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Induced Systemic Resistance through Organic Based IPM Module against Pest Infesting Chilli

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ABSTRACT

Field experiments were undertaken to study the impact of three different IPM modules viz., Bio-intensive (M₁), recommended (M₃) and suggestive modules (M₄) in comparison with farmers practice (M₂) and control (M₅) for the management of major pests of chilli under irrigated conditions during December 2010 - May 2011 and August 2012 - January 2013. The study revealed that the Suggestive module (M₄) showed great impact not only against major pests of chilli viz., *Scirtothrips dorsalis*, *Polyphagotarsonemus latus*, *Helicoverpa armigera* and *Spodoptera litura* but also on the activity of natural enemies like *Chrysopera carnea*, *Cheilomenes sexmaculatus*, *Coccinella septempunctata* and *Oxyopes* sp. The lowest population of major pests of chilli was found in Suggestive module (M₄) which indicates that integration of organic sources of nutrients and amendments [Farm yard manure, neem cake and biofertilizers (Azospinos, and silica solubilizing bacteria)] along with other eco - friendly management approaches (botanicals, biocontrol agents and Spinosad) would have efficiently managed all the major pests and registered less damage. Application of organic sources of nutrients altered the biochemical constituents of chilli plants that could be attributed to the enhanced defensive chemicals viz., phenols and silica content leading to induced resistance against pests of chilli, in addition less content of total chlorophyll and reducing sugars making the plants less prone to pest attack and found safer to natural enemies. It also enhanced the population of soil microflora which enhanced the mobilization of nutrients to the plant and in turn as increased yield.

Keywords

Chilli, Biochemical constituents, Insect pests, IPM modules, Organic amendments, Soil microflora.

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Introduction

Chilli, *Capsicum annum* L. is one of the most important valuable crops in India, grown for its fruits. It is used as vegetables, spices and condiments and also got two important commercial qualities; one is red colour because of the pigment capsanthin, other one is known for biting pungency attributed by capsaicin which has got high medicinal value. It is also rich in vitamin A, C E and oleoresin

content. India is the major, producer, exporter and consumer of chillies in the world and it is cultivated in an area of 7.75 lakh hectares with the production of 14.92 lakh tonnes (Anon., 2014). During 2014-15, Indian spices exports have been able to continue its increasing trend with 893,920 tonnes of spices, valued at Rs.14899.68 crore has been exported from our country, Chilli accounting

for 3,47,000 tonnes of total spices and fetches Rs. 3517.10 crore of rupees as foreign exchange (Supriya Lamba *et al.*, 2015). A major part of chillies produced in India are consumed within the country and only 5 to 7 per cent are exported, all though it is cultivated all over India, its productivity is only 17.40 q ha⁻¹ which is low when compared to other countries. Among the constraints in chilli cultivation, arthropod pests are the most important consequence, which significantly affect the production. A total of 57 species of insect and mite pests were recorded damaging chilli. Of these, the sucking pests like thrips, *Scirtothrips dorsalis* (Hood), mite, *Polyphagotarsonemus latus* (Banks) from seedling to fruiting stage and lepidopteran pests like fruit borers, *Helicoverpa armigera* (Hubner) and *Spodoptera litura* (Fabricus) during flowering and fruit formation stages are the major pests, responsible for causing considerable yield loss (Rajaram, 1998).

The control of insect and other pests in chilli was achieved mainly with application of synthetic pesticides. Despite its relative efficiency, chemical control has several negative impacts as the selection of resistant individuals due to the continuous use of certain active ingredients, the reduction or elimination of beneficial species, resurgence of pest and the high toxicity of products to applicators. Besides, considering the seriousness of insecticidal toxicity and higher degree of persistence of insecticide residues hinders pest management in chilli crop becoming more sensitive and challenging. To overcome these health hazards and environmental problems in the cultivation of crops, there is an urgent need for developing an effective and eco-friendly pest management approach. The National Academy of Agricultural Sciences (NAAS) recommended a holistic approach involving integrated nutrient management (INM),

integrated pest management (IPM) for enhanced input use efficiency, and adoption of region specific promising cropping systems as an alternative organic farming strategy for India and to begin with the practice of organic farming should value crops like spices, medicinal plants, fruits, and vegetables (Bhattacharya and Chakraborty, 2005). Among the various components involved, induced plant resistance to pests can contribute substantially. Through the addition of organic sources of nutrients and amendments, the production of defensive chemicals in plant increases that influence the development and survival of crop pests. So organic amendments provide an eco-technological stability in pest management and are a vital component of sustainable agriculture. Keeping this in view, the present investigation was carried out to develop eco-friendly management module comprising of organic amendments for sustainable management of major pests of chilli.

Materials and Methods

Two field experiments were conducted to evaluate three different modules in comparison with farmers practice and untreated control at Pannikundu village of Thirumangalam block of Madurai district, during December 2010 - May 2011 and Sevanellyam village of Aundipatty block of Theni district during August 2012 - January 2013 to evaluate three different IPM modules *viz.*, Bio-intensive, recommended and suggestive modules in comparison with farmers practice and control for the management of major pests of chilli in irrigated condition. Each IPM module was laid out in an area of 0.5 acre and module was divided into five regions, considering each one as replicate. Five plants per replication were randomly selected for assessing the pests and natural enemies.

The thrips and mite population were assessed from three leaves representing the top, middle and bottom portion of the plant in each of the five plants selected randomly from each module on 15, 30, 45, 60, 75, 90, 105 and 120 DAP and mean population was worked out. The population was expressed in terms of number of thrips / leaf and number of mite / leaf. Ten plants were selected randomly from each plot and scored for LCI visually by following 0-4 scale (Desai *et al.*, 2006). For fruit borers, the numbers of larvae were counted from each of the five plants selected randomly from each module on 45, 60, 75, 90, 105 and 120 DAP and expressed in terms of larvae / plant. The fruit damage was assessed based on bore holes found on the fruits. The per cent fruit damage was worked out by counting total number of fruits per plant and number of fruits damaged per plant on five randomly selected plants from each module at every picking. The population of natural enemies' viz., green lace wings, coccinellids and spiders were assessed on whole plant and the population was expressed in terms of number / plant. The chillies obtained from different IPM modules were dried plot wise and yield was recorded as kg ha⁻¹. The plant protection measures carried out in different IPM modules were furnished here under.

Biointensive module (M₁): Release of *Chrysoperla carnea* grub @ 10000 ha⁻¹, *Trichogramma chilonis* @ 50,000 ha⁻¹ at the time of moth emergence, foliar application of *H.a* NPV / *S.l* NPV @ 250 LE ha⁻¹ against respective borers once in seven days after *T. chilonis* release, NSKE 5%, *Bacillus thuringiensis* var. *kurstaki* @ 1.0 kg ha⁻¹ during fruit formation stage.

Adaptive module (Farmer's practice) (M₂): Foliar application of dimethoate 30 EC @ 1 ml l⁻¹ for sucking pests at weekly interval, monocrotophos 36 WSC @ 2 ml l⁻¹ at weekly interval against early sucking pests, Dicofol

18.5 EC @ 4 ml l⁻¹ at weekly interval against mites, chlorpyrifos 20 EC @ 2 ml l⁻¹ at weekly interval against borers, quinalphos 25 EC @ 2 ml l⁻¹ at weekly interval against borers, carbaryl 50 WP @ 2 g l⁻¹ at fruit formation stage of weekly interval against borers.

Recommended practice (M₃): Need based application of dimethoate 30 EC @ 2 ml l⁻¹ or quinalphos 25 EC @ 2 ml l⁻¹ or dicofol 18.5 EC @ 2.5 ml l⁻¹ thrice at fortnightly interval for sucking insect, installing pheromone traps for *H. armgera* and *S. litura* @ 12 Nos ha⁻¹, collection & destruction of damaged fruits and grown up larvae of *H. armgera* and *S. litura*, foliar application of *B.t.k* @ 2kg ha⁻¹ during fruit formation stage, spray carbaryl 50 WP @ 3g l⁻¹ (or) chlorpyrifos 20 EC @ 3ml l⁻¹ or Quinalphos 25 EC 2 ml l⁻¹ for borers.

Suggestive module (M₄): Seed treatment with *Pseudomonas fluorescens* @ 10 g / kg + *Azophos* 25 gm / kg of seed, soil application of FYM @ 12.5 t ha⁻¹ + *Azophos* @ 2 kg ha⁻¹ + Silica solubilizing bacteria @ 2 kg ha⁻¹ as basal and neem cake (300 kg ha⁻¹) in 2 splits at 30 and 60 days after planting, foliar application of neem oil 3%, release of *C. carnea* grub @ 10000 ha⁻¹, four release of *T. chilonis* @ 50,000 ha⁻¹ at weekly interval coinciding with flowering and emergence of moth, foliar application of *H.a* NPV / *S.l* NPV @ 250 LE ha⁻¹ once after the last release of *T. chilonis*, NSKE 5% (two rounds) once at initiation of flowering and another at 50% flowering, spinosad 48 SC @ 0.4 ml l⁻¹ during fruit formation.

Control (M₅): untreated check

Foliar application of respective sprays in respective module was imposed based on ETL of sucking pests / fruit borer in module III and IV whereas on the appearance of pests in module I and II.

Estimation of biochemical profile

To find out the effect of IPM modules on biochemical profile of chilli imparting resistance / susceptibility to the pests, biochemical analyses were estimated in leaf samples of chilli except capsaicin, which was estimated in fruits. Fresh leaf samples were collected at 60, 90, and 120 DAP from all the IPM modules and analysed for total chlorophyll (Mahadevan and Sridhar, 1986), total phenols (Malick and Singh, 1980), silica (Nayar *et al.*, 1975), reducing sugars (Sadasivam and Manickam, 1992) and Capsaicin content (%) of red fruits was measured by spectrophotometric method as described by Sadasivam and Manickam (1992).

Estimation of microbial population

Soil samples from respective IPM modules

were collected at 30, 60 and 90 DAT as per protocol to estimate the microbial population. The microbial diversity in the soil samples collected from chilli field was assessed by serial dilution plate technique (Martin, 1950). After this dilution procedure was continued to obtain a dilution of 10^{-6} . One ml portions from the solutions 10^{-3} , 10^{-4} and 10^{-6} were transferred to sterile Petri dishes for plating the fungi, actinomycetes and bacteria. Approximately 15-20 ml of molten cooled agar medium (Martin Rose Bengal Agar medium; Kenknight agar medium; Nutrient agar medium, respectively) were added to the dilutions 10^{-3} , 10^{-4} , and 10^{-6} , respectively. The population of fungi, actinomycetes and bacteria in the samples were calculated and expressed as colony forming unit (CFU) per gram of dry soil. Soil microflora were assessed using the formula as suggested by (Rangaswami, 1996).

$$\text{Number of colony forming units (CFU) = } \frac{\text{Mean number of CFU} \times \text{dilution factor}}{\text{Per gram of oven dry soil} \quad \text{weight of oven dry soil}}$$

Statistical analysis

Data obtained from the field study were subjected to ANOVA. The data on percentage values and numbers were subject to arcsine and square root transformation before statistical analysis. The field experiments on the efficacy of modules for the management of major insect pests of chilli were conducted in a randomized block design in order to know the interaction between treatments and the means obtained were separated by LSD (Least Significant Difference).

Results and Discussion

Pests and natural enemies

In the present study (Table 1), the suggestive module (M₄) recorded the lowest population of thrips (0.98 / leaf), mite (1.16 / leaf), LCI

(1.15 / plant), larval population of *H. armigera* (0.72 / plant), *S. litura* (0.52 larvae / plant) and fruit damage (7.31 %), respectively which was significantly different from Recommended module (M₃) (1.21 and 1.51 / leaf; 1.32 LCI / plant; 0.94 and 0.72 larvae / plant; 9.32 %) followed by adaptive module (M₂) (1.36 and 1.74 / leaf; 1.60 LCI / plant; 1.08 and 0.87 larvae / plant; 10.86 %) while the population of thrips and mite was 1.64 and 2.04 / leaf; 1.72 LCI / plant; larval population of *H. armigera* and *S. litura* was 1.29 and 1.06 / plant; fruit damage 12.70 per cent in bio-intensive module (M₁) and 2.99 and 3.38 / leaf; 2.59 LCI / plant; 2.35 and 1.86 larvae / plant; 20.43 per cent in untreated check (Table 1).

There was no significant difference in natural enemy activities between modules. However,

numerically higher number of *Chrysoperla* (1.16 / plant), coccinellids (1.11 / plant) and spiders (0.73 / plant) were noticed only in suggestive module (M₄) indicating its safety followed by bio - intensive module (M₁) (1.14, 1.06 and 0.66 / plant) and control (M₅) (1.02, 0.98 and 0.56 / plant) while it was 0.97, 0.93 and 0.50 / plant for recommended module (M₃) and 0.76, 0.79 and 0.39 / plant in farmers practice (M₂) (Table 2). It is evident that the Suggestive module (M₄) exhibited a great impact against major pests of chilli viz., *S. dorsalis*, *P. latus*, *H. armiger*, *S. litura* and however it has not suppressed the activity of natural enemies. There is sizeable amount of literature in a row to indicate the several such location specific modules have been developed elsewhere in India, in which various organic inputs were mixed up judiciously for the management of key pests including *H. armigera* on tomato (Ravi *et al.*, 2008), key pests of brinjal (Suresh *et al.*, 2007), key pests of chilli (Gundannavar *et al.*, 2007; Mondal and Mondal, 2012) *etc.* Also there are literatures to indicate the safety of organic amendments to natural enemies in chilli ecosystem. This is in agreement to the early reports of Subba Rao *et al.*, (2007) who opined that application of neem cake @ 250 kg + sunn hemp @ 250 kg and vermicompost @ 750 kg / ha in chilli was quite safe to natural enemies. Similarly, the organic soil amendments like vermicompost (1-2 t ha⁻¹), neem cake (0.5 to 1.0 t ha⁻¹), biogas spent slurry (1.0 t ha⁻¹) and FYM (12.5 t ha⁻¹) were found safer to coccinellids as well as *Chrysoperla* sp in chilli (Ravi kumar, 2004). Patil *et al.*, (2014) reported that organic nutrient and pest management practices when combined recorded higher number of coccinellids and *Chrysoperla* in chilli.

Bio-chemical constituents

The mean total chlorophyll content in leaf sample varied significantly between modules

which ranged from 0.95 to 1.83 mg/g of sample. The suggestive module (M₄) recorded low total chlorophyll (1.47 mg / g) compared to rest of the modules which had higher chlorophyll content (Table 3). Between IPM modules, the total phenol in leaf samples of chilli showed significant variation which ranged from 1.10 to 2.64 mg / g of sample, the suggestive module (M₄) recorded the highest mean total phenol (2.64 mg / g) as compared to minimum of 1.10 mg / g in control (M₅) and rest of the modules. Similarly, the mean silica content in leaf sample was highest in suggestive module (M₄) (1.62 %) compared to rest of the modules while silica was least in control (M₅) (1.07 %). However, with regard to reducing sugars, leaf samples of suggestive module (M₄) recorded less reducing sugars (3.35 mg / g) as compared to 5.48 mg / g in control (M₅), whereas the reducing sugars were low to moderate in rest of the IPM modules. Further, capsaicin content was the highest (0.48 per cent) in dry chilli fruit harvested from suggestive module (M₄), followed by recommended module (M₃) (0.42 %), adaptive module (M₂) (0.37 %) and bio intensive module (M₁) (0.35 %) (Table 3).

Among IPM modules, suggestive module (M₄) comprising organic sources of nutrients and amendments viz., Farm yard manure, neem cake and biofertilizers (Azospinos, and silica solubilizing bacteria) registered significantly minimum level of total chlorophyll and reducing sugar and higher content of total phenol, silica and capsaicin and thereby exhibited high level of induced resistance against pests of chilli. The present findings is in accordance with reports of Rajendran and Chandramani (2002) who reported that the application of FYM along with neem cake, *Azospirillum*, phosphobacterium and silica solubilizing bacteria increased the phenol, tannin and silica content while total chlorophyll content

and total sugars were low which reduced the incidence of aphid (*Myzus persicae* Sulz.) and thrips (*Scirtothrips dorsalis* Fab.) in chilli. Chandrasekar (2003) who also reported that lower amount of reducing sugars and high amount of amino acid, total phenol and capsaicin content was observed in FYM @ 12.5 t/ha + Neem cake @ 250 kg/ha + *Azospirillum* @ 2 kg/ha + Phosphobacteria @ 2kg/ha treated chilli plants which recorded lesser population of thrips and mites.

The present finding is also in confirmation with the findings of Irulandi *et al.*, (2010) who reported that application of FYM, neem cake, mahua cake, pungam cake and biofertilizer (Azophos) enhanced the production of defensive chemicals *viz.*, silica, phenol and tannin content in coffee leading to induced resistance in terms of antibiosis against berry borer. Bommasha *et al.*, (2012) also reported that application of neem cake and poultry manure resulted in lower level of chlorophyll, protein, reducing sugar and total sugars with increased level of phenol content in pigeon pea reduced the incidence of sucking pests and pod borers. Balasaraswathi *et al.*, (2014) who also reported that application of FYM + neem cake enhanced the production of phenol content in leaves of mulberry which exhibited induced systemic resistance against pink mealy bug. High concentration of capsaicin in chilli fruits was noticed in suggestive module (M₄) which is in accordance with Venkatesan (2002) who found that FYM + Neem cake + *Azospirillum* treated plants showed higher concentration of capsaicin due to increase in phenol content.

Soil microflora

Analysis of soil samples from chilli field, imparted with three different modules revealed that suggestive module (M₄) registered a maximum bacterial load of 65.16×10^6 CFU / g of soil. Next to bacterial, the

mean fungal load was higher (42.78×10^3 CFU / g of soil) and also highest load of actinomycetes in soil samples was recorded in suggestive module (M₄) (30.24×10^4 CFU/g of soil), which was followed by recommended module (M₃) (50.02×10^6 , 35.84×10^3 , 21.82×10^4 CFU / g of soil), farmers practice (M₂) (46.70×10^6 , 33.94×10^3 , 19.63×10^4 CFU / g of soil) and bio-intensive module (M₁) (45.09×10^6 , 32.95×10^3 , 18.56×10^4 CFU / g of soil) in contrast to and control (M₅) (40.33×10^6 , 29.52×10^3 , 16.70×10^4 CFU / g of soil) (Table 4).

Suggestive module (M₄) comprising of organic sources of nutrients and amendments registered more bacterial, fungal and actinomycetes population in soil. This is in accordance with the reports of Nambiar *et al.*, (1992) who reported that application of organic sources encouraged the growth and activity of mycorrhizae and other beneficial organisms in the soil and is also helpful in alleviating the increasing incidence or deficiency of secondary and micronutrients and is capable of sustaining high crop productivity and soil health. Similarly, the present finding was in accordance with the reports of Vemana *et al.*, (1999) who observed the maximum increase in bacterial population in farm yard manure treatment.

Further the high bacterial population with the application of FYM was also reported by Parham *et al.*, (2002). The increase in fungal population due to the application of neem cake in the present findings is in agreement with the earlier workers (Goswami, 1993), Ambika (2007) according to whom that basal application of farm yard manure @ 6.25 t/ha + neem cake @ 300 kg/ha + Azophos @ 1kg/ha was found to be significantly effective in reducing the population of chilli mite which also registered the maximum bacterial colonies 126.50×10^6 and fungal colonies 20.75×10^3 in soil of in chilli ecosystem.

Table.1 Effect of IPM modules against major pests of chilli (Pooled mean)

IPM modules		Thrips (No./leaf) ⁺	Mite (No./leaf) ⁺	LCI / plant ⁺	<i>H. armigera</i> (larvae/ plant) ⁺	<i>S. litura</i> (larvae/plant) ⁺	Fruit damage (%) ⁺
M ₁	Bio intensive module	1.64* (1.46) ^d	2.05* (1.60) ^d	1.72 ^d	1.29* (1.34) ^d	1.06* (1.25) ^d	12.70** (20.88) ^d
M ₂	Adaptive module	1.36 (1.36) ^c	1.74 (1.50) ^c	1.60 ^c	1.08 (1.26) ^c	0.87 (1.17) ^c	10.86 (19.24) ^c
M ₃	Recommended module	1.21 (1.31) ^b	1.51 (1.42) ^b	1.32 ^b	0.94 (1.20) ^b	0.72 (1.10) ^b	9.32 (17.78) ^b
M ₄	Suggestive module	0.98 (1.22) ^a	1.16 (1.29) ^a	1.15 ^a	0.72 (1.10) ^a	0.52 (1.01) ^a	7.31 (15.69) ^a
M ₅	Untreated check	2.99 (1.87) ^e	3.38 (1.97) ^e	2.59 ^e	2.35 (1.69) ^e	1.86 (1.54) ^e	20.43 (26.87) ^e
SE d		0.011	0.016	0.065	0.014	0.007	0.26
CD at 5 %		0.023	0.034	0.141	0.030	0.014	0.57

+ Each value is the mean of five replications; * Figures in parentheses are $\sqrt{X + 0.5}$ transformed values

** Figures in parentheses are Arc sine transformed values; In a column, means followed by common letter(s) are not significantly different by LSD (P= 0.05)

Table.2 Effect of IPM modules on natural enemies in chilli ecosystem (Pooled mean)

IPM modules		<i>Chrysoperla</i> (no /plant) ⁺	Coccinellids (no /plant) ⁺	Spider (no /plant) ⁺
M ₁	Bio intensive module	1.14 (1.28)	1.06 (1.25)	0.66 (1.07)
M ₂	Adaptive module	0.76 (1.12)	0.79 (1.13)	0.39 (0.94)
M ₃	Recommended module	0.97 (1.21)	0.93 (1.20)	0.50 (1.00)
M ₄	Suggestive module	1.16 (1.29)	1.11 (1.27)	0.73 (1.11)
M ₅	Untreated check	1.02 (1.23)	0.98 (1.21)	0.56 (1.03)
SE d		NS	NS	NS
CD at 5 %		NS	NS	NS

* Each value is the mean of five replications; NS - Non significant; Figures in parentheses are $\sqrt{X + 0.5}$ transformed values

Table.3 Effect of IPM modules on biochemical components in chilli for their resistant to pests

IPM modules	Total Chlorophyll (mg/g) ⁺	Total phenol (mg/g) ⁺	Silica (%) ⁺	Reducing sugar (mg/g) ⁺	Capsaicin (%) ⁺
M ₁ Bio intensive module	1.83 ^d	1.77 ^c	1.26 ^c	3.96 ^b	0.35 ^c
M ₂ Adaptive module	1.81 ^d	1.83 ^c	1.29 ^c	3.92 ^b	0.37 ^c
M ₃ Recommended module	1.66 ^c	2.07 ^b	1.38 ^b	3.66 ^c	0.42 ^b
M ₄ Suggestive module	1.47 ^b	2.64 ^a	1.62 ^a	3.35 ^d	0.48 ^a
M ₅ Untreated check	0.95 ^a	1.10 ^d	1.07 ^d	5.48 ^a	0.28 ^d
SE d	0.0061	0.0093	0.0585	0.0178	0.0232
CD at 5 %	0.0134	0.0203	0.1274	0.0388	0.0504

⁺ Each value is the mean of five replication

In a column, means followed by common letter(s) are not significantly different by LSD (P= 0.05)

Table.4 Effect of IPM modules on the population of soil microflora

IPM modules	Bacteria (x 10 ⁶ CFU/g of soil) ⁺	Fungi (x 10 ³ CFU/g of soil) ⁺	Actinomycetes (x 10 ⁴ CFU/g of soil) ⁺
M ₁ Bio intensive module	45.09 ^c	32.95 ^c	18.56 ^c
M ₂ Adaptive module	46.70 ^c	33.94 ^c	19.63 ^c
M ₃ Recommended module	50.02 ^b	35.84 ^b	21.82 ^b
M ₄ Suggestive module	65.16 ^a	42.78 ^a	30.24 ^a
M ₅ Untreated check	40.33 ^d	29.52 ^d	16.70 ^d
SE d	0.0743	0.0609	0.0393
CD at 5 %	0.1619	0.1327	0.0856

⁺ Each value is the mean of five replications

In a column, means followed by common letter(s) are not significantly different by LSD (P= 0.05)

Table.5 Effect of IPM modules on the yield of dry chilli (pooled mean)

Modules		Yield (kg / ha) *	Yield increase over control (kg / ha)	Incremental Benefit cost ratio
M ₁	Bio intensive module	1489 (38.59) ^d	379	1:2.11
M ₂	Adaptive module	1650 (40.63) ^c	540	1:2.88
M ₃	Recommended module	1793 (42.35) ^b	683	1:3.28
M ₄	Suggested module	1878 (43.34) ^a	768	1:3.50
M ₅	Control	1110 (33.32) ^e	-	-
	SE d	0.243	-	-
	CD at 5 %	0.530	-	-

*Each value is mean of five replications

Figures in parentheses are $\sqrt{X + 0.5}$ transformed values

In a column, means followed by common letter(s) are not significantly different by LSD (P= 0.05)

Murali Baskaran *et al.*, (2008) who also reported that application of vermicompost in combination with neem cake, bio-fertilizers and NPK to senna recorded the highest population of soil fungi, bacteria and actinomycetes.

Yield and economics

Suggestive module (M₄) recorded the highest dry chilli yield (1878 kg / ha) with 768 kg increase in yield over untreated check. Recommended module (M₃) ranked second with an yield of 1793 kg / ha and 683 kg increase over control, while farmers practice (M₂) (1650 kg / ha; 540 kg) and bio-intensive module (M₁) (1489 kg / ha; 379 kg) were third and fourth in terms of yield. Based on the incremental benefit cost ratio, the IPM modules were ranked. Among IPM modules, suggestive module (M₄) has recorded the highest benefit cost ratio of 1:3.50. While considering both effectiveness and economics, the suggestive module (M₄) stood first indicating its superiority over other modules. Recommended module (M₃) (1:3.28) ranked next to suggestive module (M₄) (Table 5).

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