate 20 EC @ 0.02% | 1.023 ± 0.079 [0.000] | 0.800 ± 0.040 [-39.11] | 0.843 ± 0.030 [-25.12] | 0.767±0.020 [-23.30] | 0.810 ± 0.092 [-38.41] |
| $T_3$ = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Profenophos 50 EC 0.03% | 0.820 ± 0.146 [-21.76] | 0.843 ± 0.070 [-35.35] | 0.857 ± 0.059 [23.75] | 0.800 ± 0.051 [-26.08] | 0.770 ± 0.000 [-43.02] |
| $T_4$ = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Quinalphos 25 EC @ 0.05% | 0.957 ± 0.047 [-7.074] | 0.643 ± 0.047 [-52.84] | 0.697 ± 0.033 [-39.39] | 0.623 ± 0.079 [-49.15] | 0.757 ± 0.030 [-44.52] |
| $T_5$ = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Mahua oil @ 2% | 1.037 ± 0.033 [1.501] | 0.577 ± 0.062 [-58.62] | 0.833 ± 0.082 [-26.10] | 0.723 ± 0.096 [-36.12] | 0.810 ± 0.042 [-38.41] |
| $T_6$ = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Neem oil @ 2% | 0.937 ± 0.033 [-9.218] | 0.723 ± 0.062 [-45.84] | 1.000 ± 0.058 [-9.775] | 0.797 ± 0.033 [-26.47] | 0.823 ± 0.101 [-36.91] |
| $T_7$ = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Pongamia oil @ 2% | 1.080 ± 0.010 [6.109] | 0.823 ± 0.039 [-37.10] | 1.023 ± 0.029 [-7.527] | 0.753 ± 0.039 [-32.20] | 0.857 ± 0.057 [-32.99] |
| **Mean** | 0.976 ± 0.026 | 0.850 ± 0.051 | 0.922 ± 0.031 | 0.787 ± 0.028 | 0.855 ± 0.030 |
| **F – value** | $1.342^{NS}$ | $9.716^{**}$ | $5.762^{**}$ | $2.905^{*}$ | $3.755^{*}$ |

*DAS: Days after sowing; *: p≤ 0.05; **: p≤ 0.01; NS: Non-significant; [ ] : Per cent change over control*

**Table 4. Efficacy of selective integrated management practices on natural enemies damselfly at different days after imposition of treatment on castor 2018-19**

| Integrated management practice | Day before imposition | Third day | Seventh day | Eleventh day | Fifteenth day |
|---|---|---|---|---|---|
| $T_0$ =Control | 0.813 ± 0.030 | 0.900 ± 0.040 | 0.930 ± 0.000 | 0.890 ± 0.010 | 0.833 ± 0.067 |
| $T_1$ = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS | 0.867 ± 0.117 [6.642] | 0.923 ± 0.053 [2.653] | 0.990 ± 0.061 [7.823] | 0.933 ± 0.020 [17.23] | 0.943 ± 0.043 [14.53] |
| $T_2$ =Sowing of cucumber along with castor + release of *Trichogramma chil onis* @ 2 lakh eggs/ha at 30 DAS + Fenvalerate 20 EC @ 0.02% | 0.603 ± 0.033 [-24.22] | 0.380 ± 0.049 [-59.98] | 0.367 ± 0.038 [-73.40] | 0.423 ± 0.039 [-44.22] | 0.233 ± 0.049 [-79.26] |
| $T_3$ = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Profenophos 50 EC 0.03% | 0.433 ± 0.020 [-43.83] | 0.477 ± 0.091 [-48.79] | 0.443 ± 0.127 [-63.49] | 0.357 ± 0.013 [-52.17] | 0.500 ± 0.101 [-43.99] |
| $T_4$ = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Quinalphos 25 EC @ 0.05% | 0.523 ± 0.039 [-33.45] | 0.397 ± 0.033 [-58.02] | 0.437 ± .0330 [-64.28] | 0.447 ± 0.039 [-41.33] | 0.487 ± 0.030 [-45.71] |
| $T_5$ = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Mahua oil @ 2% | 0.777 ± 0.023 [-4.152] | 0.737 ± 0.067 [-18.80] | 0.653 ± 0.062 [-36.12] | 0.787 ± 0.030 [-0.361] | 0.657 ± 0.098 [-23.25] |
| $T_6$ = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Neem oil @ 2% | 0.967 ± 0.049 [17.76] | 0.867±0.052 [-3.667] | 0.767±0.033 [-17.53] | 0.830 ± 0.100 [5.063] | 0.757 ± 0.072 [-9.124] |
| $T_7$ = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Pongamia oil @ 2% | 0.877 ± 0.029 [7.382] | 0.853 ± 0.039 [-5.421] | 0.800 ± 0.051 [-16.95] | 0.833 ± 0.020 [-5.181] | 0.780 ± 0.049 [-7.001] |
| **Mean** | 0.733 ± 0.040 | 0.692 ± 0.049 | 0.673 ± 0.050 | 0.675 ± 0.046 | 0.649 ± 0.049 |
| **F – value** | $13.40^{**}$ | $17.68^{**}$ | $14.99^{**}$ | $27.18^{**}$ | $11.42^{**}$ |

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

**Table 5. Population of other natural enemies at different days after imposition of selective integrated management practices on castor 2018-19**

| Integrated management practice | Day before imposition | Third day | Seventh day | Eleventh day | Fifteenth day |
|---|---|---|---|---|---|
| $T_0$ =Control | 0.690 ± 0.061 | 0.553 ± 0.077 | 0.623 ± 0.079 | 0.567 ± 0.033 | 0.530 ± 0.058 |
| $T_1$ = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS | 0.603 ± 0.033 [-12.61] | 0.490 ± 0.076 [-11.39] | 0.467 ± 0.084 [-25.04] | 0.633 ± 0.082 [11.64] | 0.420 ± 0.067 [-20.76] |
| $T_2$ = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Fenvalerate 20 EC @ 0.02% | 0.500 ± 0.051 [-31.51] | 0.547 ± 0.062 [-1.224] | 0.320 ± 0.049 [-64.88] | 0.357 ± 0.030 [-33.18] | 0.210 ± 0.076 [-76.19] |
| $T_3$ = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Profenophos 50 EC 0.03% | 0.557 ± 0.030 [-22.06] | 0.543 ± 0.047 [-2.041] | 0.400 ± 0.017 [-47.75] | 0.477 ± 0.062 [-14.22] | 0.220 ± 0.049 [-73.81] |
| $T_4$ = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Quinalphos 25 EC @ 0.05% | 0.543 ± 0.047 [-24.38] | 0.433 ± 0.052 [-24.49] | 0.433 ± 0.078 [-40.69] | 0.323 ± 0.023 [-38.55] | 0.367 ± 0.038 [-38.81] |
| $T_5$ = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Mahua oil @ 2% | 0.500 ± 0.051 [-31.51] | 0.413 ± 0.030 [-28.57] | 0.443 ± 0.047 [-38.54] | 0.447 ± 0.077 [-18.96] | 0.387 ± 0.043 [-34.05] |
| $T_6$ = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Neem oil @ 2% | 0.567 ± 0.020 [-20.40] | 0.513 ± 0.072 [-8.163] | 0.490 ± 0.059 [-28.48] | 0.453 ± 0.023 [-18.01] | 0.500 ± 0.017 [-7.143] |
| $T_7$ = Sowing of cucumber along with castor + release of *Trichogramma chilonis* @ 2 lakh eggs/ha at 30 DAS + Pongamia oil @ 2% | 0.590 ± 0.010 [-16.584] | 0.377 ± 0.053 [-35.92] | 0.680 ± 0.095 [12.21] | 0.487 ± 0.057 [-12.64] | 0.500 ± 0.051 [-7.143] |
| **Mean** | 0.569 ± 0.017 | 0.484 ± 0.022 | 0.482 ± 0.030 | 0.468 ± 0.025 | 0.392 ± 0.029 |
| **F – value** | $2.222^{NS}$ | $1.255^{NS}$ | $2.993^{*}$ | $3.585^{*}$ | $5.495^{**}$ |

*DAS: Days after sowing; *: p≤ 0.05; **: p≤ 0.01; NS: Non-significant; [ ]: Per cent change over control* reduction of -7.527% population as compared to control. However, at 11th and 15th days, T3 (Profenophos 50 EC at 0.03%) and T7 (Pongamia oil at 2%) registered highest green lacewing population of 0.800 and 0.857/plant with -26.08 and -32.99% decrease in population over control, respectively.

#### 3.1.2 Damselfly

Damselfly population varied on a day before the imposition of selective integrated management practices adopted for the management of leafhopper on castor. Considerable increases in population of damselfly was observed in T1 (Cucumber + *T. chelonis at* 2 lakh eggs/ha at 30 DAS) (0.923, 0.990, 0.933 and 0.943/plant) and T0 (Control) (0.900, 0.930, 0.890 and 0.833/plant) at different days (3rd, 7th, 11th and 15th) after imposition of integrated management practices on castor as these two treatments did not receive either chemical or plant based insecticides. Among the chemical and plant based treatments, T6 (Neem oil at 2%) at 3rd day (0.867/plant) and T7 (Pongamia oil at 2%) at 7th (0.800/plant), 11th (0.833/plant) and 15th day (0.780/plant) recorded considerable increase in population but their number decreased by -3.667, -16.95, -5.181 and -7.001 when compared to control, respectively.

#### 3.1.3 Other natural enemies

Population of other natural enemies didn't varied significantly on a day before and 3rd day after imposition of integrated management practices adopted against leafhopper on castor. Notably, at 7th day, significantly highest population of other natural enemies (0.680/plant) were recorded in T7 (Pongamia oil at 2%) with 12.21% increase over control. At 11th day, T1 (Cucumber + *T.chelonis* at 2 lakh eggs/ha at 30 DAS) recorded highest population of other natural enemies (0.633/plant) with 11.64% increase when compared to control. On the other hand, significantly higher population of other natural enemies (0.530/plant) was recorded in T0 (Control) at 15th day after imposition of integrated management practices together with T6 **(**Neem oil at 2%) and T7 **(**Pongamia oil at 2%) where both of them recorded other natural enemies population of 0.500/plant with a major reduction of -7.143% over control. All above explained results are represented in Tables 2 to 5.

## 4. CONCLUSION

Among the eight treatments, the lowest leafhopper/plant recorded by T6 Neem oil 2% with 59.60% reduction over control followed by T5 Mahuva oil 2% recorded 57.53% reduction over control recorded during 1st spray. The population of leafhopper 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. Lowest population of leafhopper per plant recorded by T4 Quinolphos 25 EC at 0.05% and T6 Neem oil 2% which were statistically at par with throughout the observation. The T4 quinolphos and T6 Neem oil 2% recorded as best treatments over rest of the treatments.The grain yield in the treatment. Significantly highest grain yield at 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 at 3283.30 Kg. However the chemical treatments viz., T3 Profenophos 50 EC at 0.03% and T4 quinolphos 25 EC at 0.05% recorded yield at 2956.66 and 2936.00 Kg/ha both at par with each other. While, untreated control recorded the lowest yield at 2426.03 Kg/ha. Further, there was considerable reduction in population of green lacewings was noticed when selective integrated management practices consists of chemical used for the management of leafhopper on castor. The Population of other natural enemies didn't varied significantly on a day before and 3rd day after imposition of integrated management practices adopted against leafhopper on castor.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

## REFERENCES


1. Sehgal Mukesh, Meenakshi Malik, Singh RV, Kanojia AK, Avinash Singode. “Integrated pest management in rice and its future scope”. Int. Curr. Microbiol. App. Sci. 2018;7(6):2504-11.
2. Anand Prakash, Bentur JS, Srinivas Prasad M, Tanwar RK, Sharma OP, Someshwas Bhagat, Mukesh Sehgal. Integrated pest management package for rice crop protection, Faridabad; 2014.
3. Palghar Thane, Vennila S, Ramchandra Lokare, Niranjan Singh, Subhash M Ghadge, C Chattopadhya. Crop pest surveillance and advisory project of Maharashtra, A role model for a e-pest surveillance & area implementation of IPM in India, Pune; 2016.

4. Anonymous. Castor insect pest management. Ikisan Agriinformatics and Services, [Nagarjuna Group of Fertilizers and Chemicals Limited], Andhra Pradesh; 2019.
5. Mohan Kumar R, Yamanura. Constraints in castor production and strategies to bridge yield gap in traditional and non-traditional tract of Karnataka. Mysore Journal of Agricultural Sciences. 2019;53(3):49-53.
6. Sarma AK, Singh MP, Singh SI. Studies on insect pest of castor in the agro-ecosystem of Maniupur. Journal of Applied Zoological Research. 2005;16(2):164-165.
7. Lakshminarayana M, Raoof MA. Insect pests and diseases of castor and their management. Directorate of Oilseeds Research, Hyderabad. 2005:78.
8. Basappa H. Investigation on the management of castor semilooper, *Achaea janata* Linn. [Lepidoptera: Noctuidae] Ph.D. Thesis, UAS, Dharwad. 1995:188.
9. Basappa H. Integrated pest management in Castor. National Agricultural Technology Project, Directorate of Oilseeds Research, Rajendranagar, Hyderabad; 2003.
10. Jayaraj S, Diraviam J. Integrated pest and disease management for sustainable ericulture in India. In: Advances in Disease and Pest Management in Sericulture (Eds. Govindan R, Ramakrishna Naika, Sannappa B.) Sericulture Scientific Publishers, Bangalore. 2004:146-149.
11. Gupta S. Biopesticides: An eco-friendly approach for pest control. Journal of Biopesticides. 2010;3(1):186-188.
12. Raza MH, Abid M, Faisal M, Yan T, Akhtar S, Adnan KMM. Environmental and health impacts of crop residue burning: Scope of sustainable crop residue management practices. Int J Environ Res Public Health. 2022;19(8):4753.
    DOI: 10.3390/ijerph19084753
    PMID: 35457622 PMCID: PMC9032433
13. Raghavendra KV, Gowthami R, Lepakshi NM, Dhananivetha M, Shashank R. Use of botanicals by farmers for integrated pest management of crops in Karnataka. Asian Agri-History. 2016;20(3):173-180.
14. Dutta S. Biopesticides: An eco-friendly approach for pest control world. Journal of Pharmacy and Pharmaceutical Sciences. 2015;4(6):250-265.
15. Anonymous. Package of practices for high yields. University of Agricultural Sciences, Bengaluru. 2016:256.




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