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Impact of integrated pest management modules on the activity of natural enemies in castor ecosystem

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ABSTRACT: Investigations were carried out during 2001–2004 to study the impact of biointensive integrated pest management (BIPM), chemical pesticide intensive integrated pest management (CIPM) modules and non–integrated pest management (non–IPM) modules (farmers' practice) on the natural enemies of insect pests of castor in Andhra Pradesh. BIPM module proved to be relatively safer to natural enemies with 16.13 and 66.10 % average field parasitization of *Achaea janata* (L.) eggs and larvae by *Trichogramma chilonis* Ishii and *Microplitis maculipennis* Szepligeti, compared to 6.92 and 21.2, 8.80 and 24.00, 8.92 and 22.35 % in CIPM module and non–IPM modules 1 and 2, respectively. *M. maculipennis* cocoon number per plant increased with increase in duration after treatment in the BIPM module whereas it decreased in CIPM and non–IPM modules. Similarly, average parasitisation by *Charops obtusus* Morley (3.54%), *Rhogas* spp. (4.60%), *Apanteles hyposidrae* Wilkinson (13.85%), *Euplectrus maternus* Bhatnagar (7.92%) on *A. janata* larvae and *Cotesia flavipes* Cameron (8.96%) on *Spodoptera litura* (F.) was higher in the BIPM module compared to CIPM module (1.65, 1.59, 3.50, 2.37 and 2.49%) and non–IPM modules 1(1.16, 0.80, 2.70, 1.20 and 2.68%) and 2 (1.50, 1.19, 2.80, 3.82 and 1.99%), respectively. BIPM module had higher population of predators like *Chrysoperla* sp., *Cheilomenes sexmaculata* (Fabricius), *Cantheconidea furcellata* (Wolff), *Rhynocoris kumarii* Ambrose and Livingstone and spiders per 10 plants (8.45, 3.41, 3.27 and 7.10) than CIPM module (1.75, 2.90, 1.38, 1.45 and 1.40) and non–IPM modules 1(1.20, 1.82, 1.00, 1.00 and 1.80) and 2 (1.97, 2.41, 1.32, 1.22 and 2.90), respectively. Black drongo (*Dicrurus adsimilis* Blyth) and Indian myna (*Acridotheres tristis* (L.)) were the predominant predatory birds which used bird perches frequently while predating on *A. janata, S. litura* and *Conogethes punctiferalis* (Guenee) larvae in BIPM and CIPM modules compared to non–IPM modules.

KEY WORDS: Castor, insect pests, natural enemies, impact, biointensive integrated pest management (BIPM), chemical pesticide intensive integrated pest management (CIPM)

INTRODUCTION

Andhra Pradesh in the southern part and Gujarat and Rajasthan in the western part are the major castor producing states in India. In the traditional castor growing areas of Andhra Pradesh, the crop is grown under rainfed conditions where there are several production constraints, especially biotic constraints and hence productivity is very low (387 kg ha^{-1}) compared to western part (1864 kg ha^{-1}).

A wide array of biocontrol agents has been documented on major insect pests of castor. In castor ecosystem, the egg parasitoid, *Trichogramma chilonis* Ishii, the larval parasitoid, *Microplitis maculipennis* Szepligeti, insect predators, spiders, insectivorous birds and some of the microbial agents exert greater biological resistance on the succession of the pest complex of castor.

Biointensive integrated pest management (BIPM) and chemical pesticide intensive integrated pest management (CIPM) modules were developed and validated by comparing with non–integrated pest management (non–IPM) module1 (farmers' practice with wilt resistant castor variety Jyoti) and 2 (farmers' practice without variety Jyoti) in a farmers' participatory approach in Andhra Pradesh in the southern part of India during 2001–2004. During validation of BIPM, CIPM and non–IPM modules, simultaneous investigations were also carried out to study their impact on the activity of natural enemies of major insect pests in castor ecosystem. Conservation of these natural enemies in the castor ecosystem is essential for effective, eco–friendly and sustainable pest management.

MATERIALS AND METHODS

Under National Agricultural Technology Project (NATP) on "Development of IPM Modules for Oilseeds and nutritious Cereals based Production system (ROPS–8)" a farmers' participatory integrated pest management (IPM) programme was validated in the traditional castor areas of Maheswaram watershed in four villages (Kandkur, Mohammad Nagar, Nednoor and Debbadguda) in Kandkur mandal and one village (Tummalur) in Maheswaram mandal in Ranga Reddy district of Andhra Pradesh during 2001–02, 2002–03 and 2003–04.

Benchmark survey and training of farmers in IPM Field School

A benchmark survey was conducted among the farmers growing castor crop in different villages to know their level of knowledge on natural enemies of various insect pests of castor. Two group leaders of farmers (IPM coordinators) from each village who were involved in IPM programme were trained in the IPM Field School on identification of different stages of natural enemies of major insect pests of castor and other IPM components. IPM coordinators from each village in turn trained the remaining castor farmers on IPM components, especially natural enemies of insect pests of castor. IPM farmers were trained on utilization of various IPM components under BIPM and CIPM modules at different phenological stages of the crop based on the severity of different insect pests and diseases.

Table 1. Pest management interventions in biointensive, chemical pesticide-intensive and non–IPM modules in castor ecosystem

IPM Modules	Pest management interventions
BIPM	Regular crop rotation of castor with sorghum *(Sorghum bicolor* (L.) Moench) Summer ploughing Seed treatment with carbendazim @ 2g kg^{-1} seed Use of wilt resistant castor variety Jyoti (DCS–9) Hand picking and destruction of egg masses and early stage larvae of tobacco caterpillar and hairy caterpillars as well as capsules affected by capsule borer and *Botrytis* Use of neem seed kernel extract (NSKE 5%) against defoliators Fix dried tree branches as bird perches (15 ha^{-1}) to attract predatory birds Vegetative trapping with *Jatropha curcas* L. twigs and manual killing of red hairy caterpillar Spray carbendazim @1gl^{-1} against *Botrytis* and application of 10 kg nitrogen ha^{-1} after cyclonic rains to get additional spikes.
CIPM	Regular crop rotation of castor with sorghum Summer ploughing Seed treatment with carbendazim @ 2g kg^{-1} seed Use of wilt resistant castor variety Jyoti (DCS–9) Fix dried tree branches as bird perches(15 ha^{-1}) to attract predatory birds Spray endosulfan (0.07%) against castor semilooper, chlorpyriphos (0.05%) against tobacco caterpillar and monocrotophos (0.05%) against capsule borer Opening furrow around the fields and apply quinalphos dust (1.5%) against red hairy caterpillar Spray carbendazim @1gl^{-1} against *Botrytis* and application of 10 kg nitrogen ha^{-1} to get additional spikes
Non–IPM	Quinalphos and monocrotophos spray against castor semilooper and carbendazim against *Botrytis*. Quinalphos + monocrotophos + cypermethrin against castor semilooper Cypermethrin + carbendazim against castor semilooper and *Botrytis*. Dimethoate + carbendazim against castor semilooper and *Botrytis*. Metasystax + monocrotophos against castor semilooper

Recording observations on natural enemies

Development and validation of IPM modules

All the castor IPM farmers from the five villages were involved in developing and imposing the BIPM and CIPM modules. Different pest management interventions followed under each module are given in Table 1. BIPM and CIPM modules were compared with farmers' practice (non–IPM module) by regularly recording crop protection practices followed by farmers from seedling stage till harvest. An experiment was laid out in 16 ha area using minimum 0.40ha castor field per module with buffer castor crop between modules in castor fields of ten farmers from the five villages (locations). Each farmer was treated as a replication. Castor crop was raised following recommended agronomic practices except plant protection. Under each IPM module, different components were imposed at different phenological stages of the crop based on economic threshold level (ETL) for castor semilooper (4–5 larvae plant^{-1}), tobacco caterpillar (10–15% defoliation), capsule borer (10% capsule damage), wilt (15–20%) and *Botrytis* (10%) (Basappa, 2007).

Pre– and post–treatment (1, 3 and 7 days after treatment) counts of number of *M. maculipennis* cocoons per plant were recorded. Effect of BIPM, CIPM and non–IPM modules on potential egg and larval parasitoids was studied by recording the per cent parasitization of 100 eggs and early instar larvae of *A. janata* and *S. litura* collected from the fields and reared in the laboratory at 27 $\pm$ 1°C and 65 $\pm$ 5% relative humidity. Populations of important predators were recorded on 10 plants in 5 quadrats of 25 sq. m. in 0.4 ha area under each module. The activity of different species of insectivorous birds was recorded in both BIPM and CIPM at different phenological stages of the crop. Microbial agents were purified and isolated in the laboratory from dead larvae of *A. janata* and *S. litura* collected from castor fields.

Statistical analysis

The data collected on natural enemy activity under different modules were statistically analysed. Non–IPM module–1 was included during 2002–03 and hence statistical analysis was done separately for 2001–02 and the data of 2002–03 and 2003–04 were subjected to pooled analysis. The data were subjected to statistical analysis after necessary transformation.

RESULTS AND DISCUSSION

The statistically analysed results on the population of various natural enemies recorded are based on the mean values of three seasons across farmers and locations (villages) are presented. The results indicated a wide variation in the activity of major parasitoids, predators and microbial agents in the BIPM, CIPM and non–IPM modules.

Parasitoids
Egg parasitoids

In BIPM module, the average per cent parasitization of *A. janata* eggs by *T. chilonis* was 16.13 (18.25% during 2001–02 and 14.00 % during 2002–03 and 2003–04), 6.92 (8.65% during 2001–02 and 5.20 % during 2002–03 and 2003–04), 8.80 (2002–03 and 2003–04) and 8.92 (7.05% during 2001–02 and 10.80 % during 2002–03 and 2003–04) in CIPM, non–IPM module 1 and 2, respectively (Table 2). In BIPM module, other egg parasitoids like *T. achaeae*, *Telenomus* sp. and *Trissolcus* sp. were also recorded from *A. janata* eggs but none of them were recorded in CIPM module, non–IPM module 1 and 2. The egg parasitoid, *Trichogramma evanescens* Westwood, was recorded from *S. litura* eggs in BIPM module.

Larval parasitoids

Among larval parasitoids, *M. maculipennis* on *A. janata* was found to be highly potential with field parasitization of 66.10, 21.2, 24.00 and 22.35% in BIPM, CIPM, and non–IPM module 1 and 2, respectively. Another larval parasitoid, *Euplectrus maternus* Bhatnagar on *A. janata* parasitized 7.92, 2.40, 1.20 and 3.82% of A. janata larvae in BIPM, CIPM, and non–IPM module 1 and 2, respectively. Similarly, average parasitization of larval parasitoids like *Charops obtusus* Morley (on *S. obliqua* and *A. janata), Rhogas* spp., *Apanteles hyposidrae* Wilkinson (on *A. janata* larvae) and *Cotesia flavipes* Cameron (on *S. litura*) was 3.54, 4.60, 13.85, 8.96 per cent in BIPM compared to 1.65, 1.59, 3.50, 2.49 in CIPM and 1.16, 0.80, 2.70, 2.68 in non–IPM module 1 and 1.50, 1.19, 2.80, 1.99 in non–IPM module 2, respectively (Table 2). Larval parasitoids, *Apanteles* sp., *Diadegma ricini, Theronia* sp. and *Bracon hebetor* were also found parasitising the larvae of *Conogethes punctiferalis* in BIPM module whereas in CIPM and non–IPM module 1 and 2 their activity was absent. There was no significant difference in *M. maculipennis* cocoon number per plant (0.53 to 0.56 during 2001–02 and 1.40 to 1.54 during 2002–03 and 2003–04) before imposing different IPM interventions. *M. maculipennis* cocoon number per plant increased with increase in duration after imposing different IPM interventions in the BIPM module indicating high activity of the larval parasitoid whereas it decreased in case of CIPM and non–IPM module 1 and 2 (Table 3).

Pupal parasitoids

Pupae of *S. litura* and *A. janata* collected from the field were found to be parasitised by pupal parasitoids, *Tetrastichus ayyari* Rohwer, *Trichospilus pupivorus* Ferrière and *T. ayyari* and *Phorocera* sp., respectively. In BIPM, there was almost three–fold higher parasitization by parasitoids like *T. chilonis, M. maculipennis, E. maternus, C. obtusus, Rhogas* sp., *A. hyposidrae* and *C. flavipes* compared to CIPM and non–IPM module 1 and 2 (Table 2 and 3). Higher

Table 2. Effect of biointensive, chemical pesticide-intensive and non–IPM modules on parasitoids in castor ecosystem

IPM modules	Per cent parasitisation by larval parasitoids						
	T. chilonis	*Microplitis* spp.	*Euplectrus* spp.	*Charops* spp.	*Rhogas* spp.	*Apanteles* spp.	*Cotesia* spp.
2001–2002							
BIPM Module	18.25 (4.30)	69.00 (56.33)	7.05 (2.74)	3.80 (11.26)	4.74 (12.55)	14.4 (22.17)	4.64 (12.41)
CIPM Module	8.65 (3.00)	22.80 (31.36)	2.75 (1.75)	1.42 (6.82)	1.82 (7.75)	3.2 (10.27)	1.38 (6.70)
Non–IPM Module	7.05 (2.71)	23.30 (28.82)	1.65 (1.38)	1.64 (7.41)	1.22 (6.30)	2.5 (9.10)	0.80 (5.13)
CV(%)	13.19	17.15	20.51	21.87	14.82	17.07	19.50
CD (P=0.05%)	0.28	4.27	0.26	2.16	1.53	2.75	1.83
2002–2003 and 2003–2004							
BIPM Module	14.00 (3.79)	63.20 (52.76)	8.80 (3.04)	3.28 (10.40)	4.46 (12.21)	13.30 (21.35)	13.29 (21.37)
CIPM Module	5.20 (2.38)	19.60 (26.00)	2.00 (1.55)	1.88 (7.90)	1.36 (6.65)	3.80 (11.24)	3.60 (10.94)
Non–IPM Module–1	8.80 (2.98)	24.00 (29.26)	1.20 (1.25)	1.16 (6.22)	0.80 (5.13)	2.70 (9.46)	2.68 (9.43)
Non–IPM Module–2	10.80 (3.35)	22.40 (28.21)	6.0 (2.54)	1.37 (6.70)	1.16 (6.22)	3.1 (10.14)	3.18 (10.20)
CV(%)	14.49	8.92	15.34	19.69	16.68	19.74	16.54
CD (P = 0.05%)	0.42	2.79	0.29	2.11	1.74	3.54	2.96

Figures in parentheses are arc sine transformed values; BIPM – biointensive integrated pest management module; CIPM – chemical pesticide intensive integrated pest management module; Non–IPM module1– non-integrated pest management module1 (farmers' practice with wilt resistant castor variety Jyoti); Non–IPM module 2 – non–integrated pest management module 2 (farmers' practice without wilt resistant castor variety Jyoti)

activity of parasitoids in BIPM module might be due to the inclusion of botanical biopesticides (NSKE 5%) along with other eco–friendly IPM components compared to toxic insecticides in CIPM and non–IPM modules which affected the parasitoids at different growth stages and drastically reduced their activity. The results are in accordance with the findings of Basappa and Lingappa (2002a), who reported that NSKE is harmless to natural enemies due to its weak contact effect on insects. The emergence of *T. chilonis* adults was 80–98.0 % in the laboratory and 59–98 % in the field. More than 75% adults of *M. maculipennis* emerged from botanicals treated cocoons both under laboratory and field conditions. Decrease in parasitisation by *T. chilonis, M. maculipennis, E. maternus, C. obtusus, Rhogas* sp., *A. hyposidrae* and *C. flavipes* in CIPM and both the non–IPM modules may be attributed to the toxicity of insecticides to parasitoids as reported by Basappa and Lingappa (2002b).

Predators

Insect predators

Among insect predators, *Chrysoperla* sp. and *Cheilomenes sexmaculata* were predominant and were actively predating on the eggs and neonate larvae of *A. janata* and *S. litura*. Average population of insect predators like adults and immature stages of *C. carnea, C. sexmaculata*, *Cantheconidea furcellata* (Wolff) and

Table 3. Effect of biointensive, chemical pesticide-intensive and non–IPM modules on the activity of larval parasitoid, *M. maculipennis*

IPM modules	Number of cocoons of larval parasitoid, *M. maculipennis* / plant			
	Before treatment	1 DAT	3 DAT	7 DAT
2001–2002				
BIPM Module	0.55 (1.02)	0.61 (1.05)	0.96 (1.19)	1.44 (1.38)
CIPM Module	0.53 (1.02)	0.19 (0.82)	0.38 (0.92)	0.73 (1.08)
Non–IPM Module	0.56 (1.03)	0.30 (0.88)	0.53 (0.99)	0.79 (1.11)
C.V.	1.82	14.18	15.64	15.70
CD(0.05%)	NS	0.08	0.10	0.12
2002–2003 and 2003–2004				
BIPM Module	1.40 (1.17)	1.24 (1.10)	1.41 (1.16)	1.85 (1.33)
CIPM Module	1.42 (1.18)	0.67 (0.80)	0.81 (0.88)	1.09 (1.02)
Non–IPM Module –1	1.44 (1.19)	0.71 (0.82)	0.97 (0.96)	1.14 (1.03)
Non–IPM Module –2	1.54 (1.23)	1.14 (1.05)	1.28 (1.11)	1.49 (1.20)
C.V.	4.76	16.53	16.32	13.02
CD(0.05%)	NS	0.14	0.15	0.14

Figures in parentheses are $\sqrt{x + 0.5}$ transformed values; DAT– days after treatment; BIPM – biointensive integrated pest management module; CIPM – chemical pesticide intensive integrated pest management module; Non–IPM module1 – non–integrated pest management module1 (farmers' practice with wilt resistant castor variety Jyoti); Non–IPM module 2 – non–integrated pest management module 2 (farmers' practice without wilt resistant castor variety Jyoti)

Rhynocoris kumarii Ambrose and Livingstone was 7.75,8.45,3.41 and 3.27 per 10 plants in BIPM, compared to 1.75 ,2.90, 1.38 and 1.45 and per 10 plants in CIPM and 1.20,1.82,1.00 and 1.00 in non–IPM module 1 and 1.97,2.41,1.32 and 1.22 per 10 plants in non–IPM module 2, respectively (Table. 4). General predators like mantids (*Eumantissa* GiglioTos), hymenopterans like *Polistes* sp., sphecid digger wasps (*Crabro* sp. and *Stizus vespiformis* (Fabricius)) on *A. janata* and *S. litura* larvae were more abundant in BIPM module compared to CIPM module, non–IPM module 1 and 2. In CIPM module and non–IPM module 1 and 2, there was a reduction in the activity of natural enemies due to the application of toxic insecticides. The activity of general predatory ant species *Camponotus sericius* Fabricius, *C. rufoglaucus* Jerdon and *Monomorium indicum* Forel was higher in BIPM module than that in CIPM and non–IPM modules and they were found carrying the eggs and neonate larvae of *A. janata* and *S. litura*.

Spiders

Spider population predating on early instar larvae of *A. janata* and *S. litura* was dominated by green lynx spiders, jumping spiders and crab spiders. In BIPM, CIPM, non–IPM module 1 and 2, average spider population was 7.10 (5.00 per 10 plants during 2001–02 and 9.20 per 10 plants during 2002–03 and 2003–04), 1.40 (1.80 per 10 plants during 2001–02 and 1.00 per 10 plants during 2002–03 and 2003–04), 1.80 (2002–03 and 2003–04) and 2.90 per 10 plants (1.20 per 10 plants during 2001–02 and 4.60 per 10 plants during 2002–03 and 2003–04), respectively (Table 4).

Insectivorous birds

In both BIPM and CIPM modules, activity of insectivorous birds was higher due to the use of bird perches compared to both the non–IPM modules where bird perches were not used. Cattle egret (*Bubulcus ibis*), house crow (*Corvus splendens*), black drongo (*Dicrurus adsimilis*) and Indian Myna (*Acridotheres tristis*) were preying on the resting stages of insect pests during summer ploughing. Indian Myna, black drongo, house crow, green bee eater (*Merops orientalis*), crow pheasant (*Centropus sinensis*), hoopoe (*Upupa epops*) and large grey babbler (*Turdoides malcolmi*) were more actively predating on mature larvae of *A. janata and S. litura* in BIPM and CIPM modules compared to very low activity in non–IPM modules. Indian Myna, black drongo, green bee eater, crow pheasant and large grey babbler were found predating on *C. punctiferalis* larvae.

In BIPM module, the population of predators like *Chrysoperla* sp., *C. sexmaculata, C. furcellata, R. kumarii* and spiders was three–fold higher than those of CIPM module and non–IPM module 1 and 2 (Table 4). Activity of general predators like mantids, *Polistes* sp., sphecid digger wasps (*Crabro* sp. and *S. vespiformis* on *A. janata* and *S. litura* larvae), predatory ant species *C. sericius, C.rufoglaucus* and *M. indicum* was greater in BIPM module than CIPM and non–IPM modules. BIPM module is harmless to natural enemies due to the inclusion of eco–friendly IPM components like NSKE which is having weak contact effect on insect predators. In contrast, chemical pesticides used in CIPM and non–IPM modules were very destructive to all the insect predators and there was reduction in the activity of natural enemies. Similar observations were made in upland cotton (*Gossypium hirstum* L.) in the cotton ecosystem of Queensland, Australia, where the toxicity of biorational pesticides to major predators like lady beetles, lacewings, spiders and predatory bugs was least. In contrast, chemicals were very destructive of predators (Ma *et al.,* 2000). As per the classification by Hassan (1986), the biopesticides involved in BIPM module fall in the harmless group contrary to insecticides involved in CIPM and non–IPM modules. In both BIPM and CIPM modules, activity of insectivorous birds was higher due to the use of bird perches compared to both the non–IPM modules. Cattle egret, house crow, black drongo and Indian Myna were actively feeding on resting stages of insect pests and soil insects during summer ploughing, field operations and inter–culturing in BIPM. The birds frequently used the bird perches during seedling and vegetative stages of the crop and were actively feeding on grown up larvae of *A. janata* and *S. litura* in BIPM and CIPM modules compared to very low activity in non–IPM modules due to absence of bird perches. From the reproductive stage onwards though, castor crop itself served as a live perch, but most of the above birds preferred to use bird perches in BIPM and CIPM modules as bird perches were 1.5m taller than the crop canopy. These predatory birds were also found predating on *C. punctiferalis* larvae damaging flowers and tender shoots. Basappa (2003b) studied the predatory behavior of insectivorous birds in castor ecosystem in Andhra Pradesh. There are reports of insectivorous birds predating on grown up larvae of *A. janata* in the castor ecosystem of Karnataka (Rai and Jayaramaiah, 1978) and Gujarat (Parasharya *et al.,* 1988).

Microbial agents

Spodoptera litura nucleopolyhedrovirus (SlNPV) and granulosis virus (GV) were isolated from dead larvae of *S. litura* and *A. janata* collected from IPM castor fields at Kandakur village in the Maheswaram watershed area, respectively. Entomopathogenic fungi, *Nomuraea rileyi* (Farlow) Samson and *Beauveria bassiana* (Balsamo) Vuillemin were found infecting *S. litura* and *A. janata* larvae immediately after cyclonic rains during August and September 2001–02 and 2003–04. During 2002–03, there was no incidence of entomopathogenic fungi on *S. litura* and *A. janata. A. janata* larvae infected with GV and *S. litura* larvae infected with SlNPV were recorded during August and September 2003–04 at Kandakur village in the Maheswaram watershed area where there was an outbreak of *A. janata* and *S. litura* in one of the fields following farmers' practice. The present findings confirm the observations made by Basappa (2003a). *N. rileyi* and *B. bassiana* were found affecting *S. litura* and *A. janata* larvae when there was high humidity (>80%) and low temperature (<30^0 C) after cyclonic rains during August and September 2001–02 and 2003–04. Similar observations were recorded on castor and other oilseed crops (Vimala Devi *et al*., 1996). During 2002–03, there was no incidence of entomopathogenic fungi on *S. litura* and *A. janata* as there were no cyclonic rains during August and September months. Both BIPM and CIPM modules were found to be effective in reducing insect pest population with a mean C:B Ratio of 1:3.00 and 1:2.81 compared to 1:2.74 and 1:2.10 in non–IPM module 1 and 2, respectively (Basappa, 2007).

In the present investigation, the natural enemy activity was not affected in BIPM module with NSKE along with other eco–friendly IPM components, whereas in CIPM and non–IPM modules their activity was drastically reduced due to the toxic effects of insecticides. Similar trends were observed during 2000–2002 in the traditional castor growing areas of Mahaboob Nagar district when BIPM module was used (Basappa, 2003a, 2006).

Natural enemy impact was greatest at sites adopting BIPM module and least at sites adopting CIPM and non–IPM modules. CIPM module has the potential to control insect pests under outbreak situations within a short period. BIPM module incorporates ecological and economic factors into castor production system design and decision making and addresses public concerns about environmental quality and food safety. The benefits of implementing BIPM module include reduced chemical input costs, reduced on–farm and off–farm environmental impacts, conservation of natural enemies, and more effective and sustainable pest management which will benefit the grower and the society.

Table 4. Effect of biointensive, chemical pesticide-intensive and non–IPM modules on predators in castor ecosystem

IPM modules	No. of predators / 10 plants				
	Chrysoperla spp.	*Cheilomenes* spp.	*Cantheconidia* spp.	*Rhynocoris* spp.	*Spiders*
2001–2002					
BIPM Module	8.90 (2.90)	8.88 (2.98)	3.32 (1.82)	2.96 (1.72)	5.00 (2.33)
CIPM Module	2.50 (1.65)	2.76 (1.66)	1.22 (1.10)	1.44 (1.20)	1.80 (1.46)
Non–IPM Module	1.75 (1.36)	2.32 (1.52)	1.22 (1.10)	1.22 (1.10)	1.20 (1.24)
CV(%)	23.93	17.04	13.17	13.89	21.61
CD (P=0.05%)	0.30	0.41	0.20	0.21	0.23
2002–2003 and 2003–2004					
BIPM Module	6.60 (2.66)	8.02 (2.83)	3.50 (1.87)	3.58 (1.89)	9.20 (3.11)
CIPM Module	1.00 (1.19)	3.04 (1.74)	1.54 (1.24)	1.46 (1.21)	1.00 (1.19)
Non–IPM Module–1	1.20 (1.28)	1.82 (1.35)	0.97 (0.96)	0.81 (0.88)	1.80 (1.49)
Non–IPM Module–2	2.20 (1.62)	2.50 (1.58)	1.42 (1.19)	1.22 (1.10)	4.60 (2.21)
CV(%)	14.94	18.11	11.44	15.34	18.92
CD (P=0.05%)	0.23	0.47	0.20	0.27	0.35

Figures in parentheses are $\sqrt{x}$ +0.5 transformed values; BIPM – biointensive integrated pest management module; CIPM– chemical pesticide intensive integrated pest management module; Non–IPM module1 – non–integrated pest management module1 (farmers' practice with wilt resistant castor variety Jyoti); Non–IPM module 2 – non integrated pest management module 2 (farmers' practice without wilt resistant castor variety Jyoti)

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