

## Integrated pest management strategies for Castor defoliators

### Abstract

This study aims to identify effective IPM practices for controlling castor defoliators due to their significant potential to reduce castor bean yields. Defoliation caused by castor defoliators in their larval stage results in a decrease in productivity. This research focuses on implementing green and sustainable Integrated Pest Management (IPM) strategies that combine biological, cultural, mechanical, and chemical control methods to reduce pest damage effectively. The identified main strategies include the utilization of natural enemies and parasitoids, changing the habitat, crop rotation, and the selective use of insecticides. The outcomes reveal that an integrated approach not only suppresses defoliator abundance but also improves castor crop resistance while maintaining a balance between yield and environment. These integrated pest management (IPM) practices provide suitable, cost-effective, and environmentally friendly methods for castor farmers aiming to control defoliators.

### Keywords

Castor, defoliators, Spodoptera, hairy caterpillars, semilooper, IPM

### Introduction

Castor (*Ricinus communis* L.) is a non-edible oilseed crop which is mainly grown in the semi-arid and arid areas of the country. India ranks first in the area of castor cultivation with approximately 10.9 million hectares, generating nearly 90% of the world castor oil production from an estimated total of 15.4 million tons globally, (FAO 2013). One of the most destructive pests that affect castor crops is the castor semilooper, *Achaea janata*, which is a major problem in all areas where castor is grown as a dry land crop (Basappa and Lingappa 2001). Tobacco caterpillar (*Spodopteralitura*) is another serious pest that feed on foliage and inflorescences; this pest is polyphagous and can cause severe damage if they are irregularly distributed. Other Lepidopterans that feed on leaves in the cultivated crops include the Tussock moth (*Euproctisfraterna*), Spiny Caterpillar (*Ariadne= Ergolismerionemerione*), and Slug caterpillar (*Parasa lepida*). Furthermore, the shoot and capsule borer (*Conogethes/Dichocrocispunctiferalis*) is a vital pest during the capsule development phase. Castor insect pest damage losses are estimated at 17.2 – 63.3% during the *kharif* season (Lakshminarayanan and Duraimurugan, 2014). Chemical insecticides are widely used to

control these pests; however, their uncontrolled use leads to build up of toxic compounds in the castor ecosystem. Therefore, the use of organic amendments, plant based products and microbial insecticides is a new way of controlling the pest complex in castor cultivation. **The use of IPM measures is more efficient and selective, effectively reducing cultivation costs, particularly in plant protection.** Hence, this study was formulated to assess an integrated pest management module against major insect pests of castor under field conditions.

## **Materials and Methods**

Field trials were laid in Tapioca and Castor Research Station at Yethapur between 2013 and 2016 in order to design an effective and environment friendly method for controlling castor defoliators. The aim of the present study was to evaluate the efficacy of different pest management measures such as installation of bird perches, mechanical control of defoliators, spraying of Monocrotophos 36 WSC at 0.05% and spraying of Neem seed kernel extract at 5%. Further, a triple control where bird perches were built, mechanical control was applied and Monocrotophos and NSKE were also used was compared to a control group where no treatment was given. The experiment was initiated with castor hybrid YRCH 1 under rainfed management. Treatments were applied at the vegetative phase of the castor plants when the number of defoliators was equal to or greater than the Economic Threshold Level (ETL). After the establishment of the pest population above the economic threshold level, the sprays were done twice at fifteen days interval. The research design used in the current study was Randomized Block Design (RBD) to control the confounding of effects and to reduce the variability through the use of four replicates. Information on pest densities and crop output was obtained to assess the efficacy of each treatment in castor defoliator control.

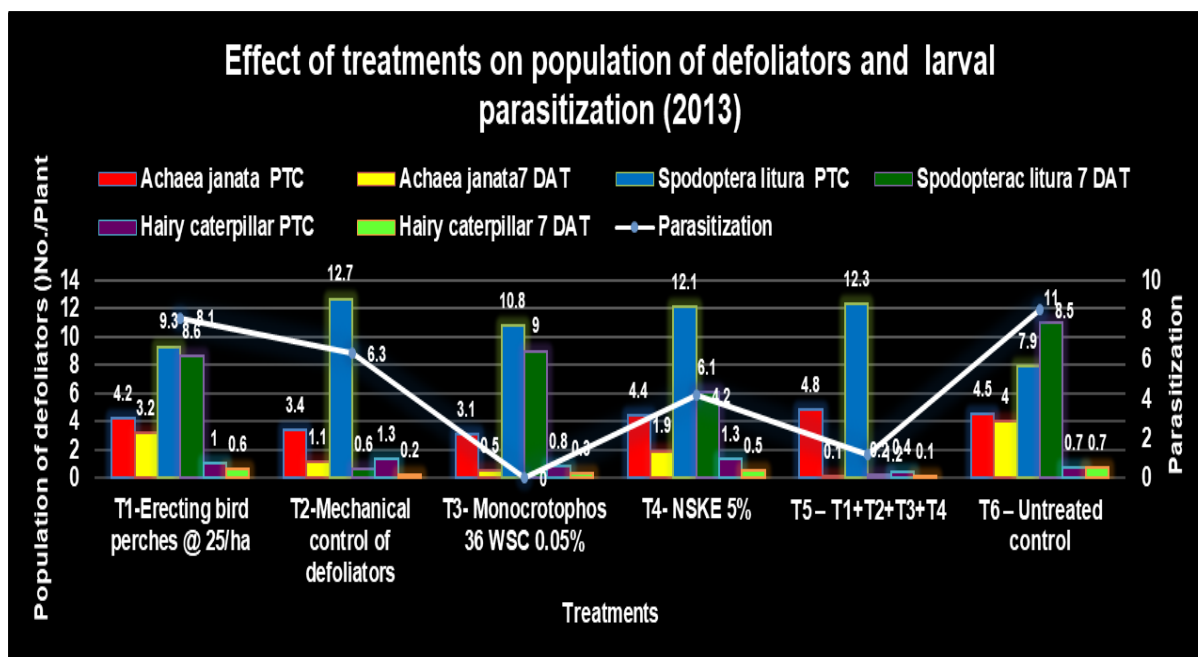
## **Observation for defoliators**

The larval density per plant and the percentage of defoliation will be assessed at 1, 3, 7, and 14 days prior and post insecticide application and ten plants will be used per treatment. **The measurements will be averaged to provide an overview of the pest problem's extent.** In addition, the percent reduction of the pest populations in relation to the untreated control will be determined by the formula developed by Henderson and Tilton (1955) known for the evaluation of insecticides efficacy.

## Results and Discussion

### Effect of treatments on population of defoliators, larval parasitization, seed yield and B: C ratio, Kharif 2013

A variation was observed among certain pest control treatments on *Achaea janata* (semilooper), *Spodoptera litura* (tobacco caterpillar) and hairy caterpillars during the Kharif season of 2013-14. In initial populations before treatment, semilooper ranged from 4.8 to 3.1 per plant, tobacco caterpillar from 7.9 to 12.7 per plant and hairy caterpillar from 0.1 to 0.7 per plant. At 7DAT, treatment T5 (multiple control methods combined) was by far the most effective, reducing semilooper average to 0.1 per plant compared with 4.0 per plant in the untreated control (T6). T3 was shown to be more efficacious than T5, T2 and T4, and the last of these, T1, proved the least efficacious. At 0.2 per plant, T5 showed the lowest numbers post treatment for tobacco caterpillars, then T2 at 0.6. **The untreated control T6 (2.5 seeds/row) had the highest count of tobacco caterpillars at 11.0 per plant, indicating its limited effectiveness.** Second, hairy caterpillar populations were best reduced by T5 and then T2, T3, and T4 with the least reduction being T6 at 0.7 per plant. In untreated plots, larval parasitization by *Microplitis maculipennis* reached 8.5%, the highest of all plots, but was much lower in treated plots, suggesting that pest management broke dependence on natural parasitization. T6 (installed bird perches), recorded 8.1, 5.2, 1.2 and 0 percent parasitization, however T5 (most integrated) recorded lowest 1.2 percent parasitization and T3 no parasitization. Treatments varied significantly with respect to seed yield. T5 produced the highest yield of 1868 kg/ha, reflecting both effective pest control and strong economic viability, with a benefit-cost (B : C) ratio of 2.81. T2 followed with a yield of 1640 kg/ha and a B : C ratio shows high cost effectiveness with C ratio of 2.54. The other treatments, T3, T4, and T1, achieved yields of 1605 kg/ha, 1590 kg/ha, and 1527 kg/ha with respective B: C ratios are 2.52, 2.37 and 2.33. The untreated control (T6) produced the lowest yield of 1522 kg/ha and had the lowest B:C ratio at 1.30. **This study concludes that T5, which employs multiple pest control methods simultaneously, most effectively reduces pest pressure, generates the highest yield, and offers the best economic return. Among them was T2, which demonstrated that it is a viable and cost-effective method for farmers aiming to enhance productivity.** In general, this research supports the use of integrated pest management as a method of greatly reducing pest numbers, increasing yields, and increasing the economic sustainability of agricultural practices, especially when mixed planting, as in T5, is practiced. Further work on these methods is suggested to increase productivity and long term sustainability in farming.



**Fig 1. Effect of treatments on population of defoliators and larval parasitization (2013)**

### Effect of treatments on population of defoliators, larval parasitization, seed yield and B: C ratio, *Kharif* 2014

The 2014 Kharif experiment compared six pest management methods in order to determine their ability to manage pests, improve seed yield, and be economically feasible. The study focused on the pests *Achaea janata* (semilooper), *Spodoptera litura* (tobacco caterpillar), and hairy caterpillars; it was established that each method had a different level of efficacy. **Treatment 1, which utilized bird perches (25 per hectare) to attract natural predators, resulted in a reduction of semilooper counts from 5.0 to 3.0, *S. litura* counts from 7.1 to 5.8, and hairy caterpillar counts from 3.0 to 2.0. This treatment produced a moderate yield of 1,560 kg/ha and achieved a benefit-cost (B:C) ratio of 1.43, indicating that it was not economically efficient.** The second treatment, which involved physical control of pests, also produced significant declines in densities; *A. janata* was reduced from 4.4 to 0.7, *S. litura* from 11.1 to 1.1 and hairy caterpillars from 3.6 to 1.1. This approach yielded 1697 kg/ha and a B:C ratio of 0.59 and a financial leverage ratio of 1.69, which are considered very effective and productive. In the third treatment Monocrotophos 36 WSC at 0.05% (chemical insecticide) was used and it affected *A. janata* from 2.8 to 0.4, *S. litura* from 10.4 to 3.2 and hairy caterpillar from 4.8 to 0.8. This method produced a yield of 1601 kg/ha with a B:C/P was 1.61, which shows that Integrated Pest Management by biological control was quite efficient in pest control but slightly offered lower economic benefits than mechanical control. Treatment 4 used Neem Seed Kernel Extract (5%), a natural pesticide, which lowered *A.*

*janata* from 5.0 to 1.6, *S. litura* from 11.0 to 1.2, and hairy caterpillars from 6.1 to 1.0, yielding 1550 kg/ha with a B:C With the C/P ratio at 1.37 it was effective but not as cost efficient as the other forms of treatment. Treatment 5, an integrated pest management (IPM) approach that combined treatments 1, 2, 3, and 4, showed the most dramatic pest reductions: *A. janata* reduced from 3.0 to 0.1, *S. litura* from 10.8 to 0.6 and hairy caterpillars from 5.2 to 0.6 which resulted into highest yield of 1811 kg/ha and B:C ratio of 1.71 this proved that maximum pest control and economic efficiency was done. Treatment 6, the untreated control, served as a benchmark and showed minimal reductions or even increases in pest populations, resulting in the lowest seed yield of 1398 kg/ha and a B:C1.10 ratio was observed, underlining the need for the active pest management activities. The percentage of parasitization by *Microplitis maculipennis* was highest in T1 and T2 (6.2% and 6.1% respectively) and lowest in T5 and T3 (1.6% and 0% respectively) which show that more intensive management measures like in T5 can decrease the natural parasitism but still maintain the pest control through other ways. Standard Error of Differences (SEd) and Critical Difference (CD) measures were used to check the consistency and efficiency of the experiment with SE obtaining 0.067 to 0.367 and CD 0.144 to 0.782 at  $p=0.05$  thus showing significance of the treatments. In general, it was established that the integrated approach (T5) provided the most effective pest control, crop yield and economic returns. Another method of control was mechanical control (T2) which also gave high results with low costs, natural control methods like bird perches and neem extract were also quite effective but with low economic returns. **This research highlights the significance of IPM as an effective farming**

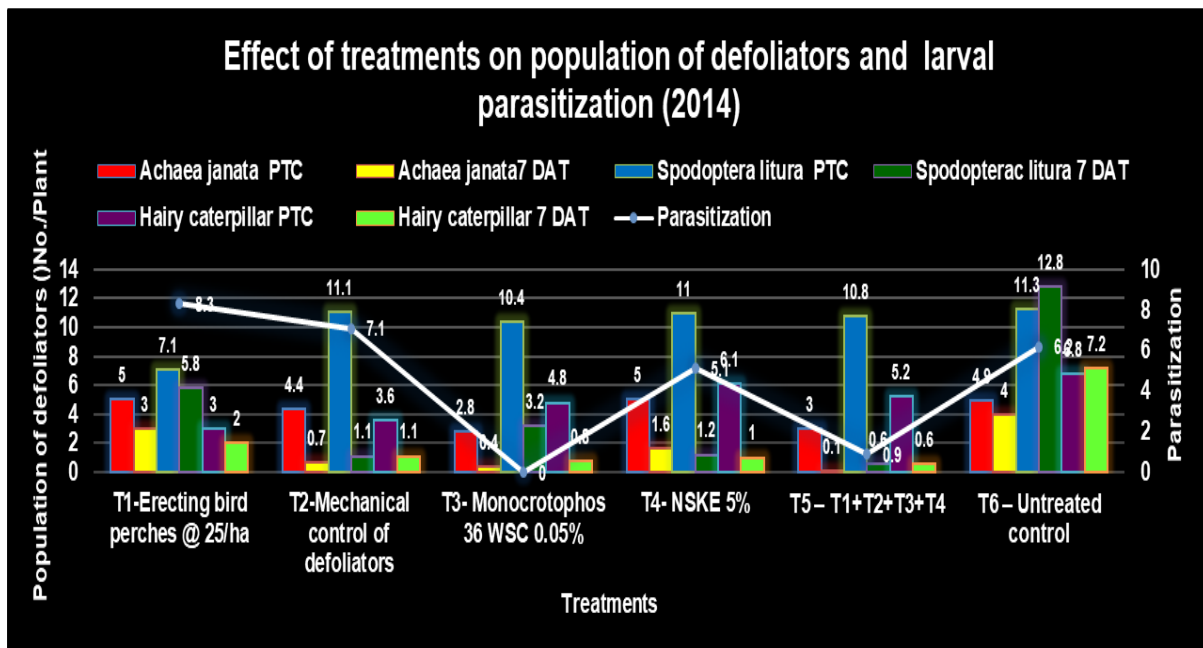
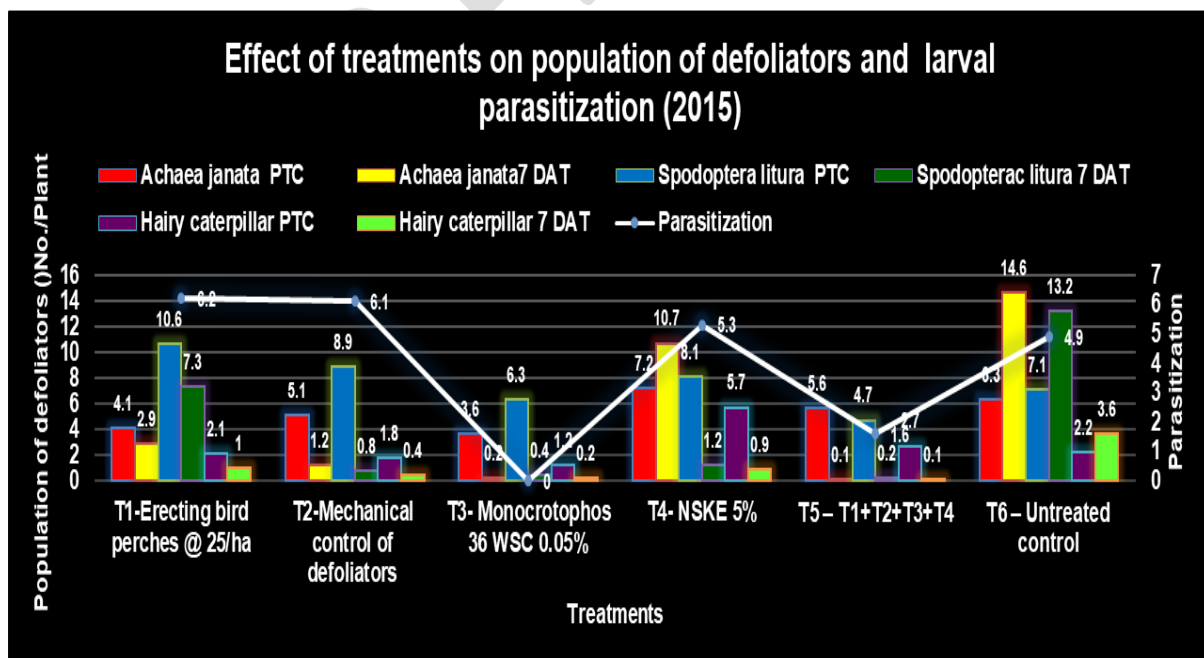


Fig 2. Effect of treatments on population of defoliators and larval parasitization (2014)

### Effect of treatments on population of defoliators, larval parasitization, seed yield and B: C ratio, Kharif 2015

The Kharif 2015-16 study evaluated six pest management treatments to control defoliators and improve seed yields, using metrics of pest reduction, yield, and benefit-cost (B:C) ratios for the economic appraisal of the company. All the treatments provided specific efficacy in pest control and yields. Treatment 1 (Bird Perches at 25/ha) relied on natural predators, reducing *Achaea janata* (semilooper) from 4.1 to 2.9, *Spodoptera litura* from 10.6 to 7.3, and hairy caterpillars from 2.1 to 1.0, achieving a seed yield of 1595 kg/ha and a B:C ratio of 2.40. Treatment 2 (Mechanical Control) involved manually removing pests, resulting in significant pest reductions against *A. janata* declined from 5.1 to 1.2, *S. litura* from 8.9 to 0.8 and hairy caterpillars from 1.8 to 0.4, with seed yield of 1690 kg/ha and B:C ratio of 2.65 denoting low cost of cultivation. Treatment 3 (Monocrotophos 36 WSC at 0.05%) applied a chemical insecticide, reducing *A. janata* from 3.6 to 0.2, *S. litura* from 6.3 to 0.4, and hairy caterpillars from 1.2 to 0.2, yielding 1610 kg/ha with a B: C ratio of 2.45 were achieved, which evidence a good pest suppression but slightly lower economic benefit than mechanical methods. Treatment 4, which involved using Neem Seed Kernel Extract at a concentration of 5%, acted as a natural insecticide. Interestingly, this treatment led to an increase in *A. janata*

populations, rising from 7.2 to 10.7. In contrast, the numbers for *S. litura* decreased significantly, from 8.1 to 1.2, and the population of hairy caterpillars fell from 5.7 to 0.9. As a result, the yield increased to 1590 kg/ha, with a benefit-to-cost (B:C) ratio of 2.35. This suggests that the treatment can be considered moderately effective. The 5<sup>th</sup> treatment, IPM comprising of Treatment 1, 2, 3 and 4, was the most effective in reducing pest population of *A. janata* from 5.6 to 0.1, *S. litura* from 4.7 to 0.2 and hairy caterpillars from 2.7 to 0.1. This treatment resulted in the highest seed production of 1740 kg/ha, and the most favorable benefit-to-cost ratio of 2.81, which supports both the economic viability and pest control aspects of Integrated Pest Management (IPM). Treatment 6 (Untreated Control) saw pest populations increase, with *A. janata* rising from 6.3 to 14.6, *S. litura* from 7.1 to 13.2, and hairy caterpillars from 2.2 to 3.6, yielding the lowest output (1350 kg/ha) and the lowest B: C ratio was 1.20 which indicated that efficient pest management practice should be undertaken. The study also involved assessment of parasitization by the parasitoid *Microplitis maculipennis* which was relatively high in T1 (6.2%) and T2 (6.1%) while low in T5 (1.6%) and zero in T3 probably due to high intensity pest control measures. Standard error of differences and critical difference were also used to ensure treatment reliability with SED ranging from 0.034 to 0.281 and CD at 0.05 level of confidence ranging from 0.072 to 0.600. The results showed that T5 (IPM) achieved the highest performance in pest management, crop yield and economic returns followed by T2 (mechanical control).



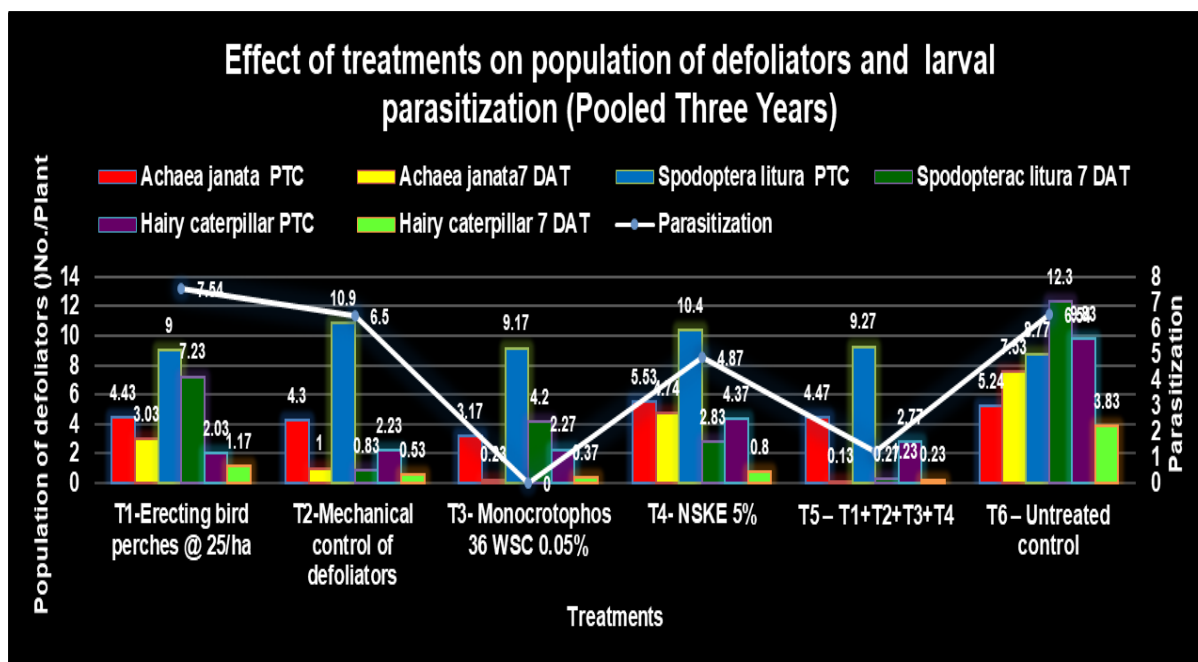
**Fig 3. Effect of treatments on population of defoliators and larval parasitization (2015)**

## **Effect of treatments on population of defoliators, larval parasitization, seed Yield and B: C ratio (pooled mean of *Kharif* 2013, 2014 and 2015)**

This research aimed at assessing the efficacy of various pest management treatments for defoliator pests, and their effects on seed yield and overall return. The treatments were bird perches, mechanical control, chemical insecticides, natural pesticides, an integrated approach where two or more strategies were used, and an untreated control. Analysis of variance showed that there was a difference between the treatments. The semilooper (*Achaea janata*) population was 3.6 to 7.2 before treatment and reduced to 0.2 in T5 after 7DAT, with the populations increasing in T6 (14.6). Density of tobacco caterpillar (*Spodoptera litura*) was 0.2 to 13.2 per plant and it was least in T5 with 0.2 per plant and T3 with 0.4 per plant. The number of hairy caterpillars per plant was lowest in T5 (0.1) and highest in T6 (3.6). Prevalence of parasitization was relatively high in T1 (6.2%) and T2 (6.1%) as opposed to T4 (5.3%) and T3 (0%). T5 and T3 had the least rate of parasitisation at 1.6% and 0% respectively. The highest seed yield of 1740 kg/ha and the most favorable B:C ratio of 2.81 was in treatment T5, while the second highest yield of 1690 kg/ha and B Ratio of 2.65 was in treatment T2. T3, T1, and T4 gave moderate grain yields of 1610 kg/ha, 1595 kg/ha, and 1590 kg/ha respectively; the lowest yield of 1350 kg/ha and the least B Ratio of 1.20 was recorded in untreated check (T6). Treatment 1: The first treatment Bird Perches (T1) entailed putting up 25 perches per hectare to encourage predator birds. This lowered *Achaea janata* to 3.03 from 4.43, whereas *Spodoptera litura* was lowered from 9.00 to 7.23 and hairy caterpillars from 2.03 to 1.17. Percentage of parasitization rose slightly from 7.54% to 8.3%. The seed yield was 1559.00 kg/ha with the B Ratio of 2.33 which is beneficial but still less effective than other treatments. Treatment 2: Mechanical control (T2) involved the physical elimination of pests, which greatly reduced *Achaea janata* (from 4.30 to 1.00), *Spodoptera litura* (from 10.90 to 0.83) and hairy caterpillars (from 2.23 to 0.53). This treatment gave the highest seed yield of 1675.67 kg/ha and a B :C ratio of 2.65 which indicated high potential for economic return. Nevertheless, it was characterized by a low level of parasitization, which implied weak food web support for natural enemies. Treatment 3: Chemical Control with Monocrotophos (T3) led to effective pest management where *Achaea janata* reduced from 3.17 to 0.23, *Spodoptera litura* from 9.17 to 4.20 and hairy caterpillar from 2.27 to 0.37.

This approach produced seed yield of 1605.33 kg/ha and B Ratio of 2.52, revealing powerful pest control measures, while possible ecological issues with non-target species appeared. Treatment 4: The natural Pesticide that was used is T4, in this case, neem seed

extract (NSKE 5%) reduced *Achaea janata* from 5.53 to 4.74, *Spodoptera litura* from 10.40 to 2.83 and hairy caterpillars from 4.37 to 0.80. Parasitization rates were 4.74% which implies there is some validation on the biological control methods. This treatment produced a control rate of 1576.67 kg/ha, with the B:C ratio at 2.37, which was still relatively good compared to mechanical control. Treatment 5: The Integrated Approach (T5) incorporated the strategies of the previous treatments and provided very good suppression of defoliator populations with *Achaea janata* reducing from 4.47 to 0.13, *Spodoptera litura* from 9.27 to 0.27 and hairy caterpillars from 2.77 to 0.23. Nevertheless, it was found to have the lowest parasitic prevalence (0.13%), which suggested that intense management strategies may preclude the development of spontaneous parasitism. This approach gave the highest seed yield of 1806.33 kg/ha and the best B :C ratio of 2.81 for the best economic returns. Treatment 6: Untreated Control (T6) had higher pest density, with *Achaea janata* increasing from 5.24 to 7.53, *Spodoptera litura* from 8.77 to 12.30 and hairy caterpillar from 9.83 to 3.83. It also had the highest parasitization rate of 14.6%, and this indicate that with no pest management measures in place natural parasitism can occur. The lowest seed yield was recorded at 1350.00 kg/ha and the B Ratio of 1.30 was an indication of poor economic benefit. Therefore, the integrated approach (T5) was the most efficient in managing pests and improving seed yield while mechanical control (T2) afforded the study good economic returns. Chemical control (T3) was successful but was concerns on the sustainability of the environment. The untreated control showed that there was a need for active pest management since it resulted in high pest pressure and low yields. Additional research is suggested for the assessment of the effects, benefits, and risks of these pest control measures for future sustainable use in agriculture.



**Fig 4. Effect of treatments on population of defoliators and larval parasitization (Pooled data 2013, 2014, 2015)**

The results of this research are consistent with the IPM concept, as evidenced by the previous research in different crop and forest ecosystems. It identifies Biological, Chemical and Cultural methods of controlling pests and diseases with a view of controlling them to sustainable levels that are profitable to the farmer. According to Zalom (2001), an effective approach of reducing pest damage incorporates the use of natural predators, parasites, use of genetically resistant plant varieties and adjustment of the environment in a way that least depends on chemical pesticides. The approach of this study, especially with the successful use of combined treatments (T5) supports this principle, suggesting that, it is possible to achieve best results in pest control with the least adverse effects on the environment through the use of bird perches, mechanical removals, botanical control using neem based treatments and selective insecticide application.

In addition, the systems approach of IPM, which looks at the relationship between plants, pests, the environment and economics (Gisi & Leadbeater, 2010) was evident in the increase of seed yield and the benefit cost ratio in this study. Through the use of a multi-method approach, the T5 combination treatment demonstrates that analyzing these interactions is crucial in order to enhance both pest control and profitability. As with Akanbi and Ashiru (1991) and Nair (1991), there are difficulties with IPM implementation, specifically, limited resources and farmers' knowledge, as well as training. This corresponds

with the constraints outlined in prior IPM studies, including inadequate access to IPM training and inadequate understanding of sustainable pest control measures as a result of socio-economic factors that hinder effective pest management in many areas.

### **Impact of IPM measures on defoliators.**

The result of this study supports previous research on the use of Integrated Pest Management (IPM) measures for the control of *Spodoptera litura* showing that combining different methods will lead to better pest management with reduced chemical pesticide use. The multiple treatment (T5) that incorporated cultural, mechanical, biological and limited chemical control was most effective in reducing defoliator damage and increasing crop yield. This is consistent with earlier works such as that of Zhou et al. (2010) who showed that trap cropping is effective when integrated in an IPM program. In their work, taro (*Colocasia esculenta*) was quite efficient in protecting tobacco plants from *S. litura* and in repelling the pests from the main crop, **further more** it increased the rate of parasitism by the predators of *S. litura* such as Microplitisprodeniae and Campoletischloridae. Likewise, the integrated approach in this study uses several control methods, all of which work to decrease pest population and promote biological control naturally for a sustainable farming system. Interestingly, Zhou et al. (2010) identified castor as a preferred host for *S. litura* but also potential trap crop for IPM. In the green house experiment, castor (*Ricinus communis*) supported higher population of *S. litura* larvae than other crops, indicating its potential in IPM to trap pests away from the crops of interest. This study was more specific to pest management within castor crops than as trap crops hence supports castor's position in integrated systems where pest distribution and management methods can be effectively planned for. The T5 treatment which incorporated bird perches alongside mechanical control, neem-based treatments and selective insecticides showed the best result with the least population of pests and increased seed yield. This builds on the work of Zhou *et. al.*, by proposing that by integrating cultural and biological control methods such as the use of trap crops or attracting natural enemies with proper use of chemicals, it is possible to greatly reduce pest pressures. A similar IPM approach is supported by Ahuja *et al.* (2012) who found that IPM programs led to a 50-60% decline in pesticide use to control *S. litura* and other pests. This work's T5 combination treatment supports Ahuja *et al.* notion that IPM has the potential to replace or at least minimize the conventional pesticide use. T5, that has low pesticide inputs gave not only good pest control but also better benefit-cost ratio, which support the effectiveness of IPM. This is in harmony with the overall strategies of IPM,

which include efficient pest control with the least adverse effects on the environment, and enhancement of the economic returns for farmers.

This study is in concurrence with Duraimurugan and Lakshminarayana (2015) who also showed that IPM approaches are beneficial for managing castor pests like the semilooper. The experiment revealed that the IPM module integrated across different castor cultivars was more effective than the conventional farmers' practices because it provided better control of insect pests with maximum yield and economic benefit. This was also the case with the combination treatment (T5) in this study, Duraimurugan and Lakshminarayana's IPM module involved mechanical control of early and gregarious stages of caterpillar pests and insecticide application based on economical thresholds. This kind of tactic is important in the practice of IPM as it reduce chemical usage, improve efficiency and beneficial organism conservation which is an IPM notion of balance (Jacobsen, 1997).

One key result of the Duraimurugan and Lakshminarayana research was that their IPM module was less hazardous to the larval parasitoid *Snellenius maculipennis* than traditional methods, a result that is in line with the principles of IPM and conservation of beneficial insects and minimizing environmental impacts. Another area where this study corroborates earlier literature is on the impact of IPM on yield and profitability. In the Duraimurugan and Lakshminarayana study, the IPM module lowered the mean semilooper population per plant to 0.3 larvae, and not to 0.6 as observed with conventional farmers' practices. Likewise, in this present study, T5 also produced a remarkable decrease in the *Spodoptera litura* and other defoliators-condition which enhanced the seed yield of 1806.33 kg/ha with a high benefit-cost ratio of 2.81. Duraimurugan and Lakshminarayana also found the IPM module to give better castor seed yield of 1348 kg/ha and net return of Rs 26,889/ha indicating that IPM is more profitable than the conventional pest management practices. These results show that IPM not only offer efficient pest management, but also leads to increased crop output and profitability, thus is a sustainable and profitable choice for farmers.

### **Effect of Integrated Pest Management (IPM) against Natural enemies**

Natural enemies are a key component of IPM because they act as biological control agents that can greatly lessen the reliance on chemicals and support environmentally friendly farming, as Romeis *et al.* (2008) pointed out. In the current study, Neem seed kernel extract (NSKE) used in treatment T4 promoted the parasitism with a 4.87% parasitism level on *Achaea janata*. This is in accord with the general IPM concept of applying selective, reduced risk treatments that benefit useful species. Through supporting natural enemy Yangon

implementation of IPM not only decrease the frequency of using chemical but also enhance the conservation of biological diversity, which is another form of biological control.

Some of the recommendations such as bird perches are in line with the the “enemies hypothesis” and the “resource concentration hypothesis” presented by González-Chang *et al.* (2019). Bird perches in T1 are positioned to attract avian predators; a form of habitat manipulation which increases biological control through encouraging natural enemies activity. These habitat management is crucial in IPM as it enable biological control, reduces pest build up and increase ecosystem health. But it is important to release natural enemies cautiously, particularly in systems with many species or invasive pests, because these can change the local ecosystem, as Costa and Anjos (2015) pointed out. However, this study is in line with the spirit of IPM research focusing on the effects of **sub lethal** doses of pesticide to non-target organisms and the importance of pesticide selectivity (Bueno *et al.*, 2017; Carvalho *et al.*, 2019). In IPM, use of selective and minimal amounts of pesticides like Monocrotophos in T3 minimize harm on other creature and minimize the chances of Pests developing resistance. This approach is in consonance with the view of Bueno *et al.*, (2017) who called for the evaluation of the impact of pesticides in the development of IPM that is both effective and environmentally friendly.

Last, the findings of the study are in line with the possibility of incorporating new Technologies with IPM for instance in using botanical treatment such as NSKE that are suitable for conservation biological control methods as suggested by Romeis *et al.*, (2008). IPM improvement such as the use of Bt crops or SNAP (shelter, nectar, alternative food sources and pollen) has the potential of enhancing populational levels of natural enemies and at the same time reducing pest pressures.

## **Conclusion**

The experiment established that different pest management practices have a direct impact on defoliator populations, seed production and overall profitability in farming systems. Among the five strategies, the integrated approach (T5) was found to give the highest seed yield and positive financial returns with the least percentage of larval parasitism. We also found that mechanical control (T2) was also quite effective as it produced the most seeds of the individual control and remained economically feasible. The third treatment method, chemical treatment, was most effective in controlling pest populations while at the same being accused of **several** environmental impacts. The untreated control group was useful in pointing out the negative impacts of pests if they are not controlled by an appropriate pest management strategy. In conclusion, the study calls for the use of multiple approaches in pest control,

yield improvement and overall economic performance since the effectiveness of the current practices remains unclear in the long-run.

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